White Paper

Deliver Fabric-Based Infrastructure for Virtualization and Cloud Computing

What You Will Learn

The data center infrastructure is critical to the evolution of IT from a cost center to a business enabler. This transition helps IT become an active participant in the business, enabling profit centers by delivering the infrastructure and applications required rapidly and efficiently. By using a fabric-based infrastructure, IT can deliver IT as a service (ITaaS) and be ready to take advantage of the world of many clouds. This document explores the ways in which the Cisco® Unified Data Center platform brings together computing, networking, management, and storage in a fabric-based infrastructure that delivers business agility, financial efficiency, and IT simplicity. It introduces concepts and capabilities that can be found in more detail in other documents.

The Promise of IT as a Service

Virtualization and cloud technologies have changed the way IT managers think about the data center. These technologies are transformational elements that can help reduce costs, increase efficiency, and better map IT priorities to the business. The promise is tantalizing: according to a December 2010 study by Forrester Research, IT departments typically spend up to 75 percent of their IT budgets on maintenance, which leaves little budget and few human resources to devote to new capabilities, services, technologies, or products. Any enabler that helps break that cycle is viewed as highly strategic.

Unfortunately, as with most transformations, there are unforeseen consequences. Virtualization has helped increase server utilization, but it has also dramatically increased overall management costs. Management costs are higher because the underlying components - particularly server, storage, and management resources - were not originally designed for virtualization and thus require complex management systems to help hold the solution together.

The cloud presents additional challenges and opportunities. Cloud computing is changing the way that both IT and end users think about computing. People use the cloud to store data for backup, position data and applications closer to their users, manage business startup costs, and accelerate the delivery of services. IT now has the opportunity to take advantage of world of many clouds. By taking advantage of public cloud services and building a robust infrastructure to deliver private cloud services, or ITaaS, IT can become a major factor in bringing innovation and value to the business.

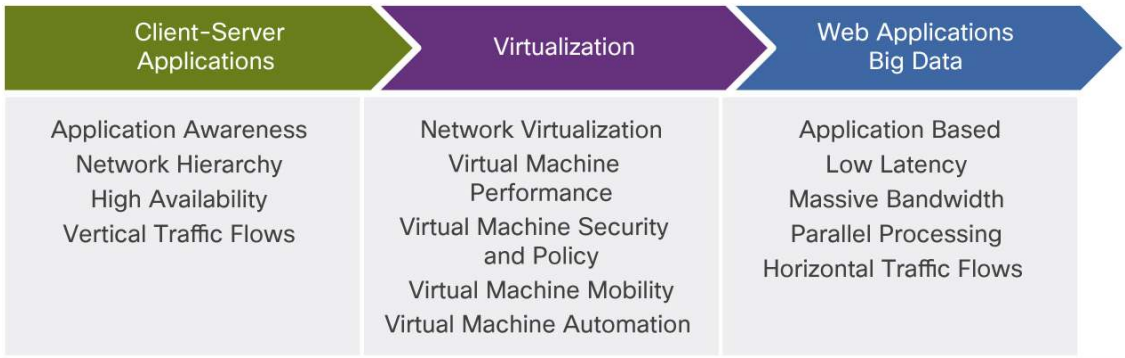
The “traditional” data center is made up of silos of infrastructure and organizations. Servers, storage, networking resources, and management systems are often delivered individually to each application or group with very few economies of scale. To create a platform to deliver IT services, IT needs to consider how to build and improve on the current underlying infrastructure while adding new technology to incrementally expand capabilities. This approach will deliver both investment protection and lower total cost of ownership (TCO) while helping enable business benefits such as increased productivity, more effective customer acquisition and retention, increased return on investment (ROI), and the capability address new markets.

What Is Driving Data Center Change?

Virtualization essentially changed everything. With virtualization, the basic unit became not the server, but the virtual machine. With a small number of virtual machines, an organization could simply buy a bigger server to handle the new technology. As the number of virtual machines increases, however, the network needs a different approach. Instead of networking servers, it needs to network virtual machines. To meet this new requirement, a strong connection needs to exist between the server and the network. This is when a network and a server start to become a fabric. A fabric should provide transparency so that virtual machines are visible on both the server and the network, with capabilities to help ensure that security policies follow the virtual machine.

