Virtualization:

Benefits, Challenges and Solutions

By Dr. Jim Metzler

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Executive Summary

While it is possible to virtualize almost any component of IT, this report will focus on three forms of virtualization: server virtualization, desktop virtualization and virtualized appliances. A key reason for this focus is that significant synergies exist between and amongst these forms of virtualization.

The majority of IT organizations have already implemented server virtualization and most intend to implement additional server virtualization during the next year. The primary factors driving the movement to deploy server virtualization are cost savings and the ability to dynamically provision and dynamically move VMs among physical servers.

There are, however, a number of significant challenges associated with server virtualization. Some of the challenges include:

Contentious Management of the vSwitch
Each virtualized server includes at least one software-based virtual switch (vSwitch). This adds yet another layer to the existing data center LAN architecture. It also creates organizational stress and leads to inconsistent policy implementation.

Breakdown of Network Design and Management Tools
The workload for the operational staff can spiral out of control due to the constant stream of configuration changes that must be made to the static date center network devices in order to support the dynamic provisioning and movement of VMs.

Limited VM-to-VM Traffic Visibility
The first generation of vSwitches doesn't have the same traffic monitoring features as does physical access switches. This limits the IT organization's ability to do security filtering, performance monitoring and troubleshooting within virtualized server domains.

Some of the emerging approaches to managing a virtualized environment include:

Dynamic Infrastructure Management
A dynamic virtualized environment can benefit greatly from a highly scalable and integrated DNS/DHCP/IPAM solution. Where DNS, DHCP and IPAM share an integrated database, this obviates the need to manually coordinate records in different locations.

Distributed Virtual Switching (DVS)

Most vSwitches include an integrated control and data plane. With DVS, the control and data planes are decoupled. This makes it easier to integrate the vSwitch's control plane with the control planes of other switches and with the virtual server management system.

Orchestration and Provisioning

Service orchestration is an operational technique that helps IT organizations to automate many of the manual tasks that are involved in provisioning and controlling the capacity of dynamic virtualized services.

Half of all IT organizations have already implemented at least some desktop virtualization and within a year roughly 75% of IT organizations will have implemented it. Desktop virtualization is driven by a combination of cost savings, increased ability to comply with myriad regulations and an improvement in data and application security. The two fundamental forms of desktop virtualization are:

- Server-side application/desktop virtualization
- Client-side application/desktop virtualization

With server-side virtualization, the client device plays the familiar role of a terminal accessing an application or desktop hosted on a central presentation server. There are two primary approaches to server-side application/desktop virtualization. They are:

- Server Based Computing (SBC)
- Virtual Desktop Infrastructure (VDI)

Client-side application virtualization is based on a model in which applications are streamed on-demand from central servers to client devices. On the client-side, streamed applications are isolated from the rest of the client system by an abstraction layer inserted between the application and the local operating system.

One of the primary challenges that are associated with implementing desktop virtualization is achieving an acceptable user experience for client-to-server connections over a WAN. For example, VDI requires at least 200 Kbps of bandwidth per simultaneous user and the minimum peak bandwidth required for a PCoIP[1] connection is one Mbps. In most cases, the successful deployment of desktop virtualization requires that WAN optimization techniques that focus on the particular characteristics of the traffic that are associated with desktop virtualization be widely deployed.

[1] PC-over-IP is a relatively recently developed display protocol from Teradici Corporation.

A *Virtual Appliance* is based on network appliance software running in a VM. Virtual appliances can include WOCs, ADCs, firewalls, and performance monitoring solutions among others. An important set of synergies exist between virtual servers, virtual desktops and virtual appliances such as a WOC or a performance monitoring solution. Perhaps the most important synergy is that virtual appliances are of particular interest to IT organizations in those instances in which server virtualization technology has already been disseminated to branch offices and has also been implemented in the data center.

In the branch office, a suitably placed virtualized server could potentially host a virtual WOC appliance as well as other virtual appliances. Alternatively, a router or a WOC that supports VMs could also serve as the infrastructure foundation of the branch office. Virtual appliances can therefore support branch office server consolidation strategies by enabling a single device to perform multiple functions typically performed by multiple physical devices.

A virtualized ADC makes it easy for an IT organization to package and deploy a complete application. One example of this packaging is the situation in which an entire application resides on VMs inside a physical server. The virtualized ADC that supports the application resides in the same physical server and it has been tuned for the particular application. This makes it easy to replicate or migrate that application as needed. In this case, a virtualized ADC also provides some organizational flexibility. For example, the ADC might be under the control of a central IT group or it might be under the control of the group that supports that particular application. The later is a possibility from an organizational perspective because any actions taken by the application group relative to the ADC will only impact their application.

One of the compelling advantages of a virtualized appliance is that the acquisition cost of a software-based appliance can be notably less than the cost of a hardware-based appliance with same functionality. In addition, a software-based solution can potentially leverage the functionality provided by the hypervisor management system to provide a highly available system without having to pay for a second appliance. Another advantage is that if virtualized appliances have been deployed, then it is notably easier than it is in a more traditional environment for various networking functions to be migrated along with VMs in order to replicate the VMs's networking environment in its new location.

A critical factor that must be considered when evaluating the deployment of virtual appliances in a dynamic, on-demand fashion is the degree of integration of the virtual appliance with the virtual server management system. Ideally this management system would recognize the virtual appliances as another type of VM and understand associations between appliance VM and application VMs in order to to allow a coordinated migration whenever this is desirable.

This report will only briefly mention the impact that virtualization has on networking. That topic will be covered in detail in a report to be published on or about October 1, 2010. That report is entitled *Cloud Networking*.

Introduction

In the current environment, almost every component of IT can be virtualized. This includes:

- Servers
- Desktops
- Applications
- Management probes
- I/O
- Wide Area Networks
- Local Area Networks
- Switches
- Routers
- Firewalls
- Storage
- Appliances such as WAN optimization controllers, application delivery controllers and firewalls

This report will focus primarily on three forms of virtualization: server virtualization, desktop virtualization and virtualized appliances. The benefits of server and desktop virtualization have been discussed in length in various trade publications. As a result, this report will not dwell on those topics, but will instead focus on defining the challenges associated with server and desktop virtualization as well as on the technologies, both existing and emerging, that enable IT organizations to respond to those challenges. Because the benefits of virtual appliances have not been discussed in length in the trade publications, this report will discuss those benefits. This report will also discuss the challenges associated with virtual appliances as well as the technologies, both existing and emerging, that enable IT organizations to respond to those challenges.

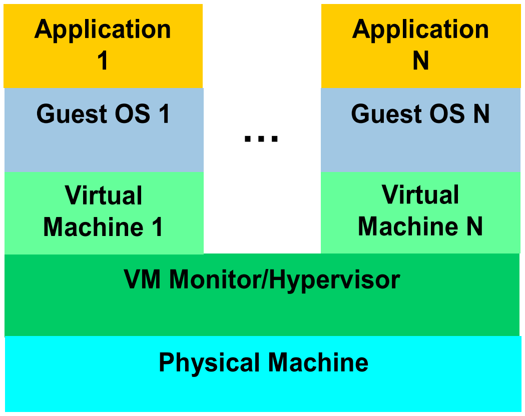
This report will only briefly mention the impact that virtualization has on networking. That topic will be covered in detail in a report to be published on or about October 1, 2010. That report is entitled *Cloud Networking*.

Server Virtualization

One of the primary benefits of server virtualization is that it allows IT organizations to consolidate servers. As shown in **Figure 1**, after being virtualized a single physical server can support multiple virtual machines (VMs). This means that applications that would normally require a dedicated server can now share a single physical server. This result in a reduction in the number of servers in a data center which leads to significant savings in CapEx (i.e., costs of server hardware, SAN Host bus adapters, and Ethernet NICs) and OpEx i.e., server management labor expense plus facility costs for power, cooling and floor space.

Initially the primary factor that drove the movement to deploy server virtualization was the cost savings discussed in the preceding paragraph. Today two other factors are also acting as significant drivers of that movement. Those factors are the ability to dynamically provision VMs and the ability to dynamically move VMs among physical servers, both within a given data center and between disparate data centers without service interruption[2].

Figure 1: Simplified View of Server Virtualization



As a result of being able to rapidly provision VMs, IT organizations can potentially respond to the business requirement for additional computing resources in a matter of seconds or minutes. The mobility of VMs means that many system administration tasks, including backup and restore, system upgrades, and hardware/software maintenance can be performed without impacting the availability of applications or services. Mobility can also be leveraged to ensure high application availability and workload balancing across a cluster of virtualized servers.

The Adoption of Server Virtualization

In early 2010, Ashton, Metzler & Associates (AM&A) administered a survey to the attendees of the Interop conference. Throughout this report, the IT professionals who responded to that survey will be referred to as The Survey Respondents.

The Survey Respondents were asked to indicate the percentage of their company's data center servers that have either already been virtualized or that they expected would be virtualized within the next year. Their responses are shown in **Table 1**.

The data in Table 1 shows the deep and ongoing interest that IT organizations have relative to deploying virtualized servers. In particular, the data in Table 1 indicates that the majority of IT organizations have already virtualized at least some of their data center servers. Two other observations that can be drawn from Table 1 are that within the next year:

[2] Within VMware, this capability is referred to as VMotion.

