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About the Author

Zig Zsiga, CCDE 2016::32, CCIE #44883, has been in the networking industry for 20 years. He is currently a principal architect supporting the Cisco CX US public sector business and customers. Zig holds an active CCDE and two CCIE certifications, one in Routing and Switching and the second in Service Provider. He also holds a bachelor of science in computer science from Park University. He is a father, a husband, a United States Marine, a gamer, a nerd, a geek, and a big soccer fan. Zig loves all technology and can usually be found in the lab learning and teaching others. This is his second published book, and he is also the host of the *Zigbits Network Design Podcast* (ZNDP), where he interviews leading industry experts about network design. All of Zig's content is located at https://zigbits.tech. Zig lives in Upstate New York, USA, with his wife, Julie, and their son, Gunnar.

About the Technical Reviewers

Martin J. Duggan, CCDE #2016::6 and CCIE #7942, is a principal network architect designing network solutions for global financial accounts at Systal Technology Solutions. Martin gained his CCIE Routing and Switching certification in 2001 and has been passionate about Cisco qualifications and mentoring ever since. He wrote the *CCIE Routing and Switching Practice Labs* series and *CCDE v3 Practice Labs* titles for Cisco Press and provides content for multiple Cisco exam tracks. Martin resides in the UK and enjoys gliding, cycling, snowboarding, and karate when not designing networks. Follow Martin on Twitter @Martinccie7942.

Nicholas (Nick) Russo, CCDE #20160041 and CCIE #42518, is an internationally recognized expert in IP/MPLS networking and design. To grow his skillset, Nick has been focused on advancing network DevOps via automation for his clients. Recently, Nick has been sharing his knowledge through online video training and speaking at industry conferences. Nick also holds a bachelor of science in computer science from the Rochester Institute of Technology (RIT). Nick lives in Maryland, USA, with his wife, Carla, and daughters, Olivia and Josephine.

Dedications

You, the reader, will never truly know the journey this book endured to reach completion. I would like to share with you the CliffsNotes version, so please bear with me. I had truly wanted to complete this book months ago…even a year ago. I wanted this book in your hands as it is now, to be used as a resource for making better network design decisions and for passing the CCDE exam. But good intentions are just that…intentions. As with anything, there is a path a book must take. This book most definitely took the path that was not paved. It had to persevere through a global pandemic, numerous family emergencies, including my own, and a number of other global events that we don't have the time to dive into here.

This book made it through it all. I promise you it is not perfect; I can only imagine what I missed or got wrong in this process, but it is here, and it is a resource for you, the network designer and CCDE candidate. I hope as you read through these chapters you feel the passion I have for this industry, network design, and the CCDE. This book, with all of the time and energy put into it, is for you.

I dedicate this book to you, the reader, the CCDE candidate, and the network design expert. May it help you on your network design journey!

Acknowledgments

I had this great idea to write a book, and while I had limited experience in the area of writing, I figured it was going to be a piece of cake. I was far from the truth. Writing this book was much harder than I thought it would be. I didn't know what I didn't know and, frankly, this book would not have been possible without the help of many people.

Thank you, Marwan Al-shawi, for graciously letting me leverage the truly outstanding content in your *CCDE Study Guide*. Your content is truly remarkable, and it didn't make sense to re-create it when it still applies today. Thank you!

Thank you to my two technical editors, Martin Duggan and Nick Russo. You both kept me honest and humble throughout this experience. I could have not asked for a better technical team. I can only imagine the thoughts that went through your heads when reading some of the chapter drafts…"What is Zig doing now?" I thank you both for being great network designers, and better friends than I could ever ask for.

Thank you, Dave Lucas, for your contributions in Chapter 8. I sincerely appreciate you.

Thank you to my Cisco leadership team: Mike Solomita, Maurice DuPas, Jim Lien, and Fred Mooney. You all gave me the space, time, and overwhelming encouragement to make this project happen. Thank you for always supporting me and my career aspirations.

Thank you, Elaine Lopez and Mark Holm, as without the two of you…well, I can't even imagine where we would all be without the CCDE. You both have been great mentors, colleagues, and friends. Thank you for always being available for my random and crazy questions. Mark, we have some work to do, my friend!

Thank you, Nancy Davis and Ellie Bru. This entire process would have been truly unbearable without the two of you. You have been with me from the start. Thank you for being so understanding about all the life events that happened during the writing of this book. Thank you for always being willing to help and guide me throughout this journey. From helping me with writer's block to creating figures to author reviews, you two have been truly amazing. You are truly the A team!

Thank you to my wife, Julie. Julie, you have always supported me with everything I thrive to do in my life. You gave me critical advice throughout this journey when I truly needed it. You kept me honest and let me know when I was just being dumb, which happened a few times. You were my sounding board on all things as they happened in real time. You are my rock, my constant, and my muse. I am truly lucky to be able to journey through our life side by side. Thank you from the bottom of my heart and always remember I love you the Everest! Kilo!

To my son, Gunnar. This book, and the journey I took to write it, is a perfect example of how you can set a goal, attack that goal, and achieve it. Will you know the steps to take to achieve every goal in your life? Most definitely not. I didn't know half of the steps to

complete this book, but here it is. Will there be roadblocks, pitfalls, and hurdles in the way? Of course. What matters is what you do when you encounter one. It's what you do when you find something standing in your way of achieving that goal. Will you have to sacrifice to make it happen? Most likely. That sacrifice might be time, energy, or sleep, but you will most likely have to endure it to achieve your goal. Once again, take this as an example that you can literally do anything you set your mind to in life; just set your mind to it and make it happen.

Reader Services

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*Be sure to check the box that you would like to hear from us to receive exclusive discounts on future editions of this product.

Contents at a Glance

Online Elements:

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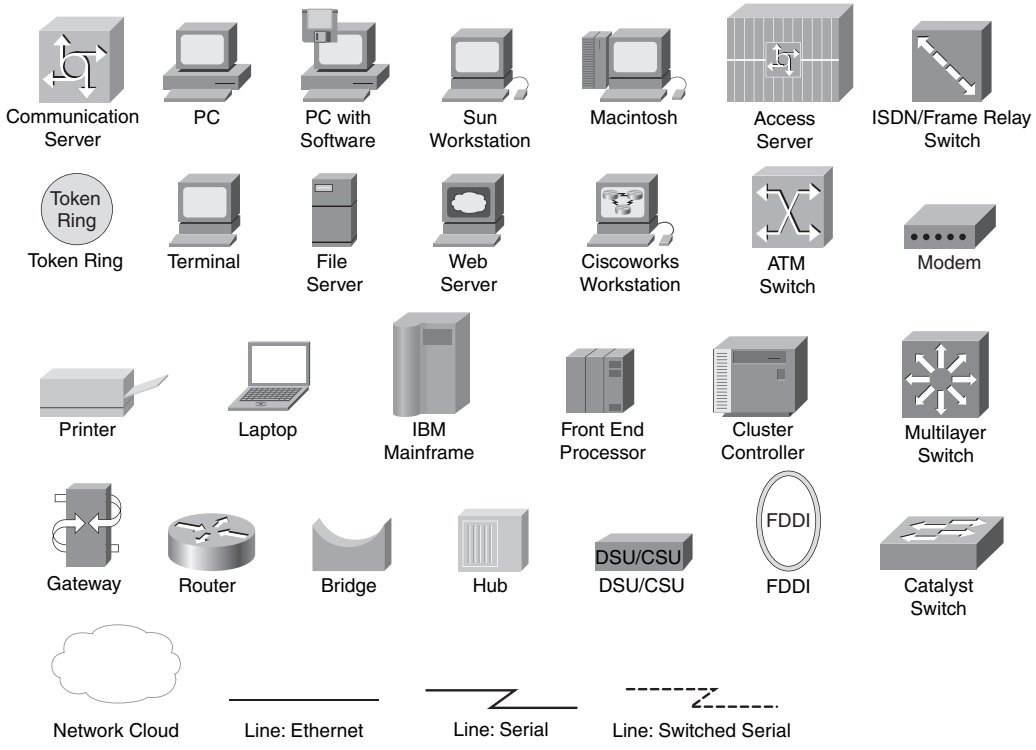
Icons Used in This Book



Command Syntax Conventions

The conventions used to present command syntax in this book are the same conventions used in the IOS Command Reference. The Command Reference describes these conventions as follows:

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a **show** command).
- *Italic* indicates arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets ([ ]) indicate an optional element.
- Braces ({ }) indicate a required choice.
- Braces within brackets ([{ }]) indicate a required choice within an optional element.

Introduction

Congratulations! If you are reading this Introduction, then you likely have decided to pursue the Cisco Certified Design Expert (CCDE) certification, a mostly vendor-agnostic, expert-level network design certification. Network design is imperative to implementing a successful, secure network, yet networking professionals typically are not taught network design, including the fundamentals, principles, techniques, frameworks, and pitfalls, early enough in their careers.

One of the major difficulties of network design is that it can't be pre-scripted or templated, because each design decision, even if it's comparing the same design options, can have very different business drivers, outcomes, constraints, and overall circumstances that create a unique situation requiring a different design decision to be made. This is why this book is going to teach you how to answer the question "Why?" with regard to design decisions, and how to map those design decisions to the business. This book bridges the gap between the technology and business. Instead of attempting to teach, and require you to memorize, every design decision tree, the goal of this book is to teach you the required skills to make proper design decisions in any situation you are presented.