IT infrastructure, however, will not change overnight. Instead, it will evolve. In fact, most IT departments are not even close to virtualizing all their servers or completely transforming IT into a private cloud service. The reason is simple: they do not have to do so. In fact, IT will likely always have a mix of traditional data center (with physical mapping of applications to server and storage resources) and virtualized data center (with applications that map to virtual machines) technologies, while at the same time being ready for emerging trends such as big data and high-performance computing (Figure 1).

Figure 1. Application Evolution of the Data Center to the Cloud



IT now needs to consider how to evolve its infrastructure to best support virtualization and cloud computing, while building on the high availability, security, and application awareness that are fundamental features of the current data center, and particularly of the network. To bring all these pieces together, IT is turning to the concept of a data center infrastructure fabric.

What Is Fabric-Based Infrastructure?

The term ”fabric” is used by different vendors, analysts, and IT groups to describe different things. Gartner offers a definition of “fabric” that can be applied across the industry: “A set of compute, storage, memory and I/O components joined through a fabric interconnect and the software to configure and manage them.” A fabric thus provides the capability to reconfigure all system components - server, network, storage, and specialty engines - at the same time, the flexibility to provide resources within the fabric to workloads as needed, and the capability to manage systems holistically.

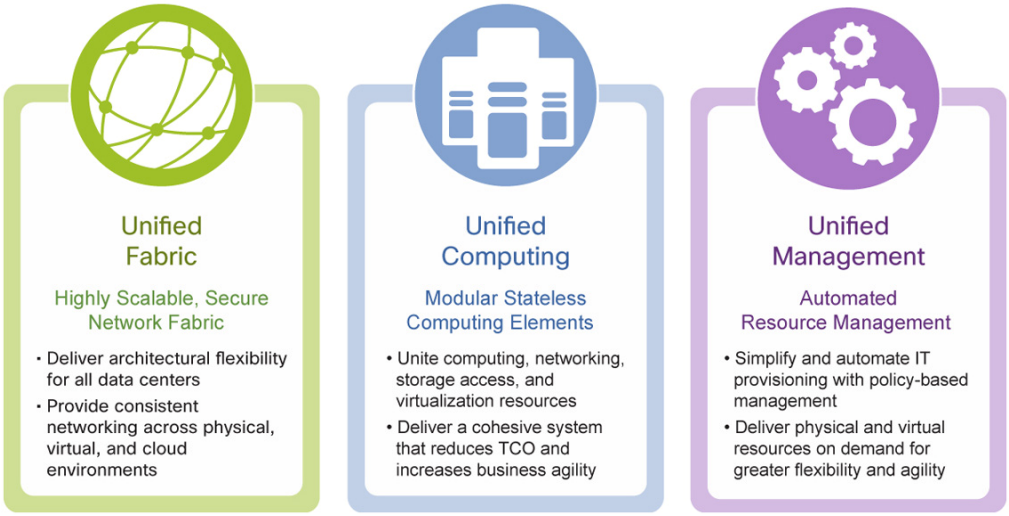
Cisco uniquely delivers a fabric-based infrastructure with the Cisco Unified Data Center platform. The Cisco Unified Data Center changes the economics of the data center by unifying computing, storage, networking, and management resources into a single, fabric-based platform designed to increase operating efficiency, simplify the data center, and provide business agility. Unlike other solutions, which add layers of management software to achieve integration, the Cisco Unified Data Center is specifically designed for virtualization and automation and enables on-demand provisioning from shared pools of infrastructure across physical and virtual environments. This approach allows IT to move from being a cost center to providing IT services that create competitive advantage.

Here are the characteristics required of the Unified Data Center:

- **Open:** Cisco provides choice by providing multiple options for consuming IT technology, including choice of technology and integration of third-party providers and standards. Technology choice and open standards are critical, and Cisco delivers and guides standards across the industry. Additionally, no vendor can provide an entire data center, and inclusion of ecosystem partners in the fabric is crucial.
- **Resilient:** Because the fabric is the element that connects resources together, its resilience cannot be understated. The Cisco Unified Data Center provides a highly available architecture within and between data centers to help ensure and enable business resilience, disaster recovery, and data mobility. By using design best practices and Cisco NX-OS Software across the switching and UCS fabric interconnect platforms, the Cisco Unified Data Center helps ensure the uptime needed for business resilience.
- **Secure:** The Cisco Unified Data Center delivers security and manageability by providing visibility and transparency at the physical and virtual machine levels, which helps ensure that security policies can be mapped to the virtual machine and follow that virtual machine wherever it moves within or between data centers.
- **Scalable:** The ubiquity of universal access to resources and the dramatic increase in data and processing, is requiring IT to consider not just the data center, but the way in which server and storage interconnects can span geographies. The Cisco Unified Data Center provides robust scaling capabilities within and between data centers and out to the user.

