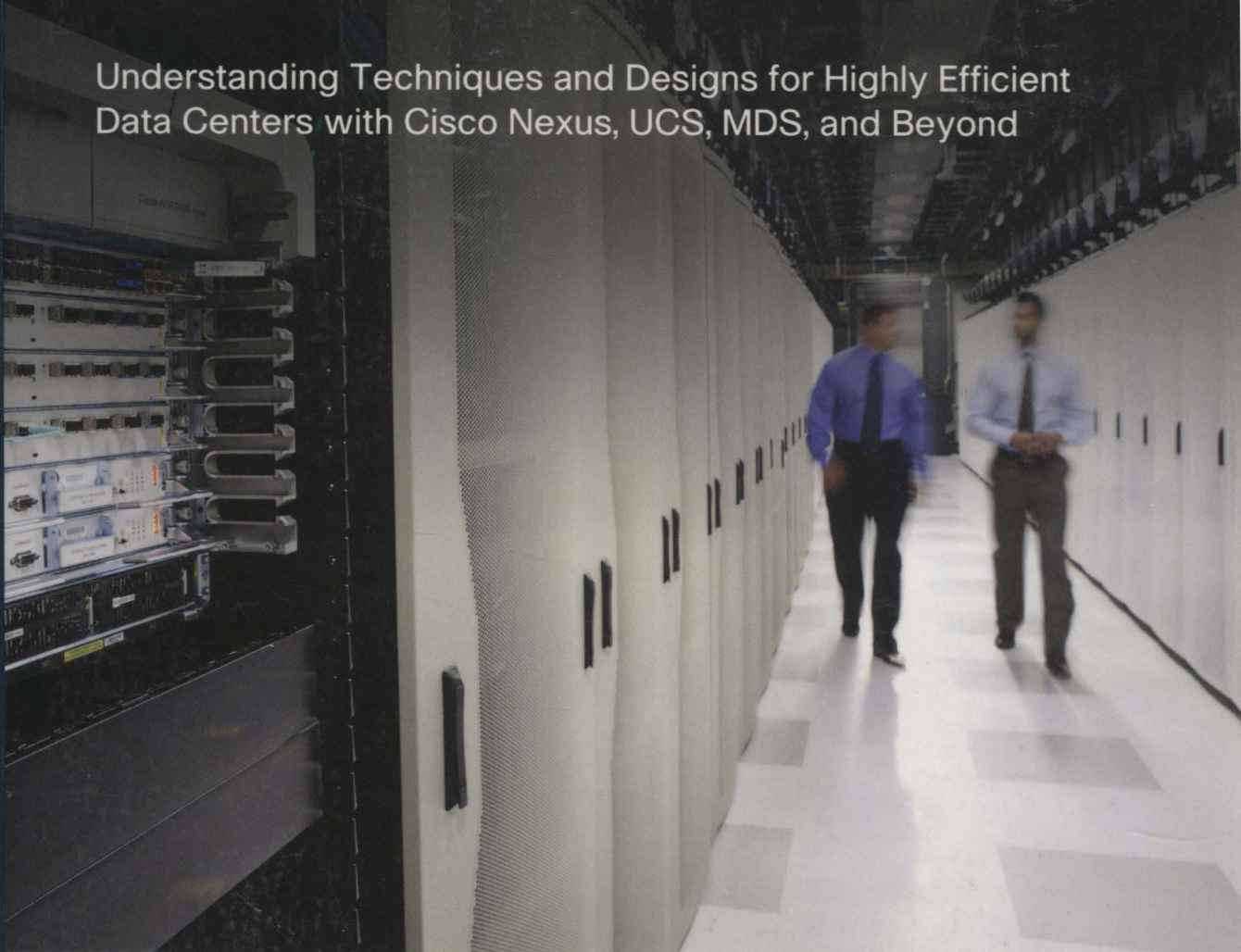




Data Center Virtualization Fundamentals

Understanding Techniques and Designs for Highly Efficient Data Centers with Cisco Nexus, UCS, MDS, and Beyond



Data Center Virtualization Fundamentals

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About the Author

Gustavo A. A. Santana, CCIE No. 8806, is a Cisco Technical Solutions Architect working in enterprise and service provider data center projects that require a greater integration among multiple technology areas such as networking, application optimization, storage, and servers.

With more than 15 years of experience in the data center industry, Gustavo has led and coordinated a team of specialized Cisco engineers in Brazil. A true believer of education as a technology catalyst, he has also dedicated himself to the technical development of many IT professionals from customer, partner, and strategic alliance organizations.