It's not enough to learn about the "why" to fully grasp the implications of our design decisions. We also need to see "how" something is done to help solidify our understanding of the "why" from a network design perspective. To accomplish this, this book (and its additional online resources) includes multiple mini-design scenarios, illustrations, lab topologies, and configurations to provide the required design perspective.

Goals and Methods

The most important and somewhat obvious goal of this book is to help you pass the Cisco Certified Design Expert (CCDE) Written Exam (400-007). In fact, if the primary objective of this book were different, then the book's title would be misleading; however, the methods used in this book to help you pass the CCDE Written Exam are designed to also make you much more knowledgeable about how to make proper network design decisions that make businesses successful. Although this book and the companion website together have more than enough questions to help you prepare for the actual exam, the method in which they are used is not to simply make you memorize as many questions and answers as you possibly can.

One key methodology used in this book is to help you discover the exam topics that you need to review in more depth, to help you fully understand and remember those details, and to help you prove to yourself that you have retained your knowledge of those topics. So, this book does not try to help you pass by memorization, but rather helps you to truly learn and understand the topics. This book would do you a disservice if it didn't attempt to help you learn the material.

This is the first book to not only target the CCDE Written Exam (400-007) but also teach you the skillsets needed to make proper designs decisions in any situation. Technology is always changing and advancing, which makes it imperative that we learn how to make proper design decisions as these new technologies, solutions, and capabilities are developed and deployed. This book is the start of your "license to design" journey.

This book covers the different design fundamentals, principles, techniques, and topics using the following approach:

- It presents the different technologies, protocols, design fundamentals, design principles, design techniques, and the associated design decisions made with all of these items in mind.
- It identifies the impact to the business when adopting the different technologies and protocols.
- It addresses the implications of the addition or integration of an element to the overall design.

The network design topics covered in this book aim to prepare you to be able to

- Identify and analyze various network design requirements, constraints, and drivers that have an influence on the corresponding network design decisions.
- Understand the impact that the different network design fundamentals, principles, and techniques have on the business and the associated design decisions.
- Understand and compare the various network design architectures and the associated implications on various network design aspects.
- Identify and analyze network design limitations or issues, and how to optimize them, taking into consideration the business requirements and constraints.
- Identify and analyze the implications of adding new services or applications and how to accommodate the design or the design approach to meet the business outcome.

Whether you are preparing for the CCDE certification or just want to be a better network designer, you will benefit from the range of topics covered and the business success approach used to analyze, compare, and explain these topics to make proper design decisions.

Who Should Read This Book?

This book is not designed to be a general networking topics book, although it can be used for that purpose. This book is intended to tremendously increase your chances of passing the CCDE Written Exam. Although other objectives can be achieved from using this book, the book is written with one goal in mind: to help you pass the exam.

In addition to those who are planning or studying for the CCDE certification, this book is for network engineers, network consultants, network architects, and solution architects who already have a foundational knowledge of the topics being covered and who would like to train themselves to think more like a network designer.

So, why should you want to pass the CCDE Written Exam (400-007)? Because it's one of the milestones toward getting the CCDE certification, and passing it is a prerequisite to being able to schedule the CCDE Practical Exam, which is no small feat. What would getting the CCDE certification mean to you? It might translate to a raise, a promotion, and recognition. It would certainly enhance your resume. It would demonstrate that you

are serious about continuing the learning process and that you are not content to rest on your laurels. It might please your reseller-employer, who needs more certified employees.

Your Path Towards the CCDE Certification

This section provides a quick high-level overview of the CCDE certification and how to obtain it. Figure I-1 shows the current path you will have to take to achieve the CCDE certification.

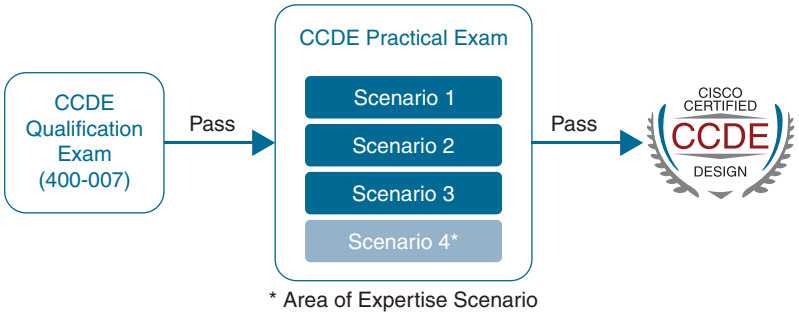


Figure I-1 *CCDE Certification Path*

Both the CCDE Written and Practical Exams focus on high-level design (HLD) aspects as well as business requirements within the context of the enterprise network architectures.

Both exams share one single unified blueprint, "CCDE v3 Unified Exam Topics." The CCDE Written Exam will validate core enterprise network architecture HLD aspects. The CCDE Practical Exam is built to be modular and provides you the flexibility to focus on your area of expertise in addition to validating core enterprise architecture HLD aspects.

This flexibility is achieved by using multiple technology lists. The "CCDE v3 Core Technology List" contains all core enterprise architecture technologies, and multiple areas of expertise technology lists contain logically grouped technologies, focusing on your area of expertise. Figure I-2 shows the breakdown of the entire CCDE certification process, including where and when to leverage each technology list.

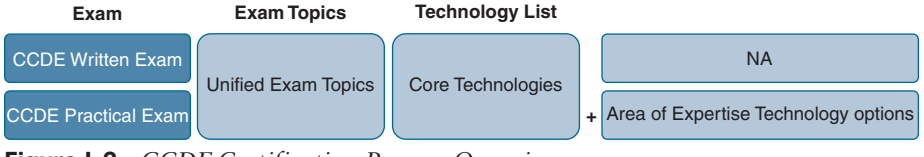


Figure I-2 *CCDE Certification Process Overview*

CCDE Written Exam (400-007)

The CCDE Written Exam is a computer-based exam that's focused on technology and architecture operations, but not on the specific configurations to implement said technology or architecture. More importantly, the Written Exam is about determining what technology out of a list of technology options should be leveraged in a specific design situation. As a CCDE candidate, you have to know and understand which solution solves

a specific problem. Then, you have to identify out of a group of solutions which one is the best option given the specific customer requirements, drivers, constraints, and circumstances, and why it is the best option. The why part is extremely important.

The Written Exam validates HLD aspects as well as business requirements within the context of enterprise network architecture. The exam is a two-hour, multiple-choice test with 90 to 110 questions that focus on core enterprise network architecture HLD aspects. The exam serves as a prerequisite for the CCDE Practical Exam. The Written Exam is closed book, meaning no outside reference materials are allowed.

For more information on what to expect on your CCDE Written Exam, refer to the following:

- "CCDE v3 Unified Exam Topics" (https://learningcontent.cisco.com/documents/exam-topics/CCDEv3.0_UnifiedExamTopics_May2021.pdf)
- "CCDE v3 Core Technology List" (https://learningcontent.cisco.com/documents/exam-topics/CCDEv30Practical_CoreTechnologyList_2.pdf)

Figure I-3 is an overview of the CCDE Written Exam process and how both the "CCDE v3 Unified Exam Topics" and "CCDE v3 Core Technology List" fit into it.

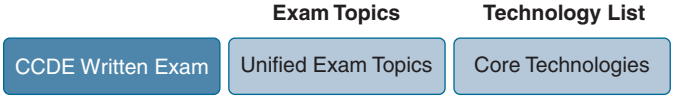


Figure I-3 *CCDE Written Exam (400-007) Process*

This book is the official certification guide for this exam, the CCDE Written Exam (400-007).

CCDE Practical Exam

After successfully passing the CCDE Written Exam (400-007), you can schedule and take the CCDE Practical Exam. The CCDE Practical Exam is an 8-hour scenario-based exam, consisting of several scenarios, one of which you can select, providing the flexibility to include topics related to your area of expertise, in addition to validating core enterprise architecture technologies. While additional areas of expertise might be added in the future, the following are the options that are available at the time of writing:

- **Large-Scale Networks:** Focuses on the aspects of designing large-scale networks, such as service provider networks or large enterprise networks and their associated technologies.
- **On-Prem and Cloud Services:** Centered on design and integration of business-critical services from a networking perspective. These services may be placed in an

on-premises data center, in the cloud, or a hybrid thereof. A deep understanding of applications and their requirements, as well as related networking technologies, is expected for this module.

- **Workforce Mobility:** Focuses on the design of solutions that benefit users in their daily job and routines, allowing them to roam freely across campuses and buildings without losing access to the services they depend on. Achieving this requires a well-planned and well-designed wireless network.

Technologies relevant to these are grouped together in areas of expertise technology lists. Each area of expertise comes with its own corresponding list. Figure I-4 shows how these different technology lists are used within the CCDE Practical Exam.

- CCDE v3 Technology Lists
  - "CCDE v3 Core Technology List"

    https://learningcontent.cisco.com/documents/CCDEv3_CoreTechnologyList.pdf
  - "Workforce Mobility Technology List"

    https://learningcontent.cisco.com/documents/CCDEv3_PracticalWorkforceMobilityTechnologyList.pdf
  - "On-Prem and Cloud Services Technology List"

    https://learningcontent.cisco.com/documents/CCDEv3_PracticalOnPrem_and_CloudServicesTechnologyList.pdf
  - "Large-Scale Networks Technology List"

    https://learningcontent.cisco.com/documents/CCDEv3_PracticalLargeScaleNetworksTechnologyList.pdf

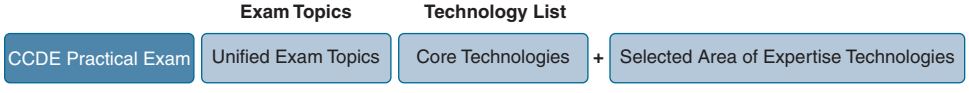


Figure I-4 *CCDE Practical Exam Process*

The CCDE v3 Practical exam is delivered at Cisco Certification Centers.

