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Chapter 1: Deciding on Virtualization

The potential value that can be derived from virtualization is significant but the key to maximizing that value is to understand what the expectations and business drivers are. Each client planning virtualization adopts one or more goals based upon product claims, press coverage, and industry peer input. For example, one common goal of virtualization is “to improve the way in which IT manages its resources”. This improvement may take the form of increased peak capacity, improved resilience, reduced configuration costs, or reduced systems management errors. One or more of these subordinate goals is often attainable. Perceived virtualization savings may also take the form of reducing the amount of hardware that IT purchases or manages.

Although there may be some debate as to where to start and how to maximize your return, there is little doubt that virtualization has value, is here to stay and will have a significant impact on how IT infrastructure is managed. Following is a selection of articles posted by several leading industry analysts and trade magazines regarding their opinions on the current state of virtualization and its future:

- http://www.gartner.com/it/page.jsp?id=1211813
- http://www.gartner.com/it/page.jsp?id=638207
- http://www.idc.com/research/viewtoc.jsp?containerId=219011

This document describes how to take advantage of virtualization by identifying a number of scenarios where virtualization can provide value, as well as best practices related to specific goals.

In this first chapter we begin by defining what we mean by the term “virtualization,” why virtualization is important and what factors need to be considered when deciding whether and how you should use virtualization.

Note: This document is a work in progress. Updates will be provided as they become available. If you have any comments or feedback on this document please forward them to ImpCDFeedback@ca.com.
What Do We Mean by “Virtualization”? 

Virtualization is a broad term that can mean different things depending on who is using/interpreting it. When this article was first authored Wikipedia (http://en.wikipedia.org/wiki/Virtualization) defined “virtualization” as the following:

"a technique for hiding the physical characteristics of computing resources from the way in which other systems, applications, or end users interact with those resources. This includes making a single physical resource (such as a server, an operating system, an application, or storage device) appear to function as multiple logical resources; or it can include making multiple physical resources (such as storage devices or servers) appear as a single logical resource."

Or, to put it more succinctly, virtualization hides the detailed physical characteristics of the computing platform from the users, showing instead another abstract, emulated computing platform.

Virtualization can take many forms. For example, a single physical resource may provide multiple virtual resources, or conversely, multiple physical resources may be represented as a single virtual resource. A combination of these approaches may also be used. Consider the following examples:

- **Platform Virtualization**
  
  In this form of virtualization a single server hosts one or more "virtual guest machines". This is also often referred to as “Server Virtualization” and may be further broken down into a large number of additional classifications including “Hardware Virtualization,” “Paravirtualization,” and “Operating system Virtualization.”

- **Resource Virtualization**

  The virtualization concept as a whole also includes virtualization of specific system resources, such as storage and network resources. This can be done within a single host server or across multiple servers (using a SAN, for example). Modern blade enclosures/servers often combine platform and resource virtualization, sharing storage, network, and other infrastructure across physical servers.

- **Desktop Virtualization**

  Virtual Desktop Infrastructure (VDI) is used to provide the end users with a computer desktop that is identical or similar to their traditional desktop computer while keeping the actual computing power in the datacenter.

  When this approach is used, the end user requires only a thin client on his desktop. Updates and/or configuration changes to the application and/or hardware are performed in the centrally located datacenter, providing greater flexibility when it comes to supplying computing power on demand to the end user.
### Application Virtualization

Application virtualization is a technology that is designed to improve portability, manageability and compatibility of individual applications. This is done by encapsulating the application so that it no longer communicates directly with the underlying operating system.

Application virtualization utilizes a virtualization layer to intercept calls from the virtualized application and translate them to call the resources needed to provide the underlying operating system.

### Computer Clusters \ Grid Computing

This type of virtualization connects multiple physical computers together as a single logical entity in order to provide better performance and/or availability. In these environments the user connects to the “virtual cluster” instead of one of the actual physical machines.

The use of grid computing or clustering of computers is typically driven by the need to support high availability, Load balancing or a need for extreme computing power.

This document focuses primarily on Platform Virtualization with some basic coverage of the other areas. Therefore, unless otherwise specified, the topic should be assumed to refer to Platform Virtualization.