Table 1: Deployment of Virtualized Servers

	None	1% to 25%	26% to 50%	51% to 75%	76% to 100%
Have already been virtualized	30%	34%	17%	11%	9%
Expect to be virtualized within a year	22%	25%	25%	16%	12%

- The number of IT organizations that have not implemented server virtualization will be cut by over twenty five percent.
- The number of IT organizations that have virtualized the majority of their servers will grow by forty percent.

As previously noted, two of the factors that are currently driving the movement to virtualize data center servers are the ability to dynamically provision VMs and the ability to dynamically move VMs among physical servers. As shown in **Table 2**, 46% of The Survey Respondents indicated that the dynamic provisioning of VMs will be of either significant or very significant importance to them by early 2011. This is a notable increase from the 29% of The Survey Respondents who indicated that this capability was currently either of significant or very significant importance to them.

The combination of the ease and speed with which VMs can be provisioned and migrated within and potentially among data centers has led many IT organizations to create initiatives to further leverage virtualization throughout their IT infrastructure. The goal of these initiatives is to have an infrastructure that has the ability to provide each application and network service with the required resources even as the demand for each service fluctuates dynamically. The ultimate in *elastic computing* (a.k.a., on-demand computing) is realized when the demand for infrastructure resources can be met with instant-on, real-time delivery of virtualized network services.

Table 2: Importance of Dynamically Provisioning VMs

	Importance Currently	Importance in a Year
Very Significant Importance	13%	23%
Significant Importance	16%	23%
Moderate Importance	20%	24%
Slight Importance	25%	15%
No Importance	26%	14%

Challenges of Server Virtualization

One way to think about the current generation of virtualized data centers, and the related management challenges, draws on the concept of a fractal[3]. A fractal is a geometric object that is similar to itself on all scales. If you zoom in on a fractal object it will look similar or exactly like the original shape. This property is often referred to as self-similarity.

The relevance of fractals is that the traditional data center is comprised of myriad physical devices including servers, LAN switches and firewalls. The virtualized data centers that most IT organizations are in the process of implementing are still comprised of physical servers, LAN switches and firewalls. In addition, these data centers house servers which have been virtualized and which are comprised of a wide range of functionality including virtual machines, a virtual LAN switch and in many cases virtual firewalls. Hence, if you take a broad overview of the data center you see certain key pieces of functionality. If you were to then zoom inside of a virtualized data center server you would see most, if not all of that same functionality. Hence, a virtualized data center can be thought of as a fractal data center.

Because of the fractal nature of a virtualized data center, many of the same management tasks that must be performed in the traditional server environment need to be both extended into the virtualized environment and also integrated with the existing workflow and management processes. One example of the need to extend functionality from the physical server environment into the virtual server environment is that IT organizations must be able to automatically discover both the physical and the virtual environment and have an integrated view of both environments. This view of the virtual and physical server resources must stay current as VMs move from one host to another, and the view must also be able to indicate the resources that are impacted in the case of fault or performance issues.

Some of the other specific challenges that server virtualization poses for the network infrastructure and network management include:

Contentious Management of the vSwitch

Each virtualized server includes at least one software-based virtual switch, and at least in the first generation of server virtualization, each of these switches had to be configured and managed manually as a separate entity. Another aspect of the management difficulty associated with server virtualization is that the server management team typically manages the new access layer that is comprised of virtual switches, while the rest of the data center network is the responsibility of the networking team. The combination of dual access layers (e.g., the new access layer

[3] http://www.pha.jhu.edu/~ldb/seminar/fractals.html

inside of the virtualized server and the traditional access layer in the data center network) and split responsibilities increases the complexity of the virtualized data center network and reduces the efficiency of management. These effects become dramatically more evident as the number of virtualized servers increases.

Breakdown of Network Design and Management Tools

As the virtual IT infrastructure becomes more dynamic in order to deliver on-demand application delivery, the traditional approach to network design and the associated labor-intensive management tools that are typically used to control and manage the IT infrastructure will not be able to keep pace with the frequent, dynamic changes that are required. For example, the traditional approach to data center network design is based on the concept of interconnecting and managing relatively static physical devices. This approach has two fundamental limitations when used to support virtualized servers. One limitation is that the workload for the operational support staff can spiral out of control due to the constant stream of configuration changes that are needed to support the dynamic provisioning and movement of VMs. The second limitation is that even if IT organizations had enough support staff to implement the necessary configuration changes, the time to support these changes is typically measured in days and weeks. In order to truly have a dynamic IT infrastructure, these changes must be made in the same amount of time that it takes to provision or move a VM; i.e., seconds or minutes.

Poor Management Scalability

The ease with which new VMs can be deployed has often led to VM proliferation, or VM sprawl. This introduces new management challenges relative to tracking VMs and their consumption of resources throughout their life cycle. In addition, the normal best practices for virtual server configuration call for creating separate VLANs for the different types of traffic to and from the VMs within the data center. While not all of these VLANs need to be routable, they all must be managed. The combined proliferation of virtualized servers, VMs, and VLANs places a significant strain on the manual processes traditionally used to manage servers and the supporting infrastructure. The problem of scalability places an emphasis on management tools that can provide some degree of integration by being able to manage homogenous, or even somewhat heterogeneous, collections of physical and virtual data center entities as a single system.

Multiple Hypervisors

As recently as 2009, VMware was the dominant hypervisor vendor. Today, VMware is still the most commonly used hypervisor. It is, however, becoming increasingly common to find IT organizations using other hypervisors, including Xen from Citrix, KVM (Kernel-based Virtual Machine) from Red Hat and Hyper-V from Microsoft.

One of the challenges associated with having multiple hypervisors is that each comes with their own management system. This means that IT organizations need to learn multiple management interfaces. Another challenge associated with having multiple hypervisors is that the management functionality provided by each hypervisor varies as does the degree to which each hypervisor management system is integrated with other management systems. As a result, the IT organization's ability to manage VMs and the associated data center infrastructure will vary based on which hypervisor supports which groups of VMs.

Limited VM-to-VM Traffic Visibility

Prior to server virtualization, IT organizations were able to leverage their data center LAN access and aggregation switches in order to monitor the traffic that flowed between servers. With traditional hardware switches, however, it is not generally possible to monitor traffic or to apply network security policy to the traffic that is switched between VMs on the same physical server by the first generation of hypervisor virtual switch (vSwitch). That follows because the first generation of virtual switches embedded within the hypervisor generally don't have the same extensive traffic monitoring features and port mirroring features as physical access switches. For example, while most embedded virtualization management tools can identify the total volume of traffic within the entire virtual environment, they cannot provide information on individual network services such as HTTP or FTP. This lack of management insight can dramatically limit the ability of the IT organization to be able to do granular security filtering and performance monitoring and/or troubleshooting within virtualized server domains.

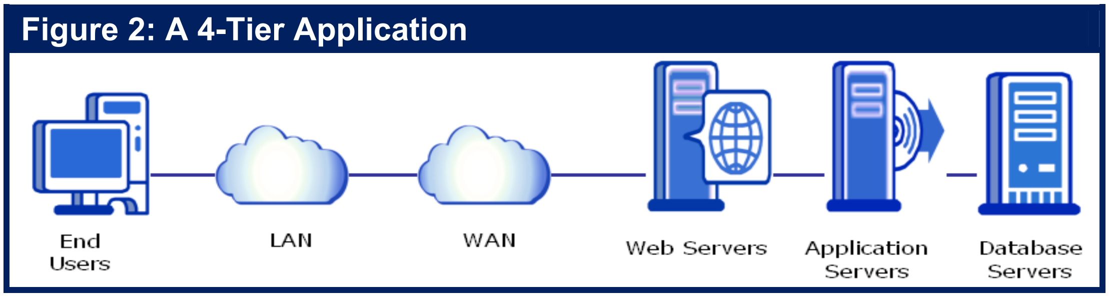
Inconsistent Network Policy Enforcement

Traditional vSwitches can lack some of the advanced features that are required to provide the degree of traffic control and isolation required in the data center. This includes features such as private VLANs, quality of service (QoS), and extensive access control lists (ACLs). Even when vSwitches support some of these features, they often must be configured manually through the virtual server management application and may not be fully compatible with similar features offered by physical access switches. This situation results in difficulties in implementing consistent end-to-end network policies.

Complex Troubleshooting on a per-VM Basis

Most IT organizations have deployed a form of distributed computing often referred to as *n-tier applications*. The typical 4-tier application (Figure 2) is comprised of a Web browser, a Web server, an application server and a database server. Even in the traditional environment in which the servers that support the application are not virtualized, when the performance of the application degrades it is typically noticed first by the end user and not by the IT organization. In addition, when the IT organization is made aware of the fact that the performance of the application has degraded, it often takes a considerable amount of time to find the root cause of the degradation.

Figure 2: A 4-Tier Application



As previously noted, many of the same management tasks that must be performed in the traditional server environment need to be extended into the virtualized environment. Another example of this is that IT organizations must be able to troubleshoot on a per-VM basis.

To put the challenge of troubleshooting on a per-VM basis into perspective, consider a hypothetical 4-tier application that will be referred to as TheApp. For the sake of this example, assume that TheApp is implemented in a manner such that the web server, the application server and the database server are each running on VMs on separate servers, each of which have been virtualized using different hypervisors. It is notably more difficult to troubleshoot TheApp than it is to troubleshoot the traditional 4-tier application in part because each server has a different hypervisor management system and in part because of the lack of visibility into the inter-VM traffic on a given physical server.