The Cisco Press book *CCDE v3 Practice Labs* (by Martin J. Duggan) is a great resource and guide for preparing to take the CCDE Practical Exam.

Strategies for Exam Preparation

The strategy you use for the CCDE Written Exam (400-007) might be slightly different than strategies used by other readers, mainly based on the skills, knowledge, and experience you already have obtained.

Regardless of the strategy you use or the background you have, the book is designed to help you get to the point where you can pass the exam with the least amount of time required. For instance, there is no need for you to practice or read about enterprise Layer 2 design if you fully understand it already. However, many people like to make sure that

they truly know a topic and thus read over material that they already know. Some readers might want to jump into new technologies or architectures, such as Cisco SD-Access, automation, Zero Trust Architecture, and DevOps. Several book features will help you gain the confidence that you need to be convinced that you know some material already, and to also help you know what topics you need to study more. As mentioned earlier, the CCDE Written Exam is not focused on configuration details, so there's no need to memorize how to configure each technology. However, some people learn better with a hands-on approach, so if you feel you get a better grasp of the technology by trying it out in a lab, there's absolutely nothing wrong with that.

The Companion Website for Online Content Review

All the electronic review elements, as well as other electronic components of the book, are available on this book's companion website.

How to Access the Companion Website

To access the companion website, which gives you access to the electronic content with this book, start by establishing a login at www.ciscopress.com and registering your book. To do so, simply go to www.ciscopress.com/register and enter the ISBN of the print book: 9780137601042. After you have registered your book, go to your account page and click the Registered Products tab. From there, click the Access Bonus Content link to get access to the book's companion website.

Note that if you buy the Premium Edition eBook and Practice Test version of this book from Cisco Press, your book will automatically be registered on your account page. Simply go to your account page, click the Registered Products tab, and select Access Bonus Content to access the book's companion website.

How to Access the Pearson Test Prep (PTP) App

You have two options for installing and using the Pearson Test Prep application: a web app and a desktop app. To use the Pearson Test Prep application, start by finding the registration code that comes with the book. You can find the code in these ways:

- **Print book:** Look in the cardboard sleeve in the back of the book for a piece of paper with your book's unique PTP code.
- **Premium Edition:** If you purchase the Premium Edition eBook and Practice Test directly from the Cisco Press website, the code will be populated on your account page after purchase. Just log in at www.ciscopress.com, click Account to see details of your account, and click the Digital Purchases tab.
- **Amazon Kindle:** For those who purchase a Kindle edition from Amazon, the access code will be supplied directly from Amazon.
- **Other Bookseller E-books:** Note that if you purchase an e-book version from any other source, the practice test is not included because other vendors to date have not chosen to vend the required unique access code.

NOTE Do not lose the activation code, because it is the only means with which you can access the QA content with the book.

Once you have the access code, to find instructions about both the PTP web app and the desktop app, follow these steps:

Step 1 Open this book's companion website, as described in the previous section.

Step 2 Click the Practice Exams button.

Step 3 Follow the instructions listed there both for installing the desktop app and for using the web app.

Note that if you want to use the web app only at this point, just navigate to www.pearsontestprep.com, establish a free login if you do not already have one, and register this book's practice tests using the registration code you just found. The process should take only a couple of minutes.

NOTE Amazon eBook (Kindle) customers: It is easy to miss Amazon's email that lists your PTP access code. Soon after you purchase the Kindle eBook, Amazon should send an email. However, the email uses very generic text, and makes no specific mention of PTP or practice exams. To find your code, read every email from Amazon after you purchase the book. Also do the usual checks for ensuring your email arrives, like checking your spam folder.

NOTE Other eBook customers: As of the time of publication, only the publisher and Amazon supply PTP access codes when you purchase their eBook editions of this book.

How This Book Is Organized

Although this book could be read cover to cover, it is designed to be flexible and allow you to easily move between chapters and sections of chapters to cover just the material that you need more work with.

This book is organized into three distinct parts. Part 1, Chapters 1 through 5, covers network design generally. Then, we dive into the different technologies in Part 2, Chapters 6 through 14, and discuss how they work. Part 3, Chapters 15 to 17, covers enterprise network architectures in the real world today.

The following list describes what is covered in each chapter in this book:

- **Chapter 1, "Network Design"**—This chapter focuses on the different network design fundamentals, principles, techniques, and pitfalls that all network designers need to know.
- **Chapter 2, "Designing for Business Success"**—This chapter discusses the different aspects of the business and how to ensure that the network design decisions being made will make a business successful. In addition, project management method-

ologies are covered, as network designers should know how these methodologies impact a business.

- **Chapter 3, "What's the Purpose of the Network?"**—This chapter covers the reason why there is a network in the first place. Coverage in this chapter includes applications, service models, cloud constructs, and data management.
- **Chapter 4, "Security Is Pervasive"**—This chapter explores the architecture-level security topics, including Zero Trust, the CIA triad, and regulatory compliance standards.
- **Chapter 5, "Reference Architecture Models and Frameworks"**—This chapter covers business architecture, enterprise architecture, and current architecture frameworks being leveraged at the time of this writing.
- **Chapter 6, "Transport Technologies"**—This chapter examines physical and logical transport topics, including Layer 2 media access, Virtual Private Wire Service (VPWS), Layer 2 VPN (L2VPN), and Ethernet VPN (EVPN).
- **Chapter 7, "Layer 2 Technologies"**—This chapter covers Layer 2 core technologies: Spanning Tree Protocol (STP), virtual local-area networks (VLANs), trunking, link aggregation, and First Hop Redundancy Protocol (FHRP).
- **Chapter 8, "Layer 3 Technologies"**—This chapter discusses Layer 3 control plane technologies from an enterprise perspective. This includes enterprise Layer 3 routing with different interior gateway protocols (IGPs), Border Gateway Protocol (BGP) routing, and associated design recommendations.
- **Chapter 9, "Network Virtualization"**—This chapter covers Multiprotocol Label Switching (MPLS) L2 and L3 VPNs and software-defined network solutions like SD-WAN and SD-LAN.
- **Chapter 10, "Security"**—This chapter explores infrastructure security topics, perimeter security and intrusion prevention, and network control and identity management.
- **Chapter 11, "Wireless"**—This chapter describes the most common IEEE 802.11 standards and protocols, and enterprise wireless network design use cases of high density, voice and video, and data.
- **Chapter 12, "Automation"**—This chapter covers automation concepts that impact a network design at the architecture level. These topics include zero-touch provisioning, Infrastructure as Code (IaC), and continuous integration/continuous delivery (CI/CD) pipelines.
- **Chapter 13, "Multicast Design"**—This chapter examines multicast switching and routing, along with the corresponding network design considerations.
- **Chapter 14, "Network Services and Management"**—This chapter covers critical IPv6 topics and network design elements for IPv6 that haven't been covered in other chapters. Additionally, this chapter covers Quality of Service and network management design.

- **Chapter 15, "Scalable Enterprise Campus Architecture Design"**—This chapter highlights campus hierarchical design models, campus Layer 3 routing design considerations, and campus network virtualization design considerations.
- **Chapter 16, "Enterprise Internet Edge Architecture Design"**—This chapter provides design recommendations and considerations from an enterprise Internet edge architecture standpoint. It explores how an enterprise gets to resources on the Internet and how customers get to locally hosted resources within the enterprise.
- **Chapter 17, "Enterprise WAN Architecture Design"**—This chapter provides design recommendations and considerations for the enterprise WAN module, WAN virtualization and overlay options, and enterprise WAN migration to MPLS VPN considerations.
- **Chapter 18, "Final Preparation"**—This chapter provides steps for you to take in your final phase of study before taking the CCDE Written Exam. This chapter also includes tools and resources that you can leverage to help in your journey.

Certification Exam Topics and This Book

The questions for each Cisco certification exam are a closely guarded secret. However, Cisco does publish an exam blueprint so that you know which topics you must know to *successfully* complete this exam.

NOTE This book covers only the "CCDE v3 Unified Exam Topics" blueprint and the "CCDE v3 Core Technology List," as they encompass all the knowledge areas required for the CCDE Written Exam.

Table I-1 lists each section in the "CCDE v3 Unified Exam Topics" blueprint along with a reference to the book chapter that covers the corresponding topic.

Table I-2 lists each section in the "CCDE v3 Core Technology List" along with a reference to the book chapter that covers the corresponding topic.

These are the same topics you should be proficient in when designing networks and making proper network design decisions in the real world.

NOTE The two topic lists covered in Table I-1 and Table I-2 below are current as of the book's writing, but may be subject to updates, so always check the blueprint at cisco.com.