The Cisco Unified Data Center is made up of three components, as shown in the Figure 2. Each component plays a critical role in defining how the fabric works and how it provides the foundation for ITaaS.

Figure 2. Components of the Cisco Unified Data Center



Unified Fabric: Building the Foundation

The Cisco Unified Fabric is the foundation on which the "data center fabric" is built. It consists of the Ethernet and Fibre Channel networking components, comprising the Cisco Nexus® and Cisco MDS 9000 Family portfolios and the Cisco NX-OS Software, which runs on both the networking products and the fabric interconnects that are integral to the Cisco Unified Computing architecture (described later).

Networks have always been at the center of the data center for the simple reason that they are the common element that connects the disparate application, server, and storage silos together. Virtualization and cloud computing have changed the way that the network needs to behave and interact with the broader systems in the data center and precipitated the need for the fabric concept. Therefore, the network provides a good foundation for looking at how to deploy a fabric-based infrastructure.

Unlike a physical workload, which is tied to a particular server, a virtual workload can exist anywhere on any server. This change requires the network to touch not just the edge of the server, but inside it all the way to the virtual machine. Additionally, virtual machines have the potential to move within and between data centers. This movement can break the traditional model of how data center networks are built, so it is important to think about how modifications to the network can be implemented. The Cisco Unified Fabric can help address these challenges and contribute to the creation of an overall fabric-based infrastructure.

Resilience and High Availability

The first factor to consider is the resiliency of the network. Resilience is a core requirement of a fabric-based infrastructure and foremost in the minds of most network administrators. For years, the three-tier design (access layer, distribution layer, and core) was used to provide a standard, deterministic, and fault-tolerant network. Innovations and enhancements delivered by the Cisco Unified Data Center can dramatically simplify the network topology, help ensure better use of bandwidth, extend the topology, and improve failover time. Taken together, these capabilities allow network administrators to move, as needed, to capabilities required to provide high availability and business continuance to the physical and virtual world without a wholesale replacement of infrastructure.

- **Simplify the network topology:** The Cisco Fabric Extender (FEX) architecture, based on the IEEE 802.1BR standard, is an innovation that extends the bridge (switch) interface to downstream devices. This technology involves two components: the parent switch (a Cisco Nexus 5000 or 7000 Series Switch) and the extender switch (a Cisco Nexus 2000 Series Fabric Extender). The Cisco Nexus 2000 Series Fabric Extender connects the physical servers themselves as a top-of-rack (ToR) switch, and the Cisco Nexus 5000 or 7000 Series Switch provides the aggregation, intelligence, and management. This solution provides enormous scale and simplicity to the overall fabric by limiting the points of management and configuration, while dramatically increasing the scalability.
- **Optimize bandwidth:** Cisco has developed a number of innovative features to integrate virtual with traditional data centers. One feature is the virtual PortChannel (vPC). This feature makes the two distribution switches look like a single switch, effectively doubling the bandwidth between the access and distribution switches by eliminating the spanning-tree blocking port. For workloads that require Layer 2 connectivity across the data center, Cisco FabricPath technology creates a large, resilient Layer 2 domain that can scale to provide the standard benefits of Layer 2 (simple configuration, flexible provisioning, and low cost) with those of Layer 3 (all links active, fast failover, and high scalability).
- **Extend the topology:** Consideration must be given to workloads that must travel between data centers. Cisco Overlay Transport Virtualization (OTV) technology is an Ethernet extension protocol that runs on top of Multiprotocol Label Switching (MPLS), IP, or dark fiber and makes many data centers look like a logical data center. The obvious benefit is that it enables easy virtual machine mobility between data centers, regardless of their locations. This benefit, however, introduces another potential challenge: how to reach a virtual machine, which is tied to an IP address, when it moves from one data center to another. Cisco has solved this problem with the Location ID Separation Protocol (LISP). This capability dynamically provides routing and rerouting of data destined for a virtual machine regardless of its location in the data center.
- **Improve failover times:** In a failure scenario, convergence times will determine whether application connections are reset, applications time out, or packet loss affects real-time communications (for applications such as video). The protocols described previously, vPC and Cisco FabricPath, both eliminate the blocked spanning-tree port and help ensure active-active links between switches. This approach increases bandwidth, and it also helps ensure that the failure of a switch port, switch, or cable does not affect the traffic forwarding; traffic simply continues forwarding on the available link.