In addition to holding two CCIE certifications (Routing & Switching and Storage Networking), Gustavo is also a VMware Certified Professional (VCP) and an SNIA Certified Storage Networking Expert (SCSN-E). A frequent speaker at Cisco and data center industry events, he holds a degree in computer engineering from Instituto Tecnológico de Aeronáutica (ITA-Brazil) and an MBA in strategic IT management from Fundação Getúlio Vargas (FGV-Brazil).

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Maurilio Gorito, CCIE, is the certification manager at Riverbed Technology Institute, leading Riverbed Technology's Certification Program. Previously, he managed the Cisco CCIE Routing and Switching certification program, and he is a triple Cisco Certified Internetwork Expert (CCIE). Maurilio has 25 years of experience in the IT field and more than 20 years of combined experience in education, testing, and assessment. Maurilio has written a book, written articles, and reviewed several technical books for Cisco Press. Maurilio holds bachelor's degrees in education, pedagogy, and mathematics from Centro Universitario Geraldo Di Biasi, Brazil. Maurilio is currently serving on the board of directors at Performance Testing Council (PTC).

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Dedications

This book is dedicated to my wife and true love, Carlene, whose sacrifice and unconditional support were crucial to this endeavor, and to my lovely daughter, Carolina, whose one-year-old curiosity constantly inspired me to go one step further.

I also dedicate this book to my parents, Honorio and Cleia, who have taught me that one can only learn by being fearless and humble.

Finally, this book is also dedicated to every person who has devoted efforts to the rewarding experience of teaching someone.

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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).
- Italics indicate arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets [] indicate optional elements.
- Braces { } indicate a required choice.
- Braces within brackets [{ }] indicate a required choice within an optional element.
- Introduction

Foreword

With the rapid growth of the Internet economy and the explosion of information technology, the data center is playing a pivotal role and is one of the most exciting fields in the world of IT today. The trend continues with both virtualization and cloud computing fueling growth and making data center solutions more efficient and scalable. More specifically, organizations using virtualization technologies are seeing greater returns and more viability to deal with the growing demands of the economy.

Data center virtualization is an evolutionary process that was started several years ago within mainframe computer rooms, and it has dramatically intensified in the last few years. Its proposed freedom from physical boundaries has produced benefits in each technology area, and much more importantly, from an architectural perspective.

However, due to these environments' increasing complexity, a data center professional must possess a challenging breadth of knowledge in several different areas, such as networking, storage, servers, operating systems, application, and security.

Data Center Virtualization Fundamentals is a comprehensive book that introduces virtualization technologies in data center environments, encompassing all these knowledge areas. It does not take a product-based approach as many others do, but an architectural one, offering theoretical concepts, illustrative configurations, and real-world designs for each virtualization technique. The book provides a first step for students and professionals who want to understand the state of data center technologies today. And in my opinion, virtualization technologies are the best way to achieve this feat because one must be aware of the physical challenges of data center environments before learning such techniques.

There is a lot of misconception when talking about virtualization, and people immediately think of it in the context of virtual servers. However, virtualization is not restricted to a single technology area in the data center. This book intends to make an account of the main data center virtualization technologies, revealing their impact and applicability to these environments as a whole. It encourages readers to escape their technical comfort-zone and learn how each decision may impact other data center teams. A strong knowledge of the theoretical basis of the data center is necessary to walk amidst clouds, and this is exactly what this book brings.

Author Gustavo A. A. Santana is a seasoned expert with years of experience, and has done a superb job putting this material together. He has demonstrated his skills and command of the technology, using a unique approach in translating the most complex and highly technical information into simple, easy-to-understand material. Readers will definitely appreciate this book.

Finally, this book is an essential reference and will be a valuable asset for potential candidates pursuing their Cisco Data Center certifications. I am confident that in reading this book, individuals will inevitably gain extensive knowledge and hands-on experience during their certification preparations. If you're looking for a truly comprehensive guide to virtualization, this is the one!

Yusuf Bhaiji

Senior Manager, Expert Certifications (CCIE, CCDE, CCAr)

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“If you can’t explain it simply, you don’t understand it well enough.”

—Albert Einstein

Introduction

“I am very interested in learning data center technologies. How should I start?”

Since I first heard this question, I have seen many IT professionals become overwhelmed with the vertigo-inducing development of new data center technologies. From my perspective, their frustration was mainly caused by attempting to understand this subject without being properly introduced to the most fundamental concepts and definitions related to these complex environments. And that opinion has always formed the basis of my advice to them.

However, as the years passed, I observed how my answer to this question was becoming more elaborate. Understandably, an increasingly diverse background was being required from these professionals, mainly because data center technologies were repeatedly consolidating different areas of knowledge such as networking, storage, application, servers, cabling, and several others. And much to my chagrin, I had to admit that the job of creating an effective introduction to these technologies was getting even harder to “crack.”