Manual Network Reconfiguration to Support VM Migration

As previously discussed, many of the benefits of on-demand computing depend on the ability to migrate VMs among physical servers located in the same data center or in geographically separated data centers. The task of moving a VM is a relatively simple function of the virtual server management system. There can, however, be significant challenges in assuring that the VM's network configuration state (including QoS settings, ACLs, and firewall settings) is also transferred to the new location. In the vast majority of instances today, making these modifications to complete the VM transfer involves the time-consuming manual configuration of multiple devices.

Regulatory compliance requirements can further complicate this task. For example, assume that the VM to be transferred is supporting an application that is subject to PCI compliance. Further assume that because the application is subject to PCI compliance that the IT organization has implemented logging and auditing functionality. In addition to the VM's network configuration state, this logging and auditing capability also has to be transferred to the new physical server.

Over-subscription of Server Resources

The RoI that is associated with server virtualization tends to increase as the number of VMs that are supported by physical server increases. However, the more VMs per server the higher the traffic load and the greater the number of CPU cycles that are required to move traffic through a software-based virtual switch. What this means is that in those instances in which a high percentage of the physical server's CPU cycles are required to support the applications that reside in the VMs, a high percentage of the physical server's CPU cycles are also required to switch the traffic between the VMs inside the physical server and between the VMs and the physical LAN switch to which the physical server is connected.

With a desire to cut cost and to reduce the need for new server acquisitions, there is the tendency for IT organizations to combine too many VMs onto a single physical server. The over subscription of VMs onto a physical server can result in performance problems due to factors such as limited CPU cycles or I/O bottlenecks. While these problems can occur in a traditional physical server, they are more likely to occur in a virtualized server due to consolidation of too many resources onto a single physical server.

Layer 2 Network Support for VM Migration

When VMs are migrated, the network has to accommodate the constraints imposed by the VM migration utility; e.g., VMotion. Typically the source and destination servers have to be on the same VM migration VLAN, the same VM management VLAN, and the same data VLAN. This allows the VM to retain its IP address, which helps to preserve user connectivity after the migration. When migrating VMs between disparate data centers, these constraints require that the data center LAN be extended across the physical locations or data centers without compromising the availability, resilience, and security of the VM in its new location. VM migration also requires the LAN extension service have considerable bandwidth and low latency. VMware's VMotion, for example, requires at least 622 Mbps of bandwidth and less than 5 ms of round trip latency between source and destination servers over the extended LAN[4].

The speed of light in a combination of copper and fiber is roughly 120,000 miles per second. In 5 ms, light can travel about 600 miles. Since the 5 ms is round trip delay, that means that the data centers can be at most 300 miles apart. That 300 mile figure assumes that the WAN link is a perfectly straight line between the source and destination ESX servers and that the data that is being transmitted does not spend any time at all in a queue in a router or other device. Both of those assumptions are unlikely to be the case and hence the maximum distance between data centers is less than 300 miles.

Storage Support for Virtual Servers and VM Migration

The data storage location, including the boot device used by the virtual machine, must be accessible by both the source and destination physical servers at all times. If the servers are at two distinct locations and the data is replicated at the second site, then the two data sets must be identical. One approach is to extend the SAN to the two sites and maintain a single data source. Another approach is migrate the data space associated with a virtual machine to the secondary storage location. In each case it is necessary to coordinate the VM and storage migrations, which may be problematical without integration of the storage subsystems under the virtual server management system.

Meeting the Challenges of Server Virtualization

At the present time, there is no overarching solution for the comprehensive management of a computing environment composed of virtualized servers, storage, and networks. Vendors, however, are beginning to address the challenges previously described by enhancing the functionality of their products with virtualization features, automation, and support for some level of integration - primarily with the virtual server management system. IT organizations, however, need to avoid introducing a new suite of management tools every time they introduce a new technology such as virtualized servers. This approach is too expensive and creates additional management silos. To avoid the proliferation of management tools, IT organizations need to identify a core suite of tools that can evolve to span or eliminate the traditional boundaries between physical and virtual infrastructure elements.

The remainder of this section of the report will describe some the key developments that can help IT departments meet the challenges of virtualization.

[4] http://www.cisco.com/en/US/prod/collateral/switches/ps9441/ps9402/white_paper_c11-591960.pdf

Dynamic Infrastructure Management

A dynamic virtualized environment can benefit greatly from a highly scalable and integrated DNS/DHCP/IPAM solution, which is also well integrated with the virtual server management system. Where DNS/DHCP/IPAM share a common database, the integration obviates the need to coordinate records in different locations and allows these core services to accommodate any different addressing and naming requirements of physical and virtual servers. Potential advantages of this approach include the automated generation of IP addresses for newly created VMs, the automated allocation of subnets for new VLANs, and the population of an IP address database with detailed information about the current location and security profiles of VMs. The integration of infrastructure utilities with the virtual server management system can also facilitate automated changes to the DHCP and DNS databases.

Virtualized Performance and Fault Management

Another example of a management capability in the traditional physical environment that is important to implement in a virtual environment is adaptive performance thresholding. This capability identifies systemic deviations from normal as well as time over threshold violations, and can automatically update thresholds based on changes to historic levels of utilization. That same capability is needed in a virtualized environment so that IT organizations can monitor the performance of individual VMs.

Virtual switches currently being introduced into the market can export traffic flow data to external collectors in order to provide some visibility into the network flows between and among the VMs in the same physical machine. Performance management products are currently beginning to leverage this capability by collecting and analysing intra-VM traffic data. Another approach to monitoring and troubleshooting intra-VM traffic is to deploy a virtual performance management appliance or probe within the virtualized server[5]. This approach has the advantage of potentially extending the fault and performance management solution from the physical network into the virtual network by capturing VM traffic at the packet level, as well as the flow level.

While changes in the virtual topology can be gleaned from flow analysis, a third approach to managing a virtualised server is to access the data in the virtual server management system. Gathering data from this source can also provide access to additional performance information for specific VMs, such as CPU utilization and memory utilization.

[5] This will be discussed in the section on virtual appliances.

Distributed Virtual Switching (DVS)

As noted earlier, with server virtualization each physical server comes with a virtual switching capability that allows connectivity among VMs on the same physical platform. The first generation virtual switch includes a data plane implemented in software, as well as an integral control plane with fairly limited functionality. With DVS, the control and data planes of the embedded virtual switch are decoupled. This allows the data planes of multiple virtual switches to be controlled by an external centralized management system that implements the control plane functionality. Decoupling the data plane from the control plane makes it easier to tightly integrate the virtual switch control plane with the control planes of physical access and/or aggregation switches and/or the virtual server management system.

DVS will be discussed in greater detail in the forthcoming report entitled *Cloud Networking.*

Edge Virtual Bridges (EVBs)

Edge Virtual Bridges constitute an alternative to virtualization of the edge of the network via DVS and virtual appliances. With EVB, the hypervisor is relieved from all switching functions, which are now all performed by the physical access and aggregation network. The IEEE 802.1 Work Group is creating a standard called Edge Virtual Bridging. The EVB standards work is based on a technology known as Virtual Ethernet Port Aggregator (VEPA). Using VEPA, all traffic from VMs is forwarded to the adjacent physical access switch and directed back to the same physical server if the destination VM is co-resident on the same server.

EVBs will be discussed in greater detail in *Cloud Networking.* Single Root I/O Virtualization (SR-IOV) will also be discussed in that report. SR-IOV will enable hardware NICs to support software-based virtual switch functionality.

Orchestration and Provisioning

Service orchestration is an operational technique that helps IT organizations automate many of the manual tasks that are involved in provisioning and controlling the capacity of dynamic virtualized services. By automatically coordinating provisioning and resource reuse across servers, storage, and networks, service orchestration can help IT organizations streamline operational workloads and overcome technology and organizational silos and boundaries. Orchestration engines use business policies to define a virtual service and to translate that service into the required physical and virtual resources that are needed for deployment. The orchestration engine then disseminates the needed configuration commands to the appropriate devices across the network in order to initiate the requested service. The orchestration engine can automatically initiate the creation of the required virtual machines while simultaneously deploying the network access and security models across all of the required infrastructure components. This includes routers, switches, security devices, and core infrastructure services. The entire process can allow setup and deployment of network routes, VPNs, VLANs, ACLs, security certificates, firewall rules and DNS entries without any time consuming manual entries via device-specific management systems or CLIs.

Orchestration engines are generally limited in the range of devices with which they can interface due to differences in device and/or vendor management interfaces. Therefore, orchestration solutions mirror to some extent the constraints of virtual data center solutions that result from vendor partnerships among manufacturers of virtual server software, networks, and networked storage. The initial focus of such partnerships has been on promulgating validated network designs and architectures rather than on fully integrated or automated management. The next logical step for such partnerships is to include orchestration capabilities.

Orchestration solutions would benefit greatly from the emergence of an open standard for the exchange of information among the full range of devices that may be used to construct a dynamic virtual data center. In the Cloud Computing arena there are a number of standards under development, including the Open Cloud Computing Interface (OCCI) from the Open Grid Forum. These standards activities may also provide value within the enterprise virtual data center, since the stated scope of the specification is to encompass “all high level functionality required for the life-cycle management of virtual machines (or workloads) running on virtualization technologies (or containers) supporting service elasticity”.