Convergence

Traditionally, LAN and storage (SAN) traffic were considered completely separate. They were owned by different teams, used different technologies, had different requirements for availability and data loss, and spoke different languages (IP addresses for the one, logical unit numbers [LUNs] for the other). In the best case, this approach yielded two different networks. However, as time went on, the number of networks the server needed to participate in grew. There were the SAN A and SAN B networks; the Ethernet network, which often had multiple connections to the server; the management network; and many others. This multiplicity of networks lead to enormous complexity and cost.

The convergence of Ethernet and Fibre Channel onto 10 Gigabit Ethernet has significant benefits. The obvious benefit is that it reduces the number of networks by half, depending on the number of LAN and SAN networks required. This reduction results in lower cabling costs (up to 50 percent), lower power and cooling costs (up to 60 percent reduction compared to current support of multiple networks), and better use of human resources by expanding the employee knowledge set and providing resources for more innovative projects.

Another important aspect of convergence, however, is the need to support multiprotocol storage. A wide range of available storage options exist, including Small Computer System Interface over IP (iSCSI), Fibre Channel over IP (FCIP), Fibre Channel, and network-attached storage (NAS), and the network needs to bring all these together under a common topology.

Convergence introduces a concept that is, culturally, difficult for many people to accept, which is that the network must be shared between different traffic types (and their network managers) that have different requirements. Many IT departments evaluating a fabric-based infrastructure are looking at convergence to see not just how they will use it, but how they can transition to it over time.

Here are some of the benefits delivered by convergence in a fabric-based infrastructure:

- **Standardize the interface:** Today, the network and storage groups each purchase their own switches: one will buy an Ethernet switch, and the other will buy a Fibre Channel switch. To help standardize the infrastructure on a common switching platform, Cisco delivers unified ports on the Cisco Nexus 5000 and 2000 Series products. A unified port can be configured as either an Ethernet port or a Fibre Channel port. Role-based access control (RBAC) helps ensure that different groups can have access to different configuration parameters of the switch, as required, helping ensure that multiple groups can use a common switching platform.
- **Consolidate fabrics:** The Fibre Channel over Ethernet (FCoE) protocol allows Ethernet and Fibre Channel to run over a common 10-GB connection. Cisco was the pioneer in bringing Ethernet and Fibre Channel together through the FCoE protocol and worked with the standards bodies to define the Data Center Bridging (DCB) protocols through the IEEE 802.1 committee and the Fibre Channel T11 committee, which defines Fibre Channel over other media. Cisco has therefore been at the forefront of creating innovative technologies to help lead the migration to, and interoperability of, Ethernet and Fibre Channel solutions.
- **Include storage in the fabric:** At some point, depending on the storage arrays being used, the converged fabric will need to break out into Ethernet and Fibre Channel networks. To accomplish this, Cisco provides native interfaces to help ensure that, when the traffic needs to be broken out natively, storage managers can accomplish this at the appropriate places in the network. This capability helps ensure that existing organizational structures and technology investments both can be maintained and that a smooth migration path can be provided to converged fabric if required. In addition, the Cisco Unified Network supports any type of storage protocol required, helping ensure backwards compatibility for existing systems.

Physical and Virtual Machine Management on the Network

Perhaps the biggest, and often overlooked, challenge that the fabric must address is the management of both physical and virtual resources. Virtualization has fundamentally altered the way that management should be evaluated. In the physical world, the network ended at the server port. Today, the network ends at the virtual machine, which exists inside the server and can move between servers. This new model raises a number of questions: How is a virtual machine managed? How do policies move? How can security and load balancing be optimized? The answers are critical to determining how effective a fabric-based infrastructure can actually be when IT expands the footprint of virtualization and begins moving to the world of many clouds.