Table I-1 CCDE v3 Unified Exam Topics

CCDE v3 Unified Exam Topics	Chapter(s) in Which Topic Is Covered
1.0 Business Strategy Design (15%)	**2**
1.1 Impact on network design, implementation, and optimization using various customer project management methodologies (for instance waterfall and agile)	2

CCDE v3 Unified Exam Topics	Chapter(s) in Which Topic Is Covered
1.2 Solutions based on business continuity and operational sustainability (for instance RPO, ROI, CAPEX/OPEX cost analysis, and risk/reward)	2
2.0 Control, data, management plane and operational design (25%)	7, 8, 9, 12
2.1 End-to-end IP traffic flow in a feature-rich network	8, 9
2.2 Data, control, and management plane techniques	7, 8, 9
2.3 Centralized, decentralized, or hybrid control plane	7, 8, 9
2.4 Automation/orchestration design, integration, and on-going support for networks (for instance interfacing with APIs, model-driven management, controller-based technologies, evolution of CI/CD framework)	12
2.5 Software-defined architecture and controller-based solution design (SD-WAN, overlay, underlay, and fabric)	9
3.0 Network Design (30%)	1
3.1 Resilient, scalable, and secure modular networks, covering both traditional and software-defined architectures, considering:	1
3.1.a Technical constraints and requirements	1
3.1.b Operational constraints and requirements	1
3.1.c Application behavior and needs	1, 3
3.1.d Business requirements	1
3.1.e Implementation Plans	1
3.1.f Migration and transformation	1
4.0 Service Design (15%)	1, 3, 4
4.1 Resilient, scalable, and secure modular network design based on constraints (for instance technical, operational, application, and business constraints) to support applications on the IP network (for instance voice, video, backups, data center replication, IoT, and storage)	1, 3
4.2 Cloud/hybrid solutions based on business-critical operations	3, 4
4.2.a Regulatory compliance	4
4.2.b Data governance (for instance sovereignty, ownership, and locale)	4
4.2.c Service placement	3
4.2.d SaaS, PaaS, and IaaS	3
4.2.e Cloud connectivity (for instance direct connect, cloud on ramp, MPLS direct connect, and WAN integration)	3
4.2.f Security	4
5.0 Security Design (15%)	4, 10

CCDE v3 Unified Exam Topics	Chapter(s) in Which Topic Is Covered
5.1 Network security design and integration	4
5.1.a Segmentation	4, 10
5.1.b Network access control	4
5.1.c Visibility	4
5.1.d Policy enforcement	4
5.1.e CIA triad	4
5.1.f Regulatory compliance (if provided the regulation)	4

Table I-2 CCDE v3 Core Technology List

CCDE v3 Core Technology List	Chapter(s) in Which Topic Is Covered
1.0 Transport Technologies	6
1.1 Ethernet	6
1.2 CWDM/DWDM	6
1.3 Frame relay (migration only)	6
1.4 Cellular and broadband (as transport methods)	6
1.5 Wireless	11
1.6 Physical mediums, such as fiber and copper	6
2.0 Layer 2 Control Plane	7, 15
2.1 Physical media considerations	7
2.1.a Down detection	7
2.1.b Interface convergence characteristics	7
2.2 Loop detection protocols and loop-free topology mechanisms	7, 15
2.2.a Spanning tree types	7
2.2.b Spanning tree tuning techniques	7
2.2.c Multipath	7
2.2.d Switch clustering	7
2.3 Loop detection and mitigation	7
2.4 Multicast switching	13
2.4.a IGMPv2, IGMPv3, MLDv1, MLDv2	13
2.4.b IGMP/MLD Snooping	13
2.4.c IGMP/MLD Querier	13
2.5 Fault isolation and resiliency	13
2.5.a Fate sharing	13
2.5.b Redundancy	13
2.5.c Virtualization	13

CCDE v3 Core Technology List	Chapter(s) in Which Topic Is Covered
2.5.d Segmentation	13
3.0 Layer 3 Control Plane	8, 9, 15, 16, 17
3.1 Network Hierarchy and topologies	8, 9
3.1.a Layers and their purposes in various environments	8, 9
3.1.b Network topology hiding	8, 9
3.2 Unicast routing protocol operation (OSPF, EIGRP, IS-IS, BGP, and RIP)	8
3.2.a Neighbor relationships	8
3.2.b Loop-free paths	8
3.2.c Flooding domains	8
3.2.d Scalability	8
3.2.e Routing policy	8
3.2.f Redistribution methods	8
3.3 Fast convergence techniques and mechanism	8, 9
3.3.a Protocols	8, 9
3.3.b Timers	8, 9
3.3.c Topologies	8, 9
3.3.d Loop-free convergence	8, 9
3.4 Factors affecting convergence	8
3.4.a Recursion	8
3.4.b Micro-loops	8
3.5 Route aggregation	8
3.5.a When to leak routes / avoid suboptimal routing	8
3.5.b When to include more specific routes (up to and including host routes)	8
3.5.c Aggregation location and techniques	8
3.6 Fault isolation and resiliency	8
3.6.a Fate sharing	8
3.6.b Redundancy	8
3.7 Metric-based traffic flow and modification	8
3.7.a Metrics to modify traffic flow	8
3.7.b Third-party next hop	8
3.8 Generic routing and addressing concepts	8
3.8.a Policy-based routing	8
3.8.b NAT	10
3.8.c Subnetting	8

CCDE v3 Core Technology List	Chapter(s) in Which Topic Is Covered
3.8.d RIB-FIB relationships	8
3.9 Multicast routing concepts	13
3.9.a General multicast concepts	13
3.9.b MSDP/anycast	13
3.9.c PIM	13
4.0 Network Virtualization	9
4.1 Multiprotocol Label Switching	9
4.1.a MPLS forwarding and control plane mechanisms	9
4.1.b MP-BGP and related address families	9
4.1.c LDP	9
4.2 Layer 2 and 3 VPN and tunneling technologies	9
4.2.a Tunneling technology selection (such as DMVPN, GETVPN, IPsec, MPLS, GRE)	9, 17
4.2.b Tunneling endpoint selection	9, 17
4.2.c Tunneling parameter optimization of end-user applications	9, 17
4.2.d Effects of tunneling on routing	9, 17
4.2.e Routing protocol selection and tuning for tunnels	9, 17
4.2.f Route path selection	9, 17
4.2.g MACsec (802.1.ae)	10
4.2.h Infrastructure segmentation methods	10
4.2.h (i) VLAN	10
4.2.h (ii) PVLAN	10
4.2.h (iii) VRF-Lite	10
4.3 SD-WAN	9
4.3.a Orchestration plane	9
4.3.b Management plane	9
4.3.c Control plane	9
4.3.d Data plane	9
4.3.e Segmentation	9
4.3.f Policy	9
4.3.f (i) Security	9
4.3.f (ii) Topologies	9
4.3.f (iii) Application-based routing	9
4.4 Migration techniques	9
4.5 Design considerations	9

CCDE v3 Core Technology List	Chapter(s) in Which Topic Is Covered
4.6 QoS techniques and strategies	14
4.6.a Application requirements	14
4.6.b Infrastructure requirements	14
4.7 Network management techniques	14
4.7.a Traditional (such as SNMP, SYSLOG)	14
4.7.b Model-driven (such as NETCONF, RESTCONF, gNMI, streaming telemetry)	14
4.8 Reference models and paradigms that are used in network management (such as FCAPS, ITIL, TOGAF, and DevOps)	5
5.0 Security	4, 10
5.1 Infrastructure security	10
5.1.a Device hardening techniques and control plane protection methods	10
5.1.b Management plane protection techniques	10
5.1.b (i) CPU	10
5.1.b (ii) Memory thresholding	10
5.1.b (iii) Securing device access	10
5.1.c Data plane protection techniques	10
5.1.c (i) QoS	14
5.1.d Layer 2 security techniques	10
5.1.d (i) Dynamic ARP inspection	10
5.1.d (ii) IPDT	10
5.1.d (iii) STP security	10
5.1.d (iv) Port security	10
5.1.d (v) DHCP snooping	10
5.1.d (vi) IPv6-specific security mechanisms	10, 14
5.1.d (vii) VACL	14
5.1.e Wireless security technologies	11
5.1.e (i) WPA	11
5.1.e (ii) WPA2	11
5.1.e (iii) WPA3	11
5.1.e (iv) TKIP	11
5.1.e (v) AES	11
5.2 Protecting network services	10
5.2.a Deep packet inspection	10
5.2.b Data plane protection	10

CCDE v3 Core Technology List	Chapter(s) in Which Topic Is Covered
5.3 Perimeter security and intrusion prevention	10
5.3.a Firewall deployment modes	10
5.3.a (i) Routed	10
5.3.a (ii) Transparent	10
5.3.a (iii) Virtualization	10
5.3.a (iv) Clustering and high availability	10
5.3.b Firewall features	10
5.3.b (i) NAT	10
5.3.b (ii) Application inspection	10
5.3.b (iii) Traffic Zones	10
5.3.b (iv) Policy-based routing	10
5.3.b (v) TLS inspection	10
5.3.b (vi) User identity	10
5.3.b (vii) Geolocation	10
5.3.c IPS/IDS deployment modes	10
5.3.c (i) In-line	10
5.3.c (ii) Passive	10
5.3.c (iii) TAP	10
5.3.d Detect and mitigate common types of attacks	10
5.3.d (i) DoS/DDoS	10
5.3.d (ii) Evasion techniques	10
5.3.d (iii) Spoofing	10
5.3.d (iv) Man-in-the-middle	10
5.3.d (v) Botnet	10
5.4 Network control and identity management	10, 11
5.4.a Wired and wireless network access control	10, 11
5.4.b AAA for network access with 802.1X and MAB	10, 11
5.4.c Guest and BYOD considerations	10, 11
5.4.d Internal and external identity sources	10
5.4.e Certificate-based authentication	10
5.4.f EAP Chaining authentication method	10
5.4.g Integration with Multifactor authentication	10
6.0 Wireless	11
6.1 IEEE 802.11 Standards and Protocols	11
6.1.a Indoor and outdoor RF deployments	11
6.1.a (i) Coverage	11
6.1.a (ii) Throughput	11