IF-MAP is another emerging standard proposed by the Trusted Computing Group and implemented by a number of companies in the security and network industries. It is a publish/subscribe protocol that allows hosts to lookup meta-data and to subscribe to service or host-specific event notifications. IF-MAP can enable auto-discovery and self-assembly (or re-assembly) of the network architecture. As such, IF-MAP has the potential to support automation and dynamic orchestration of not only security systems but also other elements of the virtual data center. For example, IF-MAP could facilitate automation of the processes associated with virtual machine provisioning and deployment by publishing all of the necessary policy and state information to an IF-MAP database that is accessible by all other elements of the extended data center.

Virtual firewall appliances can also help IT organizations respond to the challenges that are associated with server virtualization. These will be discussed in the subsequent section of this report that is entitled *Virtual Appliances*.

Desktop[6] Virtualization

The challenge of managing applications and desktop environments across the enterprise is becoming considerably more formidable as the range of applications that support employee productivity and business operations continues to grow. IT organizations are often stretched to the limit performing routine operational tasks such as:

- Deploying applications and application upgrades
- Provisioning new desktop systems
- Installing patches to keep desktop machines and applications up-to-date
- Securing systems and data from intrusions
- Providing help desk support
- Maintaining control of the PC environment to ensure demonstrable compliance with regulatory mandates

The challenge of managing applications is exacerbated in part by the increasing percentage of the employee population that is located in a branch office, a home office or is mobile. The growing number of remote and mobile workers presents IT organizations with the challenge of being able to centrally manage each of the tasks listed above without deploying an inordinate number of management tools. Remote locations differ from central facilities in that they often require more stringent security measures due to a lack of physical security and the frequent presence of guests, business partners and other visitors.

Desktop virtualization centralizes the management of complete desktops or individual desktop applications. Centralization simplifies management operations and allows a single maintenance operation to span a large number of virtualized desktops. There are a number of different approaches to desktop virtualization, but they all are share the concept that the desktop or application is virtualized in the sense that it appears to be installed on the client device when that is not actually the case.

The two fundamental forms of desktop virtualization are:

- Server-side application/desktop virtualization
- Client-side application/desktop virtualization

With server-side virtualization, the client device plays the familiar role of a terminal accessing an application or desktop hosted on a central presentation server. There are two primary approaches to server-side application/desktop virtualization. They are:

[6] In this context, the term ‘desktop’ refers to the tradition desktop as well as to various mobile devices including laptops and smartphones.

- Server Based Computing (SBC)
- Virtual Desktop Infrastructure (VDI)

IT organizations have been using the SBC approach to virtualization for a long time and often refer to is as Terminal Services. In the SBC approach the terminal server functions in a fashion similar to a time-shared multi-user computer. Virtual Desktop Infrastructure (VDI) is a relatively new variation on the overall server-side form of virtualization where a VM on a central server is dedicated to host a single virtualized desktop.

Client-side application virtualization is based on a model in which applications are streamed on-demand from central servers to client devices over a LAN or a WAN. On the client-side, streamed applications are isolated from the rest of the client system by an abstraction layer inserted between the application and the local operating system. In some cases, this abstraction layer could function as a client hypervisor isolating streamed applications from local applications on the same platform.

Figure 3: Client-side and Server-side Desktop Virtualization

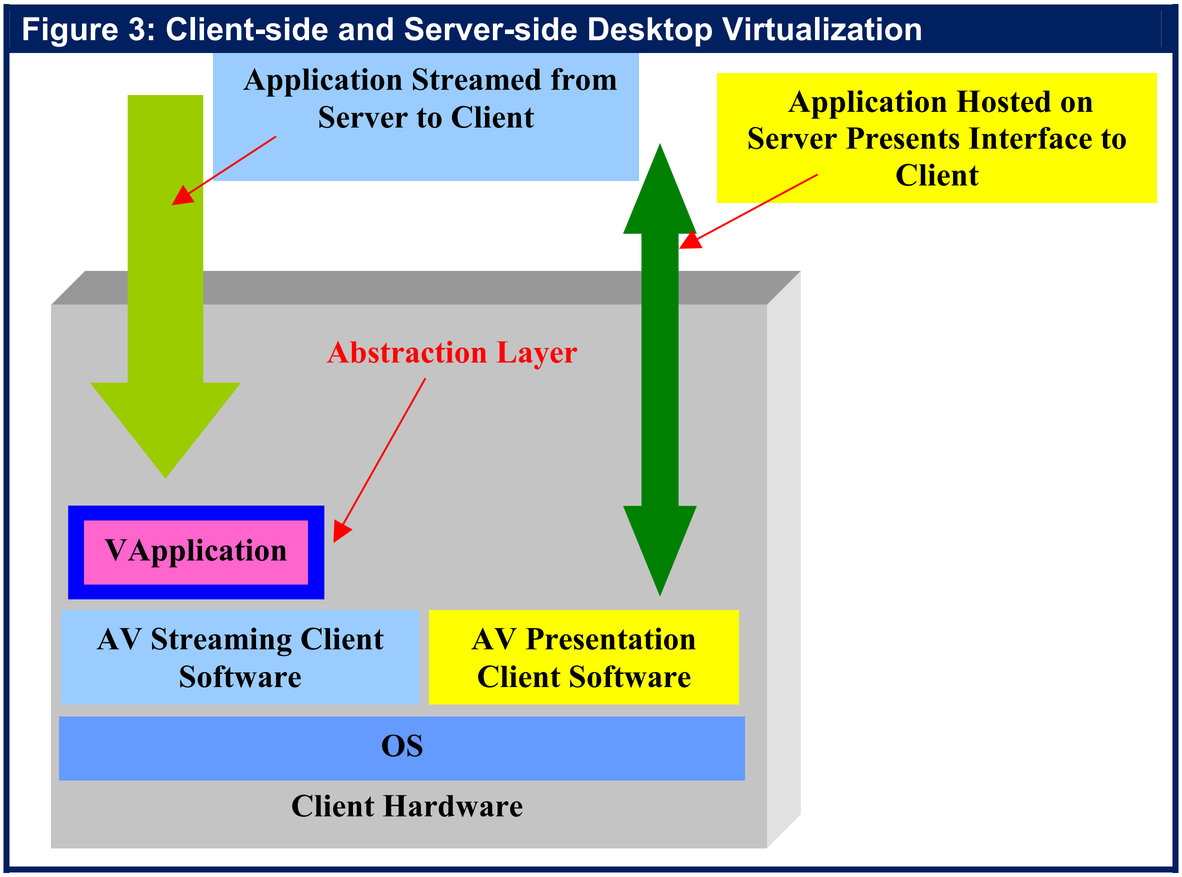

Application Streamed from Server to Client
Application Hosted on Server Presents Interface to Client
Abstraction Layer
VApplication
AV Streaming Client Software
AV Presentation Client Software
OS
Client Hardware

Figure 3 shows a client system that supports client-side and server-side virtualization models at the same time. For the server-side (or hosted) virtualization shown on the right-hand side of Figure 3, only screen displays, keyboard entries, and mouse movements are transmitted across the network. This approach to virtualization is based on display protocols such as Citrix's Independent Computing Architecture (ICA) and Microsoft's Remote Desktop Protocol (RDP). Hosted application virtualization does not require the client device to have a full-functioned operating system. As such, a primary advantage of hosted application virtualization is that the application can be securely accessed from home PCs, airport Internet kiosks, smart phones, and other thin client devices.

The left-hand side of Figure 3 shows a client system accessing a streamed client-side virtualized application. Application streaming is selective in the sense that only the required application libraries are streamed to the user's device. The streamed application's code is isolated and not actually installed on the client system. The user can also have the option to cache the virtual application's code on the client system. Caching greatly reduces the volume of download traffic for streamed applications and is particularly effective for applications that are infrequently updated. Caching also allows applications to be run locally on the client without the use of streaming in the event of network outages or other situations where the user's device lacks network connectivity.

Adoption of Desktop Virtualization

The data in **Table 3** shows the current and planned deployment of desktop virtualization as reported by the Interop Survey respondents. While a comparison of the data in Tables 2 and 3 indicates that there is less interest in desktop virtualization than there is in server virtualization, the data in Table 3 also indicates that within the next year:

- The number of IT organizations that have virtualized the majority of their desktops will almost double.
- The number of IT organizations that have not implemented desktop virtualization will be cut in half.

Table 3: The Percentage of Desktops that Already Have or Will be Virtualized

	None	1% to 25%	26% to 50%	51% to 75%	76% to 100%
Have already been virtualized	49.5%	34.7%	8.9%	1.0%	5.9%
Expect to be virtualized within a year	22.0%	46.3%	18.3%	7.3%	6.1%

Respondents to the survey indicated that the primary factors driving their adoption of desktop virtualization are a reduction in the overall cost, primarily because of lower OPEX costs for maintenance and support; an improvement in data and application security and an enhanced ability to comply with security regulations.

Challenges of Desktop Virtualization

From a networking perspective, the primary challenge in implementing desktop virtualization is achieving adequate performance and an acceptable user experience for client-to-server connections over a WAN. The ICA and RDP protocols employed by many hosted application virtualization solutions are somewhat efficient in their use of the WAN because they incorporate a number of compression techniques including bitmap image compression, screen refresh compression and general data compression. While these protocols can often provide adequate performance for traditional data applications, they have limitations with graphics-intensive applications, 3D applications, and applications that require audio-video synchronization.