After developing many learning road maps and customized trainings, I decided to challenge myself in writing a book that would address cutting-edge data center technologies and the core concepts they were based upon. From the start, the mammoth level of minutiae made me realize how close I was to a task such as writing a Beatles biography. And that exact thought inspired me to follow the steps of the best publications about the band: I had to use a *unifying theme*, something that could provide a firm backbone to a progressive presentation of these technologies. It was fairly easy for me to conclude that virtualization was this theme.

Nowadays, virtualization is deeply rooted in data center installations through technologies such as virtual memory, virtual gateways, VLANs, VRFs, virtual contexts, VDCs, vPCs, VNTag, VPLS, OTV, virtual LUNs, VSANs, IVR, NPV, FCoE, virtual machines, service profiles, virtual networking, virtual network services, and many others. All these successful techniques share a common characteristic: They were created to provide *resource optimization*. And for that reason, their examination opens up the chance to address the following:

- Traditional data center deployments and their limitations
- The benefits of each virtualization technology and their behavior
- The changes these technologies provide in data center designs and architectures

As the book cover suggests, virtualization has also modified the human aspects within data center environments. Relieved from the “chains of reality,” technical teams have been able to simplify operational tasks and accelerate the adoption of new IT models such as cloud computing. With such a central theme, it was just a question of defining *how* to approach it.

Goals and Methods

This book provides a gradual introduction to innovative data center technologies through a systematic examination of the main infrastructure virtualization techniques. And as an intentional outcome, the book also introduces fundamental concepts and definitions that are required from any professional who is involved with modern data center designs.

Because it is primarily focused on the three main data center infrastructure areas (networking, storage, and server), the book is not based on a single product nor it is written as a configuration guide. Instead, it leverages the broad Cisco Data Center portfolio (and other solutions from the Cisco ecosystem of partners and alliances) to analyze the behavior of each virtualization technique and to offer an architectural perspective of the virtualized data center.

Besides providing an technical account of the evolution of these areas, the book will address each virtualization technology through a flow of topics that involves

- A virtualization classification system (explained in the first chapter), which quickly informs the reader about the main characteristics of the specific technology
- A technology primer that immerses the reader in the physical challenges this virtualization technology overcomes
- A detailed analysis of the technique, including its characteristics, possibilities, scalability, results, and consequences
- A real-world use case scenario that demonstrates the examined technology “in action.”

I sincerely believe that design and deployment must be complementary processes. Therefore, *Data Center Virtualization Fundamentals* contains actual configuration examples that were exclusively created to illustrate each virtualization technology and its applicability to data center designs. Nonetheless, I have also included unusual topologies to specifically reinforce concepts explored throughout the book.

Who Should Read This Book

This book was written with a wide audience in mind. Because it provides an in-depth examination of data center virtualization technologies (from conceptualization to implementation), the book will satisfy beginners and experienced IT professionals alike.

In essence, its target audience comprises the following:

- Individuals with basic networking and operating system knowledge who are interested in modern data center design, deployment, and infrastructure optimization techniques
- Candidates for the Cisco Data Center certifications, including CCNA Data Center, CCNP Data Center, and CCIE Data Center

- Professionals that are specialized in a single data center technology area but also intend to acquire a broader architectural knowledge to accelerate their career development

How This Book Is Organized

With the explosion of information brought by the Internet, education in the twenty-first century must always present alternatives to the random accumulation of unstructured data. Therefore, I have intentionally applied constructivist learning theory principles (such as systematic analysis and concept synthesis) to distribute the content throughout the book. Although each chapter can be read out of sequence, their arrangement was designed to provide a logical progression of explanations that brings a more rewarding learning experience for the reader.

In times where blog posts and tweets provide “snacks” of information (do not get me wrong; there are nutritious knowledge bites out there), this book intends to serve a complete “meal,” where order and harmonization between chapters matter.