CCDE v3 Core Technology List	Chapter(s) in Which Topic Is Covered
6.1.a (iii) Voice	11
6.1.a (iv) Location	11
6.1.a (v) High density / very high density	11
6.2 Enterprise wireless network	11
6.2.a High availability, redundancy, and resiliency	11
6.2.b Controller-based mobility and controller placement	11
6.2.c L2/L3 roaming	11
6.2.d Tunnel traffic optimization	11
6.2.e AP groups	11
6.2.f AP modes	11
7.0 Automation	12
7.1 Zero-touch provisioning	12
7.2 Infrastructure as Code (tools, awareness, and when to use)	12
7.2.a Automation tools (i.e., Ansible)	12
7.2.b Orchestration platforms	12
7.2.c Programming Language (e.g., Python)	12
7.3 CI/CD Pipeline	12

Each version of the exam can have topics that emphasize different functions or features, and some topics can be rather broad and generalized. The goal of this book is to provide the most comprehensive coverage to ensure that you are well prepared for the exam. Although some chapters might not address specific exam topics, they provide a foundation that is necessary for a clear understanding of important topics. Your short-term goal might be to pass this exam, but your long-term goal should be to become a qualified network designer that can make proper network design decisions that help to make businesses successful.

It is also important to understand that this book is a "static" reference, whereas the exam topics are dynamic. Cisco can and does change the topics covered on certification exams often.

This exam guide should not be your only reference when preparing for the certification exam. You can find a wealth of information available at Cisco.com that covers each topic in great detail. If you think that you need more detailed information on a specific topic, read the Cisco documentation that focuses on that topic.

Note that as technologies and architectures continue to develop, Cisco reserves the right to change the exam topics without notice. Although you can refer to the list of exam topics in Tables I-1 and I-2, always check Cisco.com to verify the actual list of topics to ensure that you are prepared before taking the exam. You can view the current exam topics on any current Cisco certification exam by visiting the Cisco.com website, choosing

Menu, and Training & Events, then selecting from the Certifications list. Note also that, if needed, Cisco Press might post additional preparatory content on the web page associated with this book at http://www.ciscopress.com/title/9780137601042. It's a good idea to check the website a couple of weeks before taking your exam to be sure that you have up-to-date content.

CHAPTER 3

What's the Purpose of the Network?

This chapter covers the following topics:

- **Business Applications:** This section covers business applications and the associated network design elements for them.
- **Service Models:** This section covers the different service models, how to leverage them, and what the network design characteristics are for each model.
- **The Cloud:** This section covers the cloud in all its forms and the associated network design elements.
- **Data Management:** This section covers data and the data management methodologies that will help every network designer make better design decisions.

What's the purpose of the network? Why do we need a network? Why is a network there in the first place? These questions should always be at the top of your mind as network designer because understanding the purpose and goal of the network is critical to properly designing it.

As we answer these questions, a technical (and potentially a tactical) answer is that the network's purpose is to get data from point A to point B in the right amount of time. This is a generally good answer to these questions, and usually network engineers, not network designers, can easily identify.

From a network design perspective, we need to take this answer a step further. Why is the network transferring data in the first place? To meet the business outcomes and objectives… to make the business successful!

Businesses have become so reliant on networks that the required availability of the network and its associated services has to be designed at an extremely high level. This is similar to what transpired with the plain old telephone service (POTS) network. It became so relied upon that the overall availability had to be designed at an extremely high level.

There is a shift in the network, as discussed in the previous chapters, toward a service-focused network. When we talk about services in this context, we are talking about applications, service models, the cloud in all its forms, and data.

This chapter covers the following "CCDE v3.0 Unified Exam Topics" section:

- 4.0 Service Design

"Do I Know This Already?" Quiz

The "Do I Know This Already?" quiz allows you to assess whether you should read this entire chapter thoroughly or jump to the "Exam Preparation Tasks" section. If you are in doubt about your answers to these questions or your own assessment of your knowledge of the topics, read the entire chapter. Table 3-1 lists the major headings in this chapter and their corresponding "Do I Know This Already?" quiz questions. You can find the answers in Appendix A, "Answers to the 'Do I Know This Already?' Quizzes."

Table 3-1 "Do I Know This Already?" Section-to-Question Mapping

Foundation Topics Section	Questions
Business Applications	1–3
Service Models	4–7
The Cloud	8–10
Data Management	11

CAUTION The goal of self-assessment is to gauge your mastery of the topics in this chapter. If you do not know the answer to a question or are only partially sure of the answer, you should mark that question as wrong for purposes of the self-assessment. Giving yourself credit for an answer you correctly guess skews your self-assessment results and might provide you with a false sense of security.

1. Which of the following options is the correct application model for the statement "This is the simplest application model and it is equivalent to running the application on a personal computer"?
   - **a.** 3-tier model
   - **b.** Single-server model
   - **c.** 2-tier model
   - **d.** SaaS
2. Which of the following application models is like the client/server architecture?
   - **a.** 3-tier model
   - **b.** Single-server model
   - **c.** 2-tier model
   - **d.** SaaS
3. Which of the following application models has web, application, and database layers?
   - **a.** 3-tier model
   - **b.** Single-server model
   - **c.** 2-tier model
   - **d.** SaaS

4. Which service model is best used when a business requires full control of all components within an application?
   a. PaaS
   b. IaaS
   c. SaaS
   d. On-premises
5. Which service model is best for application developers?
   a. PaaS
   b. IaaS
   c. SaaS
   d. On-premises
6. Which service model is best if a business wants complete control over its virtual infrastructure but also wants to operate on a pay-as-you-go basis?
   a. PaaS
   b. IaaS
   c. SaaS
   d. On-premises
7. Which service model is best if a business wants an application to run with ensured availability but doesn't want the headache of managing the application in any form?
   a. PaaS
   b. IaaS
   c. SaaS
   d. On-premises
8. Which cloud type has the highest cost?
   a. Hybrid cloud
   b. Private cloud
   c. Multi-cloud
   d. Public cloud
9. Which cloud type is best if a business wants the most control possible?
   a. Hybrid cloud
   b. Private cloud
   c. Multi-cloud
   d. Public cloud
10. Which cloud type is best if a business wants to ease into a cloud computing environment over a long period of time?
    a. Hybrid cloud
    b. Private cloud
    c. Multi-cloud
    d. Public cloud

11. Which option is the proper data management pillar for the definition "The planning of all aspects of data management"?
    a. Data quality
    b. Data governance
    c. Data architecture
    d. Data security

Foundation Topics

Business Applications

The network is the information highway for the business applications of today, and for the business to be successful, these applications must be able to properly communicate as required between users, devices, data, databases, and other application components.

Application Models

Network designers need to understand how an application is built to properly design the network for that application. The following are the different application models being leveraged today and their associated design elements that you need to know as a network designer:

- **Single-server model:** This is the simplest application model and it is equivalent to running the application on a personal computer. All of the required components for an application to run are on a single application or server.
- **2-tier model:** This application model is like the client/server architecture, where communication takes place between client and server. In this model, the presentation layer or user interface layer runs on the client side while the dataset layer gets executed and stored on the server side.

  There is no intermediate layer (aka application layer) in between client and server.
- **3-tier model:** This application model is the most common at the time of writing. This model has three tiers or layers:
  - **Presentation:** This is the front end of the application that all end users access. This is how an end user sees and interacts with the application. This is often called the web tier or GUI tier of the application. The main function of this layer is to translate tasks and results to something the end user can understand.
  - **Intermediate:** This is the layer where all of the application's functions and logic occur. This layer processes tasks, functions, and commands, makes decisions and evaluations, and performs calculations. It also is how data is moved between the presentation (web/GUI) and database layers. This is often referred to as the application or logic layer of the application.
  - **Database:** Here information is stored and retrieved from a database. The information is then passed back to the intermediate (application) layer and then eventually back to the end user.

Breaking elements of an application into different layers like the *n*-tier architectures allows network designers to properly design the network for each tier or layer individually. Each layer may need its own load balancing, applying source NAT, DNS, source routing, and

traffic engineering design. This means more work from a network design perspective but a better purpose-built environment for each tier with all associated elements needed, which allows the different application layers to scale out as needed.

Table 3-2 shows the different network design elements for each layer of the 3-tier model and provides leading questions to ask to help elicit the information needed to make a proper design.

Key Topic

Table 3-2 3-Tier Application Model Network Design Elements

Tier	Traffic Pattern	Network Design Elements	Questions to Ask
Web tier	End user and application layer access only.	No database layer access. The web tier needs to be globally accessible for the end users. Normally located in a DMZ.	How are end users accessing the web tier globally? How are the web tier–specific networks/IP addresses being routed? What's the web tier's high-availability architecture? (Active/active, active/standby, anycast, etc.)
Application tier	Web and database access only. No end user should ever access this tier directly.	This tier is internally accessed only, so no external addresses or routing are needed. Load balancing should be implemented, but how depends on the other tier's communication method with this tier (SNAT, NAT, Sticky, etc.). Normally located internally behind multiple security layers.	How does the web tier communicate with the application tier? How does the database tier communicate with the application tier?
Database tier	Application layer access only. No end user or web tier should have access.	This tier is internally accessed only, so no external addresses or routing are needed. Normally located internally behind multiple security layers.	How is replication being done between the different database member servers? How are the database changes synchronized? The answer to his question is especially critical when there are multiple data center locations.