To respond to the challenges created by these types of applications, Citrix introduced High Definition user eXperience (HDX™) technology into XenDesktop 4. HDX is intended to support the remote display of multimedia, voice, video, and 3D graphics on client devices. Citrix HDX is comprised the following categories:

- HDX Broadcast – Ensures high-performance of virtual desktops and applications over any network, including high-latency and low-bandwidth environments.
- HDX WAN Optimization – Optimizes performance by caching bandwidth intensive data and graphics and delivering them from the most efficient location.
- HDX MediaStream – Accelerates multimedia performance through compression or when possible, through redirection and client-side rendering.
- HDX RealTime – Enhances real-time voice and video using advanced encoding and streaming to ensure a no compromise end-user experience.
- HDX 3D – Optimizes the performance of everything from graphics-intensive 2D environments to advanced 3D geospatial applications using software and hardware based rendering in the datacenter and on the device.
- HDX Plug-n-Play – Enables simple connectivity for all local devices in a virtualized environment, including USB, multi-monitor, printers and peripherals.

A relatively recently developed display protocol is the PC-over-IP (PCoIP) protocol from Teradici Corporation. PCoIP is a proprietary protocol that renders the graphics images on the host computer and transfers compressed pixel level data to the client device. PCoIP is compatible with *zero clients*. These are user display devices that have no operating system and no processor.

PCoIP is the display protocol used by the recently introduced VMware View 4 VDI product, which also supports RDP. A recently published document[7] stated that, "To support the lower bandwidth typically available over a WAN, the minimum peak bandwidth required for a PCoIP connection has been reduced to 1 Mbps." While the 1 Mbps required by PCoIP to support a single user represents a worst-case situation, it does underscore the fact that a significant amount of WAN bandwidth can be required to support desktop virtualization.

The bandwidth requirements of PCoIP also highlight the fact that before implementing desktop virtualization, IT organizations need to understand the network implications of that implementation. One of those implications is that other WAN traffic such as large file transfers, can negatively impact the user's experience with desktop virtualization. To avoid this situation, QoS needs to be implemented throughout the WAN.

Another implication of implementing desktop virtualization is that a large amount of WAN bandwidth may be required. As noted, IT organizations have been using the SBC approach to server side virtualization for a long time. As such, the bandwidth requirements of SBC are well known to be between 20 Kbps and 30 Kbps per simultaneous user[8]. Hence, if there are fifty simultaneous users in an office, that requires between 1 Mbps and 1.5 Mbps just to support desktop virtualization.

Identifying the bandwidth requirements of VDI is more difficult in part because it is a newer approach to desktop virtualization and in part because the bandwidth requirements will vary based on a number of factors. These factors include the particular display protocols being used and the types of tasks being performed. One recently published article[9] discussed the bandwidth requirements of VDI and stated, "If you're a typical worker who uses Microsoft Office and not much else, 200 kilobits of network bandwidth is probably enough. But for workers who need video streaming and 3D graphics rendering, those network requirements can scale to the hundreds of megabits."

A recent entry in The Citrix Blog[10] gave the following estimates (**Table 4**) for the amount of WAN bandwidth required by XenDesktop.

[7] http://www.teradici.com/media/resources/PCoIP-WAN-brief.pdf

[8] http://www.virtualizationadmin.com/articles-tutorials/terminal-services/performance/poor-bandwidth-latency.html

[9] http://www.pcworld.idg.com.au/article/341933/5_virtual_desktop_pitfalls/?

[10] http://community.citrix.com/display/ocb/2010/05/20/How+Much+Bandwidth+Do+I+Need+for+My+Virtual+Desktop

Table 4: VDI Bandwidth Requirements

Activity	XenDesktop Bandwidth
Office	43 Kbps
Internet	85 Kbps
Printing	553 – 593 Kbps
Flash Video	174 Kbps
Standard WMV Video	464 Kbps
High Definition WMV Video	1,812 Kbps

The entries in the right hand column of Table 4 represent the WAN bandwidth requirements for each simultaneous user of the corresponding activity listed in the left hand column. As before, if there were fifty simultaneous users in a branch office, the total WAN bandwidth requirement would be the sum of what was required by the fifty users. **Table 5** depicts one possible scenario of what fifty branch office users are doing and identifies that the total WAN bandwidth that is required by this scenario is just less than 16 Mbps.

Table 5: Bandwidth Requirements from a Branch Office

Activity	XenDesktop Bandwidth	Number of Simultaneous Users	WAN Bandwidth Required
Office	43 Kbps	10	430 Kbps
Internet	85 Kbps	15	1,275 Kbps
Printing	573 Kbps	15	8,595 Kbps
Flash Video	174 Kbps	6	1,044 Kbps
Standard WMV Video	464 Kbps	2	928 Kbps
High Definition WMV Video	1,812 Kbps	2	3,624 Kbps
Total WAN Bandwidth			15,896 Kbps

Compared with hosted applications, streamed applications are far less efficient as they typically use the same inefficient protocols that are native to the application. Furthermore, streamed applications create additional challenges for the IT organization because of the much larger amount of data that must be transmitted across the WAN when the application is initially delivered to the branch.

Meeting the Challenges of Desktop Virtualization

IT organizations that are implementing virtualized desktops should analyze the viability of implementing WAN and application optimization solutions such as those described in the 2009 Application Delivery Handbook[11]. Some of the general WAN optimization techniques described in the handbook include:

- Compression
- Caching and de-duplication
- TCP Protocol optimization
- Application and protocol (e.g., CIFS, HTTP, MAPI) optimization
- Protocol (e.g., ICA, RDP, PCoIP) optimization
- QoS and traffic shaping

Although virtually all WAN Optimization Controllers (WOCs) on the market support the functions listed above, there are some significant differences in terms of how the functionality is implemented and how well it performs. For example, the ICA and RDP protocols can be difficult to optimize for a number of reasons. One of those reasons is that these protocols only send small request-reply packets. This form of communications is best optimized by byte-level caching that is not supported by many WOC vendors. In addition, some WOC vendors provide functionality not included in the above list. Implementers of desktop virtualization need to understand these differences in the context of the applications they want to virtualize and the models of desktop virtualization that they want to deploy. A recent report[12] provides insight into the primary WOC vendors and their products.

As shown in **Table 6**, techniques such as byte level compression, caching, protocol (e.g., ICA, RDP) optimization, and QoS can provide benefits for hosted applications. Before implementing them, however, an IT organization must determine which acceleration techniques are compatible with the relevant display protocols. For example, in order to be able to compress ICA traffic, a WOC must be able to decrypt the ICA workload, apply the optimization technique, and then re-encrypt the data stream.

In order to enable the growing population of mobile workers to access enterprise applications as easily as do workers in branch offices, the communications between the mobile worker and the data center (whether it is owned by the enterprise or a third party provider such as a cloud computing service provider) has to be optimized. One way to optimize this communications is to deploy client software on the user's mobile device that provides WOC functionality. Until recently, the typical device that mobile workers used to access enterprise applications was a laptop. While that is still the most common scenario, today many mobile workers use their smartphones to access enterprise applications. Therefore, over the next few years it is reasonable to expect that many IT organizations will support the use of smartphones as an access device by implementing server-side application virtualization for those devices. This

[11] http://webtorials.com/abstracts/2009-Application-Delivery-Handbook.htm
[12] http://searchenterprisewan.techtarget.com/generic/0,295582,sid200_gci1381156,00.html

Table 6: Applicability of Common WAN Optimization Techniques

	Streamed Applications	Hosted Applications
Block Level Compression	**X**	
Byte Level Compression	**X**	X
Caching	X	X
Staging	X	
Protocol Optimization (e.g., TCP, IP, UDP)	X	X
Protocol Optimization (e.g., ICA, RDP)		X
Protocol Optimization (e.g., CIFS, HTTP, MAPI)	X	
QoS	X	X

means that in a manner somewhat similar to remote workers, mobile workers will access corporate applications by running protocols such as ICA and RDP over a WAN.

Just as was the case with workers who access applications from a fixed location, in order for mobile workers to be able to experience acceptable application performance, network and application optimization is required. In many cases the mobile worker will use some form of wireless access. Since wireless access tends to exhibit more packet loss than does wired access, the WOC software that gets deployed to support mobile workers needs functionality such as forward error correction that can overcome the impact of packet loss. In addition, as workers move in and out of a branch office, it will be necessary for a seamless handoff between the mobile client and the branch office WOC.

Many IT organizations resist putting any more software on the user's device. In addition, many users resent having multiple clients (e.g., WOC, SSL VPN, IPSec VPN, wireless/cellular access) that are not integrated on their access device. On a going forward basis, IT organizations should look to implement WOC software that is integrated with the other clients used by mobile workers.

A recently developed proprietary solution, the Experience Optimization Protocol (EOP)[13] is part of Quest Software's vWorkspace integrated platform for desktop virtualization. vWorkspace is intended to provide a unified solution for hosted applications delivered from heterogeneous environments of virtualized servers, terminal servers, or blade PCs. vWorkspace is compatible with multiple server hypervisors, but provides its own server-side and client-side software for application

[13] EOP and Xstream are alternatively looked at as display protocols and as optimization techniques.

delivery. For terminal services, there is some integration with Microsoft Remote Desktop Services.