### Why Use Virtualization

There are both advantages and disadvantages to using virtualization. Before you implement it in your environment, it is critical that you understand what virtualization can offer in conjunction with your required level of skills/commitment. It is up to you to reconcile these factors with your expectations of how virtualization can be used in your environment. Above all you should be aware that:

*applications aren’t suddenly going to require less resources just because they are virtualized*

On the contrary, virtualization *adds* overhead. A virtualized application will use more resources than before and it will not run faster unless it is hosted on faster hardware than it was run on originally. For this reason, attempting to virtualize using your existing hardware is typically a “bad” idea.

The actual amount of additional overhead depends on a number of factors, including the type of application being virtualized, the type of virtualization engine being used, the type of hardware that is available, and how it will be configured/used. According to lab tests reported in the April 2007 issue of *Network Computing* the overhead for an ESX server is typically less than 10% but ranges from 6% to 20 % (your results may vary and each user should monitor their own overhead). To view this article in its entirety, go to the following link:
It is important to make sure you have enough storage space, memory, CPU, network bandwidth and other resources to handle the applications plus the virtualization overhead. If the applications are business critical, you should plan for worst case scenarios; however avoid dedicating more resources than necessary since this will negatively impact other virtual machines on this host.

It is also important to realize that the correct answer to the question of why virtualization should be used will depend on the maturity of both your organization and the tools that are available. Virtualization maturity can be divided into the following stages:

- **Virtualization 0.0 – “Virtualization not in use”**
  As the starting point of the virtualization “ladder” this level describes an organization which has not yet implemented virtualization.

- **Virtualization 1.0 – “Islands of centrally unmanaged virtualization”**
  Unlike level 0.0, organizations at level 1.0 are employing virtualization, however, it is often implemented by individuals or individual groups within the organization without a centralized management or centralized resources to support the infrastructure. The reasons for using virtualization at this point are often reactive – to fight fires – and ad hoc - to create virtual machines for testing and development - and in order to address specific issues for non- business critical systems. The lack of central management and change control at this maturity level can potentially lead to serious security issues.

- **Virtualization 2.0 – “Consolidation and Managing Expenses”**
  The primary driver for Virtualization 2.0 is to consolidate servers and increase the utilization of available resources. When done correctly, consolidating small or underutilized servers into larger servers, this can be very efficient and it can save a significant amount of money.

  However, the key to saving costs is identifying the right servers for virtualization. While there might be valid reasons to virtualize larger servers as well, you should not expect to save money on hardware in doing so.

- **Virtualization 3.0 – “Agility / Flexibility”**
  The driver for the next step on the virtualization maturity ladder is the need for enhanced flexibility, enabling you to add/remove resources on demand and even move workload between physical hosts. This ability can be used to balance workload or to support an HA solution that allows virtual machines to be restarted on a different physical server after a server failure.
Why Use Virtualization

- **Virtualization 4.0 - “Continuous Adaptivity”**

  The driver behind this next natural step is the desire to fully automate all of this in order to enable software solutions, often with hardware support, to predictably and dynamically balance the load between servers, rebalance resources between virtual machines, start up and shut down virtual servers based on need, control power saving features in both the virtual machines and the host system itself, etc. This automation should be service-aware and look at factors such as measured and expected workload, tariffs for energy, importance and urgency of requested resources, and demand from other services, and use all available information to best use the available resources.

  The major hardware vendors are working on releasing new solutions to better support these maturity levels and tools that support Virtualization 4.0 are just starting to reach the market. As more and more attention is given to Virtualization 4.0, we can expect that the technologies and tools to support it will become more mature and more complete over the next few years. A few examples of tools that support Virtualization 4.0 initiatives are VMware Virtual Center, Microsoft System Center Virtual Machine Manager, and Citrix Essentials as well as 3rd party tools, such as CA Technologies suite of products, which includes CA Spectrum Automation Manager, CA Virtual Assurance for Infrastructure Managers/CA Virtual System Performance for Infrastructure Managers, CA Virtual Assurance, CA Virtual Automation and CA Virtual Configuration.