The Cisco Unified Data Center offers these benefits for management:

- **Manage the virtual machine:** Virtualization has blurred the demarcation between the network and the server, making it important to provide some level of visibility into the virtual machine and associated policies to the network administrator. Some hypervisors, such as VMware vSphere, offer their own virtual

switches. However, the separation and disconnection from the networking team can cause significant policy and security challenges. To solve that problem, Cisco delivers the Cisco Nexus 1000V Series Switch software (offered as part of VMware vSphere 4.0 and higher) and the Cisco Nexus 1010 Virtual Services Appliance. These capabilities provide switching functions at the hypervisor layer, bringing in networking capabilities such as VLANs, quality of service (QoS), access control lists (ACLs), and NetFlow. Virtual machine policies can now be enforced both within the server and on the network.

- **Secure the virtual machine:** Security is a paramount concern in a virtualized environment and even more so in the cloud. Whether the virtual machine is at rest or in motion, the creation, management, and enforcement of policies is critical to protecting the data center from internal and external threats. To address this challenge, the Cisco Virtual Security Gateway (VSG), software that resides in the Cisco Nexus 1000V Series and provides context-aware security, enforces policies when data is being switched between virtual machines and establishes zones of trust. Additionally, these policies are mobile, so that, should the virtual machine move within or between the data center, the policies will follow the virtual machine.
- **Create management domains:** Often, network managers need to segment off particular networks, either for security or organizational reasons. In a traditional data center, this segmentation requires the purchase and management of more switches, which defeats the purpose of a fabric. To solve this problem, Cisco delivers virtual data center domains within the Cisco Nexus 7000 Series Switch. These domains make the Cisco Nexus 7000 Series Switch look like up to four different switches, each managed separately, saving the cost of buying new switches while maintaining organizational and security integrity.

Unified Computing: A Fabric Computing Architecture for Virtualization and Cloud

The Cisco Unified Fabric plays a crucial role in creating the fabric-based infrastructure. It is the element that interconnects all the elements in the data center. It is Cisco Unified Computing, however, that extends fabric into a revolutionary computing platform.

Not surprisingly, virtualization and cloud computing have had the greatest impact on server architecture. According to IDC, in the paper “New Economic Model for the Data Center,” server spending has remained relatively flat, but spending on virtualization and associated management platforms has increased dramatically. Virtualization has added complexity to the data center and increased the layers of management and number of people needed to handle maintenance and management functions. Clearly, new methods are needed.

To address these challenges, Cisco developed the Cisco Unified Computing System™ (Cisco UCS™), the industry’s first fabric computing architecture. Cisco UCS combines high-performance servers and high-speed networking, storage access, and virtualization into an integrated, smart infrastructure. Automatically configured through unified, model-based management, Cisco UCS simplifies deployment of enterprise applications running in bare-metal or virtualized environments. Cisco UCS greatly enhances flexibility and reduces TCO.

How does UCS deliver fabric computing? It does so through tight integration of the unified fabric components within the Cisco UCS architecture. Therefore, by design, Cisco UCS delivers a resilient, secure, open, and scalable system that transparently connects to the data center network: that is, in essence, the data center fabric runs from the virtual machine on the server to the core of the data center network.

Using the Cisco FEXLink technology in the Cisco UCS B-Series Blade Server chassis, the network fabric is extended directly to blade servers and virtual machines, with traffic meeting at a single point for consistent, centralized management and exceptional visibility and control of virtualized environments. The fabric extenders are then connected with dual homing to the Cisco UCS 6000 Series Fabric Interconnects using FCoE. By

integrating IP, storage, and interprocess communication networks into a single I/O infrastructure, Cisco UCS simplifies cabling and upstream switching while delivering the highest levels of performance. From there, traffic can be categorized into Ethernet and Fibre Channel streams if necessary. This approach allows the computing blades or rack servers to focus on what they do best: delivering computing power.

In addition to the networked elements that help deliver a fabric-based infrastructure, Cisco UCS provides a management component that delivers on the management promise of a fabric-based infrastructure.