The EOP display protocol accelerates the display of images and multimedia content. EOP's Xstream provides further acceleration of EOP and RDP traffic on high latency WAN links. vWorkspace also supports other remote display technologies, including HP's Remote Graphics Software (RGS), Wyse's Thin Client Experience (TCX) and Virtual Desktop Accelerator (VDA). RGS is a remote display solution that might be applicable to terminal-style access to hosted applications, but is optimized for collaborative screen-sharing sessions. Like PCoIP, RGS applies compression at the pixel level. TCX and VDA work in conjunction with ICA and RDP to enhance thin client access to hosted applications and desktops.

Table 7 provides an overview of the display protocols currently supported by VDI vendors. Table 7 is not intended to be a complete listing of display protocols. Rather, Table 7 is intended to highlight the breadth of protocols that IT organizations may need to support and optimize if they implement VDI.

Table 7: Vendor Support of Remote Display Protocols

Vendor	VDI Product	Display Protocols
VMware	View	RDP, PCoIP
Citrix	XenDesktop	ICA, HDX
Microsoft	VDI Premium Suite	RDP7
Red Hat	Desktop Virtualization	SPICE
Quest Software	Vworkspace	EOP, RDP, EOP Xstream
Sun	Sun Ray	Appliance Link Protocol (ALP)

As previously noted, application streaming creates some significant WAN performance problems that require the deployment of a WOC. For example, the code for streamed applications is typically transferred via a distributed file system protocol, such as CIFS, which is well known to be a chatty protocol. Hence, in order effectively support application streaming, IT organizations need to be able to optimize the performance of protocols such as CIFS, MAPI, HTTP, and TCP. In addition, IT organizations need to implement other techniques that reduce the bandwidth requirements of application streaming. For example, by using a WOC, it is possible to cache the virtual application code at the client's site. Caching greatly reduces the volume of traffic for client-side virtualized applications and it also allows applications to be run locally in the event of network outages. Staging is a technique that is similar to caching but is based on pre-positioning and storing streamed applications at the branch office on the WOC or on a branch server. With staging, the application is already locally available at the branch when users arrive for work and begin to access their virtualized applications.

Whether it is done by the WOC itself, or in conjunction with the WOC, supporting application virtualization will require that IT organizations are able to apply the right mix of optimization technologies for each situation. For example, pre-staging and storing large virtual desktop images on the WOC at the branch office must be done in an orchestrated fashion with the corresponding resources in the data center. Another example of the importance of orchestration is the growing requirement to automatically apply the right mix of optimization technologies. For example, as noted protocols such as ICA and RDP already incorporate a number of compression techniques. As a result, any compression performed by a WAN optimization appliance must adaptively orchestrate with the hosted virtualization infrastructure to prevent compressing the traffic twice - a condition that can actually increase the size of the compressed payload.

Virtual Appliances

A *Virtual Appliance* is based on network appliance software, together with its operating system, running in a VM on top of the hypervisor in a virtualized server. Virtual appliances can include WOCs, ADCs, firewalls, and performance monitoring solutions among others[14]. An important set of synergies exist between virtual servers, virtual appliances such as a WOC or a performance monitoring solution and virtual desktops. Throughout the rest of this report, those synergies will be referred to as the Virtuous Synergies of Virtualization (VSV). The key components of the VSV are depicted in **Table 8**.

A cornerstone of the VSV is that virtual appliances are of particular interest to IT organizations in those instances in which server virtualization technology has already been disseminated to branch offices and has also been implemented in the data center. When server virtualization pervades the enterprise, a wide variety of networking functions can be deployed wherever needed easily and cost effectively with virtual appliances, without the installation of additional hardware.

In the branch office, a suitably placed virtualized server could potentially host a virtual WOC appliance as well as other virtual appliances. Alternatively, a router or a WOC that supports VMs could also serve as the infrastructure foundation of the branch office. Virtual appliances can therefore support branch office server consolidation strategies by enabling a single device (i.e., server, router, WOC) to perform multiple functions typically performed by multiple physical devices. These physical devices include a WOC, router, firewall, IDS/IPS, DHCP/DNS server, client-side application virtualization staging server, local application server, etc.

[14] The argument could be made that a virtual router is a virtual appliance. Virtual routers will be discussed in *Cloud Networking.*

One of the compelling advantages of a virtualized appliance is that the acquisition cost of a software-based appliance can be notably less than the cost of a hardware-based appliance with same functionality[15]. In many cases the cost of a software-based appliance can be a third less than the cost of a hardware-based appliance. In addition, a software-based client can potentially leverage the functionality provided by the hypervisor management system to provide a highly available system without having to pay for a second appliance[16]. As a result of these cost savings, IT organizations will be able to afford to deploy virtualized appliances more broadly than they would be able to deploy hardware-based appliances.

As discussed in the preceding section of this report, WOCs that implement the appropriate techniques can make virtual desktops a viable solution for provisioning and managing branch office desktop environments. While these advantages occur whether the WOC is hardware based or software based, the fact that a virtual WOC is so much more cost effective than a hardware based WOC means that they are more likely to be deployed. Because virtual WOCs can be deployed broadly in a cost effective manner, IT organizations are more likely to be successful with desktop virtualization.

Another advantage of a virtual appliance is that it offers the potential to alleviate some of the management burdens in branch offices because most of the provisioning, software updates, configuration, and other management tasks can be automated and centralized at the data center. In addition, as previously mentioned, in many instances the benefits of the dynamic movement of a VM from one server to another are maximized if the supporting infrastructure can also be dynamically moved. If virtualized appliances have been deployed, then it is notably easier than it is in a more traditional environment for various networking functions (WOC, ADC, firewall, etc.) to be migrated along with VMs in order to replicate the VMs's networking environment in its new location.

WOC and ADC virtualization can also be leveraged to provide "acceleration as a service" to facilitate and improve performance in deployments of service-oriented environments, including SOA and SaaS. In the case of SOA, Virtual WOC and ADC images can be easily deployed to be co-resident on the virtual servers that host the various components of a geographically-distributed SOA application. In the SaaS space, virtual WOCs and ADCs can be provided as a standalone managed software service or bundled with other managed software services to increase their performance as needed. One of the features that enables the overall system to dynamically increase performance of a SaaS solution is the ability to automatically add additional virtualized ADCs (a.k.a., autoscaling) as demand increases.

[15] The actual price difference between a hardware-based appliance and a software-based appliance will differ by vendor.

[16] This statement makes a number of assumptions, including the assumption that the vendor does not charge for the backup software-based appliance.

A virtualized ADC makes it easy for an IT organization to package and deploy a complete application. One example of this packaging is the situation in which an entire application resides on VMs inside a physical server. The virtualized ADC that supports the application resides in the same physical server and it has been tuned for the particular application. This makes it easy to replicate or migrate that application as needed. In this case, a virtualized ADC also provides some organizational flexibility. For example, the ADC might be under the control of a central IT group or it might be under the control of the group that supports that particular application. The later is a possibility because any actions taken by the application group relative to the ADC will only impact their application.

The recent formation of the Virtual Computing Environment (VCE) has placed more emphasis on the concept of pre-packaging data center solutions. The VCE is a coalition that is comprised of Cisco, EMC, and VMware and it has the stated mission of minimizing the risk for enterprises who are deploying pervasive virtualization en route to private cloud implementations. One of the key concepts that underlies the VCE is the concept of Vblock solutions. Vblock solutions are computing systems that are pre-integrated and pre-configured. A Vblock combines virtualization, networking, storage, security, and management.

As noted in the preceding section, one approach to monitoring and troubleshooting inter-VM traffic is to deploy a virtual performance management appliance or probe (vProbe). One of the characteristics of a virtualized server is that each virtual machine only has at its disposal a fraction of the resources (i.e., CPU, memory, storage) of the physical server on which it resides. As a result, in order to be effective, a vProbe must not consume significant resources. The way that a vProbe works is similar to how many IT organizations monitor a physical switch. In particular, the vSwitch has one of its ports provisioned to be in promiscuous mode and hence forwards all inter-VM traffic to the vProbe. As a result, the use of a vProbe gives the IT organization the necessary visibility into the inter-VM traffic.

As noted in the preceding section, a virtual firewall appliance can help IT organizations meet some of the challenges associated with server virtualization. That follows because virtual firewall appliances can be leveraged to provide isolation between VMs on separate physical servers as well as between VMs running on the same physical server. Ideally, the firewall virtual appliance would use the same software as the physical firewalls already in use in the data center. The security appliance can potentially provide highly integrated functionality to help secure virtual machines, applications, and traffic. This includes firewall, VPN, anti-malware, IDS/IPS, integrity monitoring (e.g., registry changes), and log inspection functionality.

Virtualized security management makes it is possible to meet critical regulatory compliance requirements for full application segregation and protection within the confines of virtualized physical servers. Through tight integration with the virtual server management system, firewall appliances can also be dynamically migrated in conjunction with VM migration where this is necessary to extend a trust zone to a new physical location. In addition, hypervisor APIs, such as VMware's Vsafe, can allow physical/virtual firewall consoles to monitor servers for abnormal CPU, memory, or disk activity without the installation of special agent software. With some virtual switches, such as the Cisco Nexus 1000v, it is possible to establish private VLANs (PVLANs). PVLANs are useful in restricting traffic in flexible ways. For example, DMZ VMs on a PVLAN in "Isolated mode" are able to communicate only with hosts on the non-local network.