**Areas Where Virtualization Provides Quick Value**

Following is an overview of scenarios where virtualization can provide quick value:

1. Organization needs to maintain a library of servers with different configurations, such as:
   - Software Development (Test scenarios)
   - Quality Assurance
   - Software support, where it’s important to be able to quickly and easily reproduce a relatively large number of environments.
   - Demo centers / demo scenarios

   This is a common starting point for many companies since it is easy to realize significant value and the risks are typically minimal.

   Value is quickly seen in reduced time to provision servers as well as in reduction of errors.
2. Organizations with multiple, mature, horizontally scalable applications that occasionally need to address peak load by adding temporary worker nodes.

In these cases virtualization supports a very efficient usage of existing hardware by enabling a number of applications to share the resources of a few host servers. Planning, however, is critical since you need to calculate for support of a worst case scenario – such as what happens if all - or many - of the applications are peaking and requiring access to the shared resources at the same time.

3. Consolidating selected business applications deployed to:
   - Lightly used servers. This typically includes:
     - Service Providers (xSP) that have multiple small clients.
     - Multiple mid-tier managers originally implemented on separate servers for political, organizational or legal reasons.
   
   In many cases isolation provided by virtualization is sufficient, especially if the data is separated onto private disk systems; however, it is critical to verify that virtualization satisfies the organization’s isolation/separation requirements.
   
   - Servers with predictable resource consumption profiles. This will allow you to plan the distribution of work for virtualized servers. In these cases, keep in mind that:
     - Special care is required for applications that require lots of I/O.
     - Applications that require different sets of resources at the same time can coexist on the same physical server.
     - Applications that require the same resources at different times can also coexist on the same physical server.

   In each of these cases value is realized through a reduction in the number of servers resulting in both hardware maintenance and management cost savings. Additional details on attaining rapid ROI through virtualization are provided later in this document.

   In most cases, unless your project falls into one of these categories you may find that it is hard to save money through virtualization alone. While there may be other good reasons to consider virtualization it is critical that you understand what you expect to accomplish with it.
When to Avoid Virtualization

Regardless of whether it is possible to virtualize servers and applications in your environment, there are certain situations in which the potential risks far outweigh any advantages that might be gained.

Applications that require direct access to specialized hardware or that make frequent and unpredictable demands on a large part of the system’s available resources are not ideal candidates for virtualization. A couple of examples are:

- Applications that require USB keys or other hardware components for licensing.
- Applications using specialized hardware, such as advanced video capturing equipment, tape drives, and fax/modems.
- Applications that, even on modern hardware, consistently have a high utilization of resources such as CPU, disk, network and/or memory.
- Large database servers. Virtualization of large database servers is rarely beneficial. Database server utilization is better improved by employing multiple database instances.
- Application or Desktop Virtualization type servers, such as Citrix, and other types of servers that already include their own techniques for virtualization.

Additional examples of more common disadvantages are listed later in this guide. In these situations, projects should be analyzed, on a case by case basis, to carefully calculate the risks connected to the application / system.

Common Advantages

Following are some of the more common advantages to virtualization. The relative importance of each will depend on your exact environment and specific requirements.

Facilities Management

- Saving Datacenter Space

A common problem with datacenters is that the ever increasing number of managed applications requires more and more servers which, in turn, require more and more floor space. Virtualizing a significant number of these applications may save you from having to move into a new larger datacenter, and, in fact might enable you to use a smaller datacenter or to allocate some of the existing space for other functions.
Why Use Virtualization

- **Hardware Cost Savings**
  Server virtualization typically requires larger and more expensive servers, however, when done correctly, combining multiple, under-utilized servers into a single larger system can result in a significant cost savings (e.g., lower hardware purchase cost and lower hardware maintenance cost). Fewer servers require less supporting infrastructure in the form of floor space, air conditioning, racks, networks, wires, cables, power supplies and backup systems.

- **Reduced Energy Bills**
  Reducing the number of servers in the datacenter reduces the electricity bill. This cost savings can be significant when you account for the servers, the monitors and the air conditioning required to keep them cool.

  *InformationWeek* (December 18/25 2006) cites one example where an organization reduced costs by half - from $7000 to $3500 per month.