Chapters 1 through 17 and the appendixes cover the following topics:

- **Chapter 1, “Virtualization History and Definitions”:** This introductory chapter presents a historical account of virtualization in data center environments and, through some illustrative examples, provides a unified definition of virtualization in this context. It also proposes a classification system (which is called “virtualization taxonomy”) that will be used throughout the book to quickly introduce a new virtualization technology for the reader.
- **Chapter 2, “Data Center Network Evolution”:** Using the evolution of the Ethernet protocol as a canvas, this chapter addresses the main aspects and factors that govern traditional data center network topologies. It also discusses the general benefits that virtualization can offer to these networks.
- **Chapter 3, “The Humble Beginnings of Network Virtualization”:** Focused on the explanation of virtual local-area networks (VLAN) and Virtual Routing and Forwarding (VRF), this chapter provides a deep analysis of these well-established structures as virtualization techniques, illustrating the book approach and revealing important concepts that are hidden behind common knowledge.
- **Chapter 4, “An Army of One: ACE Virtual Contexts”:** This chapter discusses the importance of network services in data centers, concentrating on server load balancers. It presents virtual contexts as important tools that can increase flexibility and optimize hardware resources as these application environments scale.
- **Chapter 5, “Instant Switches: Virtual Device Contexts”:** The innovative characteristics of virtual device contexts (VDC) are detailed in this chapter, which also shows their applicability in challenging data center network scenarios.

- **Chapter 6, “Fooling Spanning Tree”:** This chapter demonstrates how virtualization techniques such as EtherChannel and virtual PortChannel (vPC) have adapted the limitation of Spanning Tree Protocol (STP) to the strict requirements of data center networks. It also introduces FabricPath, a Layer 2 multipathing technology that has provided the most secure path toward the replacement of STP in these environments.
- **Chapter 7, “Virtualized Chassis with Fabric Extenders”:** Fabric Extenders (FEX) constitute a virtualization technique that provides cabling optimization and network management consolidation in the data center network access layer. This chapter fully explores the many flavors of this technology.
- **Chapter 8, “A Tale of Two Data Centers”:** The classic problem of extending Layer 2 domains between geographically distinct data center sites is discussed throughout this chapter. It builds on concepts developed in previous chapters to offer a hands-on examination of the many different virtualization technologies that can solve this challenge.
- **Chapter 9, “Storage Evolution”:** This chapter explores the main concepts related to storage and storage access technologies that are used in data centers today. It also provides an account of how virtualization is deeply ingrained in the interpretation of stored data.
- **Chapter 10, “Islands in the SAN”:** Virtual storage-area networks (VSAN) can overcome Fibre Channel fabric challenges in a simple and elegant way. This chapter presents the necessary protocol concepts to understand how they can be applied in real-world scenarios.
- **Chapter 11, “Secret Identities”:** This chapter presents three virtualization techniques whose dissimulation tactics benefits data protection, environment isolation, and scalability in storage-area networks.
- **Chapter 12, “One Cable to Unite Us All”:** Binding concepts from network and storage virtualization, this chapter fully examines the details and benefits from the I/O consolidation brought about by Data Center Bridging (DCB) and Fibre Channel over Ethernet (FCoE).
- **Chapter 13, “Server Evolution”:** This chapter introduces the main concepts related to modern server architectures. It also presents server virtualization and describes how it has changed the operational landscape of data centers in the beginning of the twenty-first century. The chapter also deals with the definition of unified computing and explains how its innovative architecture principles can drastically simplify server environments.
- **Chapter 14, “Changing Personalities”:** Although server virtualization has helped to streamline server workloads within a data center, “bare metal” server provisioning and management are still considered massive challenges in these environments. This chapter demonstrates how service profiles can bring several server virtualization benefits to these scenarios.

- **Chapter 15, “Transcending the Rack”:** Demonstrating how the technologies explored in this book are extremely intertwined, this chapter shows how server virtualization has also revolutionized networking. It presents the virtual networking concepts through the analysis of VMware vSwitches, Nexus 1000V, and Virtual Machine Fabric Extender (VM-FEX).
- **Chapter 16, “Moving Targets”:** The way that virtual machines can migrate between different hosts and locations has also changed the way network services are deployed. This chapter explores the unique characteristics of services provided by solutions such as virtual firewalls (Virtual Security Gateway [VSG] and ASA 1000V), virtual accelerators (virtual Wide Area Application Services [vWAAS]), and virtual routers (CSR 1000V). It also presents site selection as a special network service and illustrates some solutions that can optimize client session routing to roaming virtual machines.
- **Chapter 17, “The Virtual Data Center and Cloud Computing”:** This chapter consolidates concepts explained throughout the book to discuss how 1+1 can be more than 2. It discusses how the deployment of multiple virtualization technologies has created a perfect storm for “cloud computing” momentum and how this IT delivery model is influencing the evolution of data center networks.
- **Appendix A, “Cisco Data Center Portfolio”:** To preserve the book’s focus on virtualization concepts and feature behavior, this appendix contains the description of all Cisco Data Center products that actually deploy these technologies.
- **Appendix B, “IOS, NX-OS, and Application Control Software Command-Line Interface Basics”:** If you are not used to the command-line interface characteristics from the different network operating systems used in this book, this appendix will introduce you to their most typical characteristics and definitions.