A potential issue to keep in mind is that each virtual appliance is running in a VM, so all of the challenges of managing a virtual server environment described earlier are also applicable to virtual appliances. In particular, visibility of VM-to-VM traffic would be more critical in order to troubleshoot a virtual server environment where traffic traverses several virtual appliances on its way to a destination VM located in the same physical server. In this instance, the deployment of one form of virtual appliance, a vProbe, eliminates some of the challenges associated with implementing other forms of virtual appliances; i.e., WOCs, ADCs and firewalls.

Table 8: The Virtuous Synergies of Virtualization
The fact that IT organizations have already deployed server virtualization means that it is easier and less costly to implement virtualized appliances.
Because it is easier and less expensive to deploy a software-based appliance than it is to deploy a hardware-based appliance, they are more likely to be broadly deployed.
Because software-based WOCs can be broadly deployed, they can enable the deployment of virtual desktops.
Because vProbes can be broadly deployed, they enable IT organizations to manage the performance of applications that run on virtualized servers.
Because virtual firewalls can be broadly deployed, they enable IT organizations to meet regulatory and compliance requirements for applications that run on virtualized servers.
As part of moving a VM, virtual appliances can be easily migrated along with the VM in order to replicate the VMs's networking environment in its new location.
Because vProbes can be broadly deployed, they eliminate some of the challenges associated with other forms of virtual appliances; i.e., WOCs, ADCs and firewalls.

One of the potential downsides of a virtual appliance is performance. The conventional wisdom in our industry is that a solution based on dedicated, purpose-built hardware performs better than a solution in which software is ported to a generic piece of hardware, particularly if that hardware is supporting multiple applications.

However, conventional wisdom is often wrong. Some of the factors that enable a virtualized appliance to provide high performance include:

- Moore's law that states that the price performance of off the shelf computing devices doubles every 18 months.
- The deployment of multiple core processors to further increase the performance of off the shelf computing devices.
- The optimization of the software on which the virtual appliance is based.

Because of the factors listed above and because of the advantages that they provide, IT organizations should evaluate the performance of a virtual appliance to determine if a virtual appliance is an appropriate solution.

Another critical factor when evaluating the deployment of virtual appliances in a dynamic, on-demand fashion is the degree of integration of the virtual appliance with the virtual server management system. Ideally this management system would recognize the virtual appliances as another type of VM and understand associations between appliance VM and application VMs to allow a coordinated migration whenever this is desirable. In addition to VM migration, integration with the virtual server management system should support other management features, such as:

- Provisioning of Virtual Appliances

  Software images can be deployed and provisioned from a central location to virtual servers anywhere within the organization's infrastructure.

- Resource Scheduling and Load Balancing

  The system manager can increase the resources available to virtual appliances to meet periodic surges in application traffic. Resource changes can be made manually, scheduled, or automatically triggered by changes in performance levels. Dynamic allocation of resources facilitates higher degrees of virtual server and virtual appliance consolidation in both the data center and the remote branch office.

- Virtual Machine File System

  Support for the VM file system allows virtual appliance images to reside on any networked or directly attached storage device supported by the virtual server infrastructure; e.g., SCSI, iSCSI, Fibre Channel SAN, SATA, etc.

- High Availability

  High availability virtual server features can be leveraged to maximize the availability of virtual appliances. High availability features can automatically restart a stalled virtual appliance on the same server or move the virtual appliance to a backup server (with appropriate network connectivity) via Live Migration.

- Business Continuance/Disaster Recovery

  Virtual server environments can support a variety of Business Continuance and Disaster Recovery tools. Integration with the virtual server management systems allows virtual appliances to benefit from these tools in the same way as applications that run in VMs benefit.

Conclusions

As shown in this report, there are significant advantages to server virtualization, desktop virtualization and appliance virtualization. As was also shown, there are also some Virtuous Synergies of Virtualization.

Of the three forms of virtualization described in this report server virtualization presents the greatest benefits. It also presents the broadest set of challenges, including the:

- Contentious Management of the vSwitch
- Breakdown of Network Design and Management Tools
- Multiple Hypervisors
- Limited VM-to-VM Traffic Visibility
- Inconsistent Network Policy Enforcement
- Complex Troubleshooting on a per-VM Basis
- Manual Network Reconfiguration to Support VM Migration
- Over-subscription of Server Resources
- Layer 2 Network Support for VM Migration
- Storage Support for Virtual Servers and VM Migration

At the present time, there is no overarching solution for the comprehensive management of a computing environment composed of virtualized servers, storage, and networks. Some the key developments that can help IT departments meet the challenges of virtualization include:

- Dynamic Infrastructure Management
- Virtualized Performance and Fault Management

- Distributed Virtual Switching
- Edge Virtual Bridges
- Orchestration and Provisioning

Desktop virtualization centralizes the management of complete desktops or individual desktop applications. Centralization simplifies management operations and allows a single maintenance operation to span a large number of virtualized desktops. The two fundamental forms of desktop virtualization are:

- Server-side application/desktop virtualization
- Client-side application/desktop virtualization

From a networking perspective, the primary challenge in implementing desktop virtualization is achieving adequate performance and an acceptable user experience for client-to-server connections over a WAN. Protocols such as ICA and RDP can often provide adequate performance for traditional data applications, but they have limitations with supporting graphics-intensive applications, 3D applications, and applications that require audio-video synchronization. For this reason, myriad other protocols such as PCoIP and HDX have recently been deployed. In many cases, these protocols consume significant WAN bandwidth.

In most cases, the successful deployment of desktop virtualization will require the deployment of WAN optimization techniques that focus on the particular characteristics of the traffic that is associated with desktop virtualization. For example, protocols such as ICA can be difficult to optimize in part because these protocols only send small request-reply packets and in part because in order to compress ICA traffic, it is necessary to decrypt the workload, apply the optimization technique and then re-encrypt the traffic. In addition, protocols such as ICA and RDP already incorporate a number of compression techniques. As a result, any compression performed by a WAN optimization appliance must adaptively orchestrate with the hosted virtualization infrastructure to prevent compressing the traffic twice - a condition that can actually increase the size of the compressed payload.

An important set of synergies exist between virtual servers, virtual desktops and virtual appliances such as a WOC or a performance monitoring solution. Perhaps the most important synergy is that virtual appliances are of particular interest to IT organizations in those instances in which server virtualization technology has already been disseminated to branch offices and has also been implemented in the data center. Another synergy stems from the fact that software-based appliances cost notably less than hardware-based appliances. This means that virtual appliances can be deployed more broadly which enables the broad deployment of desktop virtualization. A third synergy is that if virtualized appliances have been deployed, then it is notably easier than it is in a more traditional environment for various networking functions to be migrated along with VMs in order to replicate the VMs's networking environment in its new location.

In the branch office, a suitably placed virtualized server could potentially host a virtual WOC appliance as well as other virtual appliances. Alternatively, a router or a WOC that supports VMs could also serve as the infrastructure foundation of the branch office. Virtual appliances can therefore support branch office server consolidation strategies by enabling a single device to perform multiple functions typically performed by multiple physical devices. A critical factor that must be considered when evaluating the deployment of virtual appliances in a dynamic, on-demand fashion is the degree of integration of the virtual appliance with the virtual server management system. Ideally this management system would recognize the virtual appliances as another type of VM and understand associations between appliance VM and application VMs in order to allow a coordinated migration whenever this is desirable.

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Division Cofounders:
Jim Metzler
jim@webtorials.com
Steven Taylor
taylor@webtorials.com

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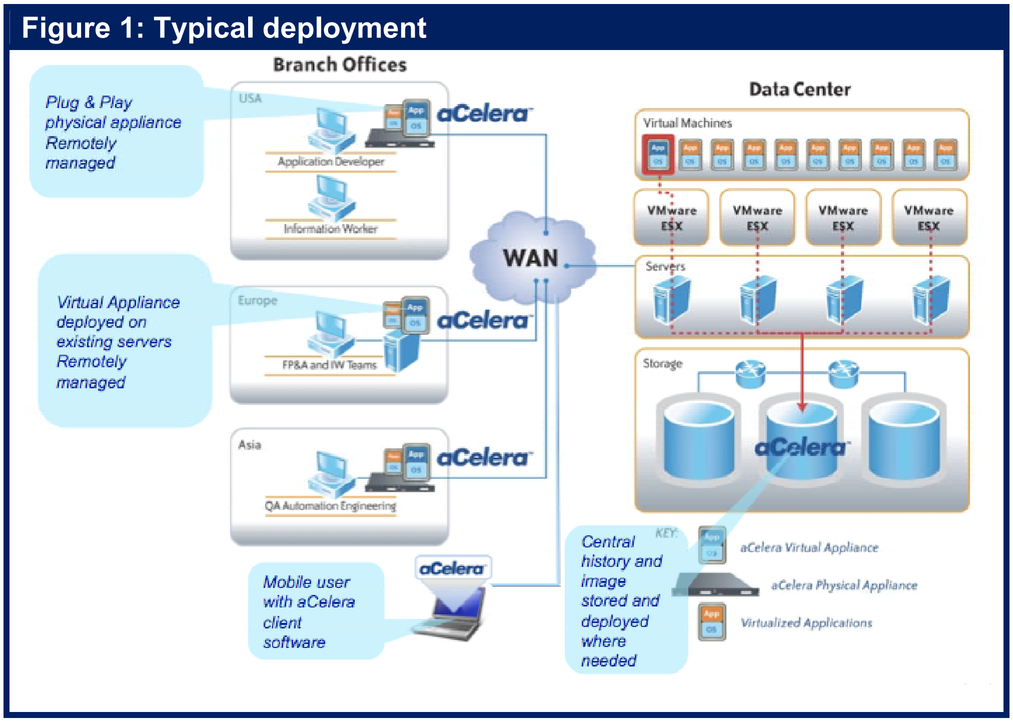
"Productivity isn't everything, but in the long run it is almost everything." Paul Krugman, New York Times columnist and professor of Economics and International Affairs at Princeton University

High performing key applications and services are core to running a productive company. IT executives need to deliver consistent high performance services across the enterprise whether it is meeting a storage environment recovery point objective or a customer relationship management system page load time. This commitment to productivity is critical to every company's ability to generate revenue and deliver services; however, achieving this goal is difficult due to a wide variety of technical and organizational challenges.