**Security / Business Continuity**

- **Easy to backup the complete image**
  Copying a complete virtual environment (image) to a backup location or to a staging area to allow controlled upgrades of the application/operating system is a trivial task when virtualization is used.

- **Simplifies the process of keeping systems patched**
  In many situations maintenance can be applied to a clone of the production system. After update and testing is completed, that clone can then be used to replace the original instance, resulting in minimal downtime. This approach also provides access to the original, un-patched, system in the event you need to roll back the patch. See the “Management” section on page 10 for additional details. Even if you cannot replace the image, this approach provides value because you can still perform a majority of the testing/verification on a clone of the production system.

- **Efficient component level Fault Tolerance**
  When correctly implemented, the host systems should be deployed on large servers where many/most of the components are fault tolerant.

  Ideally, all guest VMs should be configured to take advantage of the shared backup component in the event a hardware component fails. Furthermore, if the network is set up using teamed networks connecting to multiple network switches, this practice can guarantee connectivity even if one of the switches fails.
Why Use Virtualization

- **Disaster Recovery / Business Continuity**
  As previously noted, virtualized copies of the environment can easily be moved to off-site servers. Keep in mind, however, that many applications depend on fixed IP addresses and/or the availability of other resources (for example SANs). Therefore, it is critical that you identify these requirements beforehand, by conducting tests in an environment in which the complete original infrastructure is down (or simulated to be down). During these tests it is also important to verify that any other applications that rely on any of these services in the virtualized environment can find the new clones of those services.

- **Virtual appliance might enhance security**
  Since you have complete control over the required resources in a virtual appliance you can enhance security by removing any components that aren’t required for this specific application. When this is done correctly, it can greatly enhance security; however it might also complicate the process of patching the system.

- **Virtual Desktops provides enhanced control over security**
  Virtual Desktop Infrastructure can allow simplified and enhanced control over security by limiting a user’s access to specific resources and certain types of data. For example, by providing a trusted partner with a secured virtual desktop instance to access sensitive information you minimize the risk that data will leave the central server. In addition, a virtual desktop can be set up to provide secure remote access to your desktop environment.

**Resource Management**

- **Simplifies Chargeback systems**
  Decoupling services from physical servers simplifies chargeback systems by enabling you to delineate utility pricing based on a pay-per-use model. The utilization metrics required for the chargeback system are often the same as those required to manage load balancing between systems.

- **Optimized usage of existing hardware resources**
  In most datacenters there are a large number of servers that rarely take full advantage of the available resources. By managing your virtualized environment wisely, you can enable multiple logical servers to share resources in a way that allows access to more resources when needed but to share them with other applications when they are idle or close to idle.

  When planning your deployment, however, you should allow for a worst case scenario and identify which applications might need resources at the same time.
Why Use Virtualization

- **Faster deployment of new logical servers**
  With the necessary hardware resources available, virtualization technology can significantly simplify the task of deploying certain types of servers. For example, you can deploy an additional web server fairly quickly and add it to the load balancer rotation as additional resources are required. This often reduces the provisioning time for a new server from days (or maybe even weeks) to hours.

- **Moving logical servers between hardware**
  Virtualization enables you to manage server load more efficiently by allowing you to move complete virtual servers to new hardware whenever additional resources are needed.
  
  This is especially easy to do if you have the tools and infrastructure for "hot migration" - which allows you to move logical servers while they are still running (for example VMOTION or Live Migration together with a SAN infrastructure).
  
  **Note:** When planning for Hot Migration it is critical to understand that this typically isn’t supported between machines with different CPU architectures. Current technology often requires that the CPU have the same vendor, processor family and core stepping. Some hypervisor systems partially address this problem by allowing you to group host servers and set them up for a compatibility mode. This basically limits each host to only being able to take advantage of CPU functions that ALL hosts have access to.
  
  In addition, the source and target servers need to have access to the same external resources, such as SAN and network resources.

- **More flexible infrastructure**
  Since logical servers can move easily between hardware sources, a virtualized environment is one in which the hardware is completely decoupled from the operating systems and the software. The result is a very flexible infrastructure where the hardware can be used to support the services/applications that are most important at this moment. This abstraction allows you to reduce costs since hardware and software upgrades are no longer directly coupled to each other.