Application Constraints and Requirements

As a network designer, there are a number of common application constraints and requirements that you should be aware of. These are topics that a network designer should be asking about as a network is being designed to support an application. This is by no means an all-inclusive list.

- **Multicast:** Usually leveraged between a cluster of servers to keep data synchronized, such as a backend database replication architecture, or as a transport mechanism for

data streaming applications like IPTV and real-time stock market updates for day traders. In these situations, not having multicast breaks the application in question.

- **Layer 2 extension:** Probably one of the most common network design requirements after an application has completed its development process. As the application is being deployed, it is quickly identified that the application servers, maybe in a 3-tier model, do not communicate outside of their Layer 2 segments. Now it's the network designer's job to provide Layer 2 extension options that allow the application to properly function. This leads to bad network designs with large Layer 2 fault domains that are generally unreliable. Even though these are bad network design options from a network design perspective, they do solve the application requirement and thus they make the business successful. If there is a requirement to extend Layer 2, some of these limitations can be mitigated with overlay technologies while still allowing for an expanded Layer 2 environment.
- **Hardcoded items:** Thankfully, we are seeing issues with hardcoded items in the code less frequently today. They do happen, and that's why network designers need to know about them. These hardcoded items bring a security element into the mix with compliance controls and overall security requirements for the application in question. From a network design perspective, though, how do we handle hardcoded IP addresses in the code? The simplest answer is to not allow hardcoded items in the code, but what do you do as a network designer when it does happen? This is where solutions like Network Address Translation (NAT), traffic engineering, and source routing can be leveraged to help mitigate this issue.
- **High availability:** How an application is designed for high availability has a large impact on the network supporting that application. Is the application in multiple locations, such as geographically separated data centers? If so, how is the application data synchronized between these locations? How do end users access the applications in each location? Is one location preferred over the other at all times (active/standby), or can the application be accessed from either location at any time (active/active)? What about the load-balancing options for the application? Is it leveraging DNS load balancing or a physical load balancer? Does the application require the use of source NAT (SNAT) between its different application layers? There are so many network design–related questions that we have to ask and answer to properly facilitate the creation of a network design that makes the application successful.

When creating a network design that's goal is to make an application successful, it really comes down to the applications, services, and so forth being created incorrectly. Network designers have been forced to provide band-aid solutions like Layer 2 extension options because of these problems. This is most definitely not solving the true issue of proper application development. We simply extend Layer 2 as a short-term solution that ends up becoming a permanent one. This is similar to hardcoding IP addresses and hostnames in an application's code. Network designers always have to provide bad network design options because of these application issues.

To solve these issues, a network designer and a security specialist should be part of the team that builds and reviews an application, to ensure network design and security controls are being properly considered in the application. It's not fair to expect an application developer to know and understand the details of network design or security; network designers have to help them, teach them, and show them.

If we want to change these situations with the plan to limit them from happening, we need to be a part of the creation process so we can explain the reasons to the business at those critical steps. The business doesn't know what a network designer knows. A network designer can tell the business *why* they shouldn't rely on a Layer 2 extension for the application, *why* they shouldn't hardcode IP addresses, hostnames, usernames, and passwords in code, and *why* they should ensure security controls are implemented during the creation process.

In the end, it all comes back to business decisions and the respective trade-offs.

Service Models

We highlighted the different application models for how an application can be created earlier. This section takes that discussion a step further by covering the different service models that can be leveraged for the application. These service models determine where the application is located and what elements of the application are owned and managed by the business. The following are the most common service models:

NOTE There are other service models that are not covered in this section, such as Database as a Service (DBaaS), Compliance as a Service (CaaS), and Security as a Service (SECaaS). What is covered in this section are the most common service models at the time of writing.

- **On-premises:** On-premises is the service model where a business owns and manages an application. A business will procure all of the infrastructure required to run the service and then fully manage, maintain, and operate it. In some situations, the management is outsourced but the infrastructure is procured and owned by the business.
- **Software as a Service (SaaS):** SaaS is where a vendor makes its software available to users, usually for a monthly or annual subscription service fee.
- **Platform as a Service (PaaS):** PaaS is where a vendor provides hardware and software tools, and people use these tools to develop applications. PaaS users tend to be application developers.
- **Infrastructure as a Service (IaaS):** IaaS is a pay-as-you-go service model for storage, networking, and virtualization—all of a business's infrastructure needs. IaaS gives users cloud-based alternatives to on-premises infrastructure, so businesses can avoid investing in expensive onsite resources.

Table 3-3 shows the comparison between these service models.

Key Topic

Table 3-3 Service Model Comparison

Service Model	Characteristics	Advantages	When to Use
On-premises	Business owned and managed. Available locally. Hosted within the business's server environment.	Full control over all components of the application.	When a business requires full control of all components within the application. This is most often seen with security compliance and data classification requirements.

Service Model	Characteristics	Advantages	When to Use
SaaS	Available over the Internet. Hosted on a remote server by a third-party provider. Scalable, with service offerings based on need.	No need to install and run software on any computer. Everything is available to the end user over the Internet. Access to software can be from any device, at any time, with Internet connectivity.	When a business wants an application to run with ensured availability but without the headache of maintaining that application at any level.
PaaS	Accessible by multiple users. Scalable. Built on virtualization technology. Easy to run without extensive IT knowledge.	Primarily used by developers to create software or applications. Developers don't need to start from scratch when creating applications.	When a business wants to create a unique application without spending a ton of money or taking on all the responsibility.
IaaS	Highly flexible. Highly scalable. Accessible by multiple users. Cost-effective.	On-premises IT infrastructure is expensive. The business maintains control over the infrastructure.	When a business requires complete control over its infrastructure and wants to operate on a pay-as-you-go basis.

The Cloud

When a business starts planning to leverage cloud in any form, there are three use cases that network designers should consider throughout the design process:

- **Securely extending a private network to a single or multiple public cloud environments:** Includes multiple clouds (for example, multiple Amazon Web Services [AWS] and Azure), multiple regions in a cloud, or multiple VPCs in a cloud; VPN; multi-cloud and multi-VPC connectivity; scaling; and performance optimization of transit VPC. Also supports extending data centers into the cloud and enabling direct branch-to-cloud connectivity.
- **Optimizing data center and branch connectivity performance to cloud IaaS and SaaS:** Includes best path to a destination, cloud segmentation, monitoring to assure the best performance, visibility into traffic going to applications, and traffic shaping/Quality of Service (QoS). Also supports extending data centers into the cloud and enabling direct branch-to-cloud connectivity.
- **Securing access to the Internet and SaaS from the branch:** Includes connecting and protecting branch office users directly to the multi-cloud environment using Direct Internet Access (DIA) and properly securing them.

Cloud Connectivity Models

When businesses start to leverage cloud in any form, be it public, private, hybrid, or multi-cloud, how the business is going to connect to cloud environments is a topic for a network designer to address. There are multiple options, each with its own pros and cons.

Direct Cloud Access

Direct cloud access (DCA) allows a remote site to access SaaS applications directly from the Internet and through dedicated private connections. The cloud permits only the designated application traffic to use the directly connected Internet transport securely, while all other Internet-bound traffic takes the usual path, which could be through a regional hub, a data center, or a **carrier-neutral facility (CNF)**. This feature allows the remote site to bypass the latency of tunneling Internet-bound traffic to a central site, subsequently improving the connectivity to the prioritized SaaS application; this feature is commonly referred to as Direct Internet Access (DIA). The edge router chooses the most optimal Internet path for access to these SaaS applications. Different applications could traverse different paths because the path selection is calculated on a per-application basis.

If any SaaS application path becomes unreachable or its performance score falls below an unacceptable level, the path is removed as a candidate path option. If all paths cannot be path candidates because of reachability or performance, then traffic to the SaaS application follows the normal, routed path. Figure 3-1 illustrates a remote site using DIA to access SaaS applications

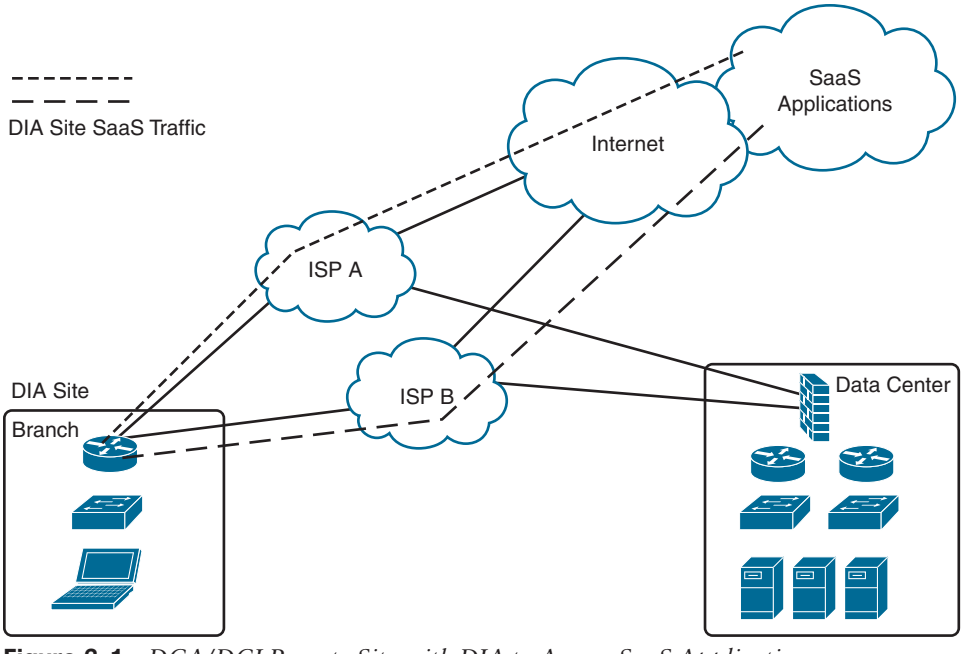


Figure 3-1 *DCA/DCI Remote Site with DIA to Access SaaS Applications*

Cloud Access Through a Gateway (Cloud Access Point)

Many businesses do not use DIA at the branch office, because either their sites are connected only by private providers (MPLS, VPLS, etc.) or centralized policy or security requirements do not permit it. They may use data centers, regional hubs, or even CNFs to enable Internet connectivity. In this case, SaaS traffic is tunneled to the best-performing gateway site, where it is subsequently routed to the Internet to reach the requested SaaS application service.