Technologies such as virtualization and cloud computing all provide compelling solutions to many of the challenges faced by IT management trying to increase productivity while lowering costs. Unfortunately, the ability to successfully deliver the real benefits of these 21st century technologies across the globe is often dependent on 20th century appliance technology for wide area network (WAN) optimization. Appliances do not support the dynamic nature of these solutions. Virtual appliances seamlessly integrate with these and emerging technologies that enable enterprises to deliver resources and services to all users without compromising on performance, scalability, or cost reduction.

Certeon is the leading supplier of 21st century WAN optimization software solutions. aCelera virtual appliances enable enterprises to improve application performance across the WAN by up to 95 percent while reducing WAN bandwidth consumption by 65 to 95 percent. These dramatic results enable companies to leverage their virtualized infrastructures, networks, and application environments to create new revenue and service opportunities. aCelera leverages enterprises' growing virtual infrastructures, in both data centers and branches, allowing IT management to realize clear TCO benefits from saved acquisition, operations, real estate, power, cooling and maintenance/support costs in ways not possible with hardware-based WAN optimization solutions.

Figure 1: Typical deployment


Branch Offices
Plug & Play physical appliance Remotely managed
USA
aCelera
Application Developer
Information Worker
Virtual Appliance deployed on existing servers Remotely managed
Europe
aCelera
FP&A and IW Teams
Asia
aCelera
QA Automation Engineering
Mobile user with aCelera client software
aCelera
WAN
Data Center
Virtual Machines
App
OS
VMware ESX
VMware ESX
VMware ESX
VMware ESX
Servers
Storage
aCelera
Central history and image stored and deployed where needed
KEY:
aCelera Virtual Appliance
aCelera Physical Appliance
Virtualized Applications

aCelera Virtual Appliances vs. Network Farm Appliances

aCelera is software running on any major hypervisor that can be provisioned and scaled using the system resources of the virtual machine (VM) environment. Hardware WAN optimization and application acceleration solutions typically host some virtualization capabilities by providing a limited virtualization session on top of the appliance's standard operating system. These appliances do not support hypervisors because the appliance design requires complete control of the system resources (CPU, memory, storage) and allocates limited capabilities for other applications**.**

aCelera WAN optimization virtual appliance software delivers:

- **Acceleration:** All WAN traffic is optimized without single purpose hardware
- **Ease of Maintenance:** VMware® VMotion and Microsoft® Quick Motion capable - a running image of aCelera can be moved from one virtual machine to another over the network without disrupting operations or traffic flow
- **High Availability:** In the event of a hard failure, virtualization management software can automatically spin up an aCelera instance on designated backup server ensuring reliable performance in the event of a failure
- **Central Management:** The aCelera instance can be deployed and provisioned via the aCelera CMS and monitored by VMware VirtualCenter or Microsoft SCVMM from central data centers to any aCelera across the enterprise
- **Dynamic Resource Scheduling (DRS):** DRS provides the ability to scale or manage Disk, CPU and memory resource allocation across virtual machines
- **True Branch in a Box Capability:** aCelera virtual appliances can share server resources with ANY other VM applications on industry standard hardware
- **Multi-purpose:** The aCelera virtual appliance can be deployed as many times and anywhere that makes sense for your application environment’s topology and load: (**Figure 1**)
  - Application Acceleration
  - File Delivery Optimization
  - Backup and Replication
  - Client Support

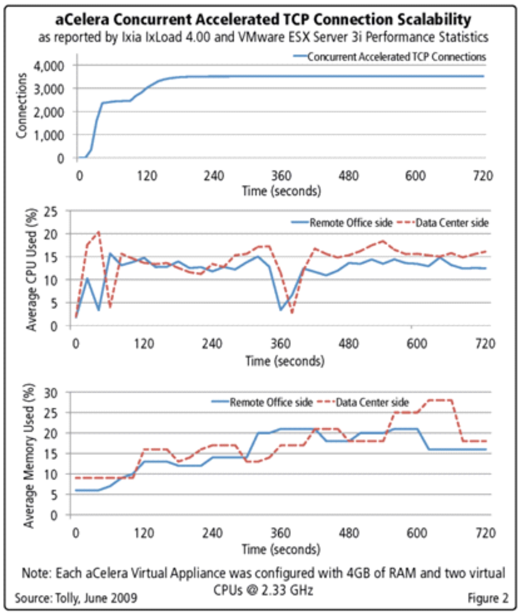
Bottom line: Hardware appliances cannot take advantage of the scalability, flexibility and manageability benefits of virtualization. aCelera virtual appliance software leverages all of these capabilities.

Virtualization of Enterprise Network Features

Conditioned to buying their way out of transport challenges by adding capacity with next generation hardware or additional network bandwidth, enterprises are finding more challenges when dealing with today’s virtualized server and storage environments. Many enterprises are thinking of moving internal IT to a private cloud service model in order to achieve the level of agility they need to respond to the changing business environment. Most have already taken the first step by applying virtualization to production IT; however, virtualization of WAN optimization and other network services is also required since an efficient and cost-effective network is key to delivering on the dynamic needs of the enterprise.

Deploying network technologies conventionally - piling proprietary boxes on top of each other in a farm - is no longer the way to go. A networking appliance farm including WAN optimization, just like a server farm, drives up capital costs, operational expense and energy consumption. Virtualization technologies have successfully reduced server and storage farm sizes and complexity. Now is the time to use virtualization to downsize the network and optimization appliance farm. The currently accepted way of delivering network services is unacceptable. Hardware appliances are inflexible, inefficient and unable to change fast enough to meet business demands. Virtualized WAN optimization appliances make an entire network more scalable and more reliable.

Figure 2: Tolly #209129/CPU and Memory used by aCelera



Note: Each aCelera Virtual Appliance was configured with 4GB of RAM and two virtual CPUs @ 2.33 GHz

Source: Tolly, June 2009

With the increasing popularity of virtualization in the enterprise, Certeon's aCelera Virtual Appliance software delivers a software application acceleration platform that can reduce hardware footprint

aCelera: Scalable Performance and Lower TCO

aCelera software is delivered as a virtual appliance supported on industry-standard servers running hypervisors such as VMware ESX and Microsoft® Hyper-V and as software installed on industry standard laptop systems. aCelera software packages are delivered over a network and installed by Certeon CMS in data centers, at remote sites, or on end user PCs in less than 30 minutes. aCelera creates a virtual WAN Infrastructure or "WAN-in-a-box" and delivers a responsive, global and scalable WAN that can scale to meet your application and user performance needs.

Every network has two ingredients: nodes and connections. In the global networks that enterprises are now assembling, the number of the nodes is collapsing, due to virtualization, while the quantity of connections and the demands placed on these connections is exploding, mainly due to virtualization, the advent of managed services and cloud computing. aCelera provides exceptional performance by leveraging every ounce of resource available in the virtualized environment.

aCelera software exceeds the scalability and performance requirements of today's enterprises and reduces WAN optimization TCO by 60 percent when compared to hardware WAN optimization deployed in an appliance farm.

Pound for pound aCelera supports 50 percent more concurrent accelerated connections than hardware WAN optimization appliances. aCelera is designed to leverage enterprise virtualization scalability and is ready for the usage demands of managed services and cloud computing (**Figure 2**).

Replacing the Network Farm with Dynamic Virtualized WAN Optimization

aCelera enables IT managers to operate applications, desktop, and server infrastructures where they will be most effective: in branch offices, centralized data centers or even in on-premise or off-premise cloud infrastructures.

The use of hardware-based WAN optimization technology in heavily virtualized enterprise environments will not provide the required application performance or meet IT managements' need for flexibility. Proprietary WAN optimization appliances with hosted virtualization do not stand up to anyone's definition of a virtualized or cloud service. Hardware centric approaches to delivering virtualized network resources like WAN optimization creates castaway technology - islands of virtualization capabilities surrounded in a sea of proprietary technology.

aCelera virtual appliances deliver performance benefits and advantages without the downsides of additional hardware costs and management. aCelera virtual appliances leverage the virtual infrastructure and can easily be scaled on existing platforms or migrated to more powerful platforms and processors when business conditions dictate.

Certeon's aCelera software embodies all of the performance advantages of WAN optimization with the flexibility, scalability, manageability and cost-savings of virtualization. aCelera can be deployed in virtualized private, public, and hybrid cloud computing environments and is poised to meet the evolving needs of the dynamic enterprise.

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