- **Abstract personality:** In most server environments, the server is a self-contained entity, often with a few parameters that can be configured, such as IP address and so forth. Therefore, each server needs to be managed individually. Cisco delivers two innovations to manage and help ensure rapid deployment of server resources. Because of the fabric nature of Cisco UCS, it can completely abstract the personality of the server into configurable elements, which are programmed into the server platform by the Cisco UCS server profiles. Server profiles allow server managers to create templates for each server that include hardware configuration, hypervisor, memory, and other details, so as new blades or rack servers are added to the fabric, they can be rapidly configured and brought on line.
- **Provide a single point of management:** Cisco UCS Manager is a major management innovation. It runs on the Cisco UCS 6000 Series Fabric Interconnects and is responsible for managing all Cisco UCS components. With Cisco UCS Manager, users can manage the entire Cisco UCS platform through a single pane, thereby reducing management complexity. This management includes the networking modules and ports in the system, hardware elements such as fans and power supplies, and server elements such as disks and BIOS. The native language of Cisco UCS Manager is XML, so third-party tools can easily integrate with Cisco UCS Manager.
- **Interconnect virtual machines:** Virtual machines have changed the way that networking needs to work. In a fabric computing platform, the networking elements need to be extended to the virtual environment as well as the physical environment. The Cisco Nexus 1000V Series virtual switch is integrated into the virtual machine. In addition, the Cisco Data Center Virtual Machine Fabric Extender (VM-FEX) is integrated into Cisco UCS itself. Whereas Cisco FEXLink extends the network fabric from a Cisco Nexus 5000 or 7000 Series Switch to a Cisco Nexus 2000 Series Fabric Extender, Cisco Data Center VM-FEX extends networking to the virtual machine itself out to the network. Each virtual machine receives a switched interface on the network, so it looks like a port on a switch. This approach dramatically simplifies networking in Cisco UCS and brings the physical and virtual networks together.

Cisco UCS brings together stateless computing and unified fabric into a true fabric computing architecture. With Cisco Unified Fabric as the underlying networking element in both the fabric computing architecture and the data center network, organizations can now create true fabric-based infrastructure. These elements are all tied together with the Cisco NX-OS operating system, which runs on the Cisco UCS 6100 Fabric Interconnects and forms the management foundation for Cisco UCS, and on the Cisco Nexus and Cisco MDS 9000 Family data center switching platforms. This consistency of software simplifies the management, configuration, and training required to manage and operate the Cisco Unified Data Center.

Unified Management: Coordinating the Fabric to Deliver a Service

The final elements that make the Cisco Unified Data Center a true fabric-based infrastructure are orchestration and automation. As stated in earlier, a fabric requires the software to configure and manage the fabric. Cisco Unified Fabric and Unified Computing create the physical fabric; Cisco Unified Management helps bring these

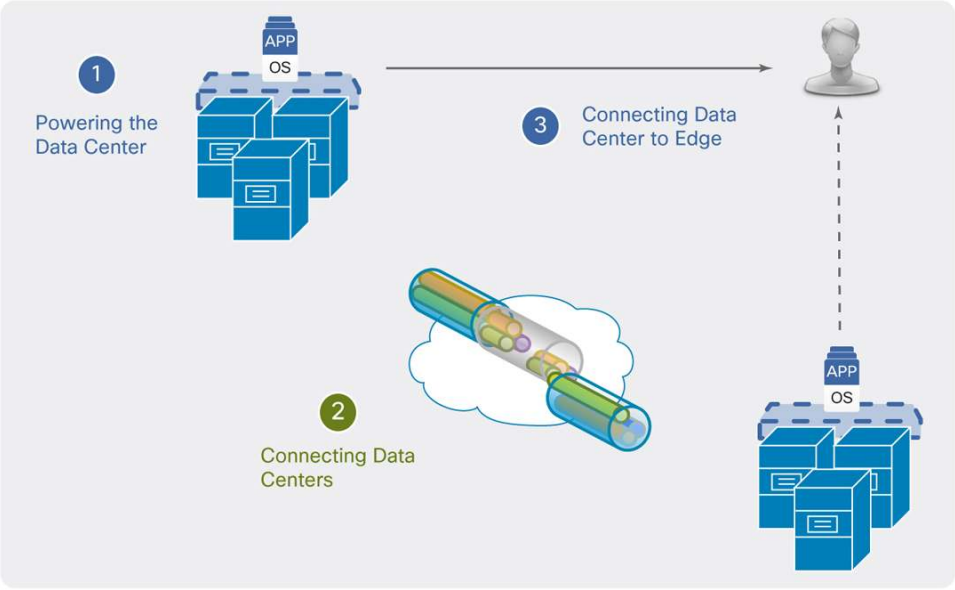
pieces together. The Cisco Unified Data Center delivers components to simplify the orchestration and automation of these resources:

- **Provide programmable networking elements:** All Cisco Unified Fabric and Unified Computing elements have APIs that enable easy management, configuration, orchestration, and automation. For Cisco Unified Fabric, the management platform is Cisco Data Center Network Manager (DCNM), and for Cisco UCS the management platform is Cisco UCS Manager. The management platform provides the hooks for intelligent automation, which brings the fabric together.
- **Provide intelligent automation:** When delivering a service, all the resources required - networking, storage, and computing - must be brought together, rapidly provisioned, and then managed overall. The Cisco Intelligent Automation for Cloud solution is software that brings together an orchestration engine for computing and storage, the Cisco Network Services Manager for network orchestration, and a self-service portal and service catalog from which users can choose their requested services.

The Power of Unification: Bringing It All Together

None of the capabilities discussed in this document function in isolation; they are all built to work together to build the fabric of the data center infrastructure. Nor does this fabric exist only in a single data center; it needs to span data centers and extend to the users themselves. Typically, the fabric is built in stages, with those stages often determined by critical IT projects such as desktop virtualization, consolidation and virtualization, private cloud, and business continuance. By using common capabilities such as Cisco NX-OS Software or a standardized computing platform such as Cisco UCS, IT can begin the process of standardizing infrastructure while reducing costs and dramatically increasing agility through overall simplification (Figure 3).

Figure 3. The Power of Unification



Many IT departments start first within the data center and then often with some part of the data center, with the focus triggered by some of the projects mentioned (the exception being the need to build out a new data center). Starting with simple steps will often yield big results in building a fabric-based infrastructure. The new capabilities required, such as virtual machine mobility, business continuance, or disaster recovery, will compel the fabric to

operate between data centers. Eventually, as trends such as cloud computing, use of mobile devices, and the proliferation of data continue to be factors in the data center, acceleration of data center services close to the user will dramatically improve the users' experience, productivity, and satisfaction.

Table 1 summarizes the steps for IT to follow within, between, and beyond the data center.

Table 1. Steps to Deliver Fabric-Based Infrastructure

	Capability Required	Cisco Solution	Benefit
Within the Data Center	Power critical applications.	Cisco UCS	Simplify computing architecture for any application workload (physical, virtual, and cloud) while delivering industry-leading performance and simplicity.
	Manage the physical and virtual networks.	Cisco Nexus 1000V Series Switches and Cisco VSG	Simplify and streamline management of the physical and virtual machine networks.
	Consolidate the network access layer.	Cisco Fabric Extender Technology (FEX Technology) and Data Center VM-FEX	Simplify the network topology for ToR deployments.
	Attain massive scalability.	Cisco FabricPath	Achieve resilient Layer 2 topology with massive scalability.
	Orchestrate infrastructure and workloads.	Cisco Intelligent Automation for Cloud	Automate and orchestrate infrastructure to deliver IT services.
Between Data Centers	Extend the Layer 2 fabric.	Cisco OTV	Extend Layer 2 domains for virtual machine mobility on top of MPLS, dark fiber, or other transport protocol.
	Achieve global IP address mobility.	Cisco Location-Independent Separation Protocol (LISP)	Separate internal and external IP addressing schemes to enable mobility between data centers.
Beyond Data Centers to the User	Optimize the user experience.	Cisco Wide Area Application Services (WAAS) and Virtual WAAS (vWAAS)	Optimize application delivery over the WAN from the data center to the branch office.
	Extend security.	Cisco VSG	Help ensure that security policies follow the application regardless of where it resides on the fabric.
	Unify the computing platform in branch offices and data center.	Cisco UCS Express	Deploy a common computing platform in the data center and branch office within the Cisco branch router.

Conclusion

Fabric-based infrastructure is gaining traction as a means of delivering and enhancing virtualization and cloud computing. The industry has seen how virtualization can affect the economics of the data center by requiring multiple layers of management. A true fabric-based infrastructure has been built from the ground up to deliver stateless computing, networking down to the virtual machine, and an easy way of bringing these elements together. The Cisco Unified Data Center is the only platform that can integrate computing, storage, and networking resources on a common fabric and then orchestrate those resources to transform IT from a cost center to a service center and open the way to the world of many clouds.

For More Information

Please see http://www.cisco.com/go/udc, http://www.cisco.com/go/ucs, http://www.cisco.com/go/unifiedfabric.

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