NOTE Different remote sites and different applications may use different gateway sites and paths, depending on the application and measured application performance. Remote sites that use gateway sites for Internet access are referred to as *client sites*.

Figure 3-2 shows how cloud access can be achieved through a gateway in a data center or a **cloud access point (CAP)**. A branch office tunnels SaaS traffic to a gateway location and then uses the Internet at the gateway location to access the SaaS application.

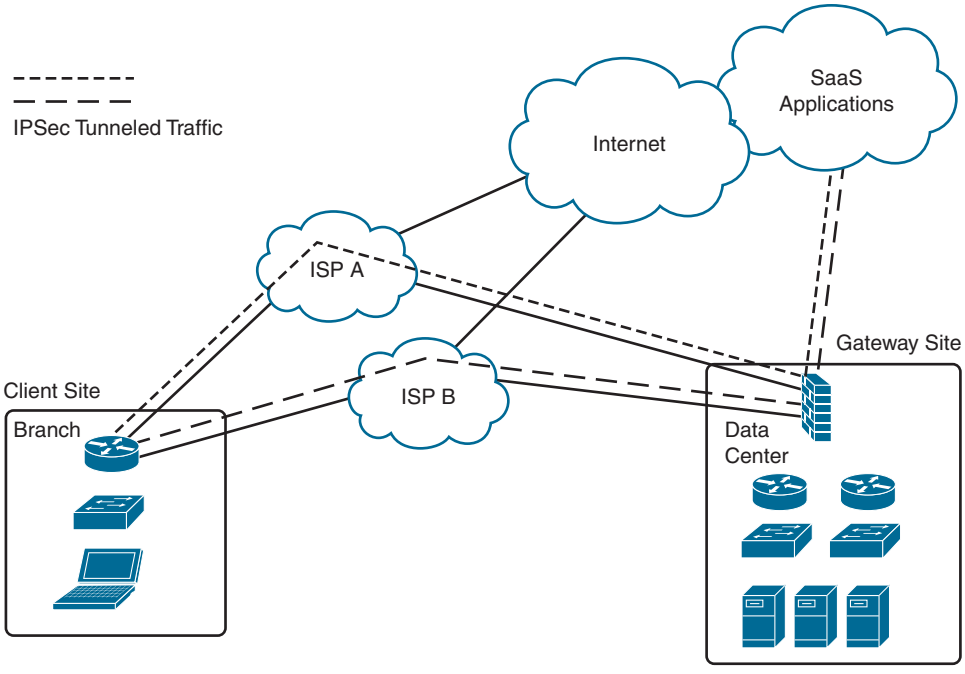


Figure 3-2 *Cloud Access Through a Gateway*

Hybrid Approach

It is possible to have a combination of DIA and client/gateway sites. When defining both DIA and gateway sites, SaaS applications can use either the DIA exits of the remote site or the gateway sites for any given application, depending on which path provides the best performance. DIA sites are, technically, a special case of a client site, but the Internet exits are local instead of remote.

Cloud Types

When selecting a cloud solution, there are a number of different types to choose from, each with its own associated benefits and limitations:

- **Private cloud:** A private cloud consists of cloud computing resources used by one business. This cloud environment can be located within the business's data center footprint, or it can be hosted by a cloud service provider (CSP). In a private cloud, the resources, applications, services, data, and infrastructure are always maintained on a private network and all devices are dedicated to the business.
- **Public cloud:** A public cloud is the most common type of cloud computing. The cloud computing resources are owned and operated by a CSP. All infrastructure components are owned and maintained by the CSP. In a public cloud environment, a business shares the same hardware, storage, virtualization, and network devices with other businesses.
- **Hybrid cloud:** A hybrid cloud is the use of both private and public clouds together to allow for a business to receive the benefits of both cloud environments while limiting their negative impacts on the business.
- **Multi-cloud:** Multi-cloud is the use of two or more CSPs, with the ability to move workloads between the different cloud computing environments in real time as needed by the business.

Table 3-4 compares the different cloud types in relation to each other based on various characteristics.

Key Topic

Table 3-4 Cloud Types Detailed Comparison

Cloud Type	Control	Maintenance	Flexibility	Scalability	Migration	Cost
Private cloud	Most control	High	Least flexibility	High scalability	Hard migration	High cost
Public cloud	Least control	None	Flexibility	High scalability	Hard migration	Lowest cost
Hybrid cloud	Mix of both	Medium	Flexible	Lowest scalability	Ease of migration	High cost
Multi-cloud	Least control	No maintenance for each CSP, but across the CSPs is high	Most flexibility	Highest scalability	Hardest migration	Highest cost

Cloud-Agnostic Architecture

A cloud-agnostic architecture is when there are no vendor specific features and functionality that are proprietary. It is focused on leveraging the same cloud capabilities across the different cloud providers no matter what vendor it is. When looking at cloud service providers and migrating applications to the cloud, there are three primary focus points that should be leveraged within a cloud-agnostic architecture:

- **Portability:** Moving to the cloud inherently provides a level of portability, but if not carefully architected, applications and services can lose their portability as they get locked into specific CSP services. Portability here specifically allows mobility between different CSPs with a proper abstraction layer.
- **Abstraction:** Leveraging an abstraction layer within the cloud architecture allows for a decoupling from the underlying cloud-specific platform functionality, which provides a direct cost reduction and an increase in flexibility. For example, using this abstraction layer to seamlessly invoke the same cloud capability between cloud provider one and cloud provider two, when there are different mechanisms and processes to do so. In addition, this same capability could be proprietary, but using this abstraction layer mitigates a potential hardcoded proprietary service call.
- **Interoperability:** Developing applications and services with cloud interoperability as a key priority will not be tied to a specific cloud feature set. This allows for these applications and services to leverage different cloud platforms without major redevelopment or changes. This specifically allows for a cloud-agnostic approach.

To achieve a cloud-agnostic architecture, network designers should consider adopting the following practices.

Decoupling

There are two perspectives to think about for decoupling. First, all applications should be designed to be inherently decoupled from the underlying cloud platform they are on. This can be accomplished by leveraging service-oriented architecture (SOA), which is discussed in detail a bit later in this chapter. Second, all cloud components should be decoupled from the applications that leverage them.

Containerization

All applications should follow a containerized architecture. This is critical for cloud applications as well as on-premises data center applications. Ensuring all applications are developed with containerization in mind allows for real cloud adoption and portability. Container technology helps decouple applications from the cloud-specific environment, which provides an abstraction layer away from any of the CSP dependencies. The goal is to ensure that it is relatively easy to migrate applications between different cloud vendors if the mission requires it. Cloud containerized architectures is a topic that is covered in detail in an upcoming section.

Agnostic Versus Proprietary Cloud Services

Each cloud service provider is different and has unique services, with its own avenues to provision them to customers. There is a need to provide a mechanism to differentiate where these specific services interact with applications while also allowing for the standardization of agnostic services. Figure 3-3 shows how to delineate from an architecture perspective between cloud-agnostic services and cloud-proprietary services. This is how you should plan to migrate applications to a CSP.

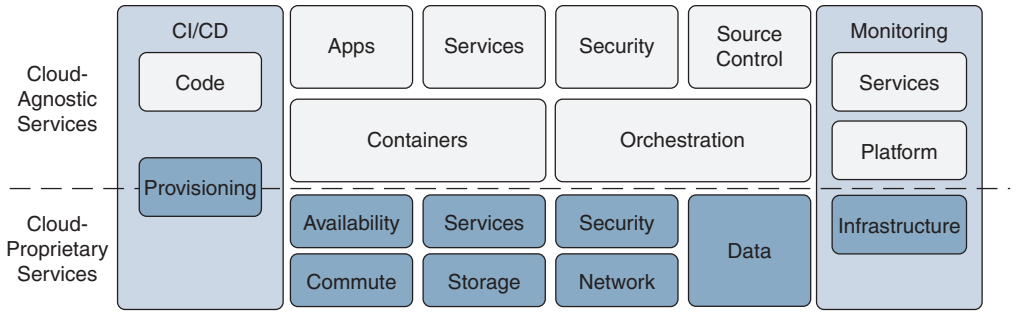


Figure 3-3 *Agnostic vs. Proprietary Cloud Services*

Service-Oriented Architecture

To ensure a successful cloud-agnostic architecture, incorporating the software design service-oriented architecture (SOA) is hyper-critical. SOA is a style of software design where services are provided to other parts of an application component themselves. This is accomplished through network communication protocols. The underlying principles are vendor and technology agnostic. In SOA, services communicate with other services in two ways. The first way is to simply pass data between the different services. The second way is to logistically coordinate an activity event between two or more services. There are many benefits to SOA:

- Code can be created so that it is reusable, which cuts down on time spent in the development process.
- Developers can leverage multiple coding languages with SOA because it uses a central interface, which allows for flexibility and scalability within the software development cycle.
- With SOA, a standard communication process is created that allows systems to function on their own and communicate effectively between them.
- SOA is much more scalable, limiting client-server interaction, which allows for a direct increase in efficiency.

Cloud Containerized Architecture

Containerization is a large part of a cloud-agnostic architecture. Figure 3-4 shows the progression from a traditional on-premises deployment to a containerized cloud deployment.

Traditional Deployment Architecture

Traditionally, organizations and companies ran applications on physical servers. You could deploy multiple applications on the same physical server, but there was no way to properly restrict resources or set up controls to govern application guidelines. Because of these issues, there were a number of allocation and performance issues. Most of the time, each physical server was dedicated to a single application because of these limitations. This increased cost and resources and limited overall scalability.

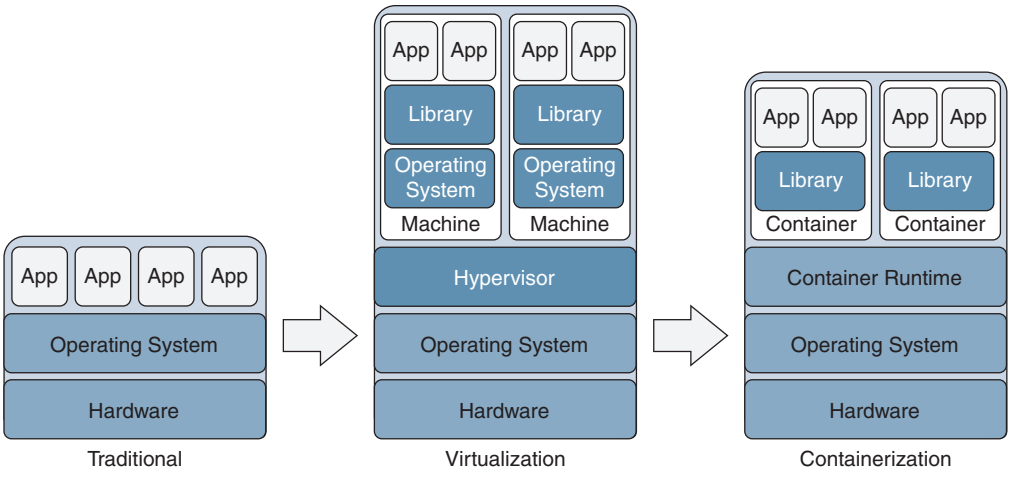


Figure 3-4 *Progression from Traditional to Containerized Deployment*

Virtualization Deployment Architecture

Virtualization allows for multiple virtual machines (VMs) to be deployed on a single physical server. Each VM is isolated from other applications with its own resources and security controls allocated to it individually. Virtualization allows for better utilization of resources on a physical server and scales better because applications (VMs) can be added and removed as needed depending on the needed resources. Each VM runs all components that a physical server would run, such as the application and the operating system.

Container Deployment Architecture

Containers are similar to VMs but have less stringent isolation controls that allows them to share the operating system among other applications. Because of this, containers are lightweight. A container has its own file system, shares CPU time, memory, process space, and more. Because containers are decoupled from the underlying infrastructure, they are moveable between different fabrics as needed by the underlying business requirements.

Containers provide a number of benefits:

- Agile application creation and deployment (CI/CD)
- Separation of responsibilities between development and operational tasks
- Real-time application-level health analytics
- Standardization and consistency across all environments and enclaves
- Real-time distribution with the capability to port into other operating systems and locations as required
- Increased overall predictability of application performance and requirements
- Increased resource efficiency

Cloud Application Strategy

As a business readies its business lines of efforts and their respective applications for migration to the cloud, it is highly recommended that the business incorporate an application assessment process. As part of this process an application assessment team should be created with the following roles and purposes:

- **Line of business owner:** The business stakeholder for this application. They understand the application's business role and impact. They also understand the implications of this application and can appropriate business resources and priorities to this effort.
- **Security specialist, compliance auditor:** The security team member in charge of the security controls, compliance regulations, and auditing of code. These are all critical roles that will direct decisions and actions from a risk management perspective for this application.
- **Application owner, application developer:** The software engineering member responsible for this application. Creates code, modifies current code, and drives associated technical requirements for the application.
- **Network engineer, network designer, network architect:** Facilitates the network resources to properly service the application based on the different requirements from the line of business owner, security specialist, and application owner.

Each application will have different requirements as it's being reviewed in this process. The team will need to properly identify what the application is dependent on and make appropriate decisions to ensure the application is ready for the migration to the cloud environment.

The application assessment team will document in an *application binder* (or *run book*) everything that is discovered, decided on, and implemented for this application. The application binder should include all requirements and where they originated from; all security controls and regulatory standards that this application must comply with; and where the application is in the migration process and what is needed for it to be successful.

Data Management

Data is the most critical resource that all other resources will be leveraging. We have to manage all data effectively, accurately, and securely so that these additional resources can properly leverage that data with ensured integrity, availability, and confidentiality. Data management in essence lays the foundation for data analytics. Without good data management, there will be no data analytics. Data management can be broken down into 11 pillars:

1. **Data governance:** The planning of all aspects of data management. This includes availability, usability, consistency, integrity, and security of all data within the organization.
2. **Data architecture:** The overall structure of an enterprise's data and how it fits into the enterprise architecture.
3. **Data modeling and design:** The data analytics and the corresponding analytics systems. This includes the designing, building, testing, and ongoing maintenance of these analytics systems.
4. **Data storage and operations:** The physical hardware used to store and manage the data within the enterprise.

5. **Data security:** Encompasses all security requirements, controls, and components to ensure the data is protected and accessed only by authorized users.
6. **Data integration and interoperability:** The transformation of data into a structured form to be leveraged by other systems and resources.
7. **Documents and content:** All forms of unstructured data and the work necessary to make it accessible to the structured databases.
8. **Reference and master data:** The process of managing data in a way that allows it to be redundant, and if there are any errors or mistakes that can be normalized by standard values.
9. **Data warehousing and business intelligence:** Involves the management and application of data for analytics and business decision making.
10. **Metadata:** Involves all elements of creating, collecting, organizing, and managing metadata (i.e., data that references other data).
11. **Data quality:** Involves the practices of data monitoring to ensure the integrity of the data being delivered is maintained.

For a true data management model, all of these pillars need to be included. Without one of these pillars, there is an area of data management that is not being addressed. For example, if there isn't a solution for metadata management, the business loses the ability to easily categorize data. Without data quality being ensured, all data is at risk and the analytics of that data becomes useless.

Summary

What is the purpose of the network? To ensure business success! This chapter went into great detail on how a network designer can accomplish this.

This chapter covered how businesses rely heavily on the network and the corresponding services and applications riding on it. This chapter also covered application and service models, showing how the location and architecture of the application or service directly affect the required network design elements. In addition, this chapter highlighted the multitude of cloud options and the associated advantages of each option. This chapter highlighted the preference for agnostic cloud services over proprietary cloud services, to ensure a business doesn't lock itself into a specific cloud service provider, and how adopting a service-oriented architecture can be beneficial to the business. Last but not least, this chapter gave a quick overview of the importance of data and data management by highlighting the 11 data management pillars. Ensuring the confidentiality, integrity, and availability of a business's data is paramount to the business's success. If a business's data is compromised, it can no longer make valid decisions on that data, which handicaps the business until the data is fixed.

Reference

Al-shawi, Marwan, *CCDE Study Guide* (Cisco Press, 2015)

Exam Preparation Tasks

As mentioned in the section "How to Use This Book" in the Introduction, you have a couple of choices for exam preparation: the exercises here, Chapter 18, "Final Preparation," and the exam simulation questions in the Pearson Test Prep Software Online.

Review All Key Topics

Review the most important topics in this chapter, noted with the Key Topic icon in the outer margin of the page. Table 3-5 lists a reference of these key topics and the page numbers on which each is found.

Key Topic

Table 3-5 Key Topics for Chapter 3

Key Topic Element	Description	Page Number
Table 3-2	3-Tier Application Model Network Design Elements	70
Table 3-3	Service Model Comparison	72
Table 3-4	Cloud Types Detailed Comparison	76

Complete Tables and Lists from Memory

Print a copy of Appendix D, "Memory Tables" (found on the companion website), or at least the section for this chapter, and complete the tables and lists from memory. Appendix E, "Memory Tables Answer Key," also on the companion website, includes completed tables and lists to check your work.

Define Key Terms

Define the following key terms from this chapter and check your answers in the glossary:

single-server model, 2-tier model, 3-tier model, web tier, application tier, database tier, on-premises, Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS), carrier-neutral facility (CNF), cloud access point (CAP), private cloud, public cloud, hybrid cloud, multi-cloud

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