**Management**

- **More, smaller applications, logically separated from each other**
  Logically separating applications from each other through the use of virtual appliances can simplify support by reducing the likelihood of applications “colliding” with one another.
  
  Without virtualization you might be tempted to run multiple smaller applications within the same OS but this quickly leads to a large number of application combinations to certify and support.
Another advantage of using multiple smaller components is that, if the solution is correctly designed, this simplifies the ability to support additional load by “scaling out” - temporarily or permanently adding another component (virtual server) to handle more workload.

**Fewer servers**

Since virtualized environments typically have fewer physical servers they can be easier to manage, especially from a security point of view. However, in order to reap the full benefits of virtualization, it is critical to carefully manage and monitor the performance and health of the individual virtual machines, the host systems and the connected SAN systems.

You will also need to account for the many additional management issues related to virtualization (see “Management” on page 18).

**Hardware maintenance**

The ability to move logical servers between hardware can simplify hardware upgrades by enabling you to build a new server, verify its functionality and compatibility with a copy/clone of the live image - all without affecting the existing application. When testing is done, you move the live applications over to the new server.

In a similar way you can easily and quickly have another physical server take over the role of hosting the applications when the original server has a hardware problem.

**Software maintenance**

With the right planning, change control for software maintenance can also be significantly enhanced through judicious use of virtualization. Since the complete logical machine can be copied and handled as a set of files you can easily set up separate areas for:

- Development
- Test / Quality Assurance (QA)
- Available Images / Gold Images
- Archive
- Configuration
- Production

Using a structure like this you can easily upgrade and test a new version in the “Development” and ”QA” areas while still running the old version in “Production.” When the new version is approved and you have a copy in the gold master library you can schedule a small maintenance window and transfer over to the new, already updated and verified, image. This topic is discussed in greater detail in the “Identifying Change Control Methods” section on page 35.
Common Disadvantages

Following is a summary of the common disadvantages associated with virtualization. These should be carefully weighed against the advantages to determine if virtualization is right for your environment.

Facilities Management

- **Hardware Investments**
  A common reason for virtualization is to save money by limiting the required number of servers in your environment.
  
  While it is true that you will have fewer servers after a virtualization project is done, in order to support the added load on the remaining individual servers they will need to be larger, and typically more expensive, compared to what may have been previously employed. It is far from an absolute truth that you always will save money on hardware; however, it will always lead to a need for some significant initial investments.

- **Datacenter Infrastructure Investments**
  Unless you have a modern, well designed datacenter it is likely that these new high end servers will require you to update your existing infrastructure in order to provide the necessary cooling, network, and power requirements.
  
  To clarify, since you will have fewer servers in the data center, the total need for cooling and electricity will likely be less than before, however the datacenter will need to handle the hotspots that are commonly generated by the concentration of new high end servers occupying less physical floor space.

Security / Risks

- **Internal Resistance**
  A problem often encountered during a server consolidation project is that some parts of the organization might resist giving up control over their existing hardware or applications. It is very important to address this early to ensure cooperation from all application owners.

- **Management of "sleeping" Virtual Machines**
  In a virtualized environment it is common to have some virtual machines that are not always in active use. For example, these could be images that are ready for “on demand computing” or gold standards that are used to clone new servers.
  
  It is critical that you have an automated process in place to patch and configure these virtual servers before they are used in any open environment.
New, relatively unproven technology, tools and processes

Though "virtualization" is not a new concept in software, the changes introduced in its most recent form, as well as the impact and implications of those changes, need to be clearly understood (and, thoroughly tested). This includes the introduction of new:

- Abstraction layers

  Virtual Engines/hosts introduce a new abstraction layer that can potentially introduce new failures as well as security exposures. This is particularly true for engines which employ hypervisors since, by nature, hypervisors should be as lightweight and efficient as possible and, therefore, have limited error recovery and security implemented. This may, however, be mitigated by configuring the hypervisor or using a specific security-related virtual appliance or a plug-in to the hypervisor that manages the system.

  However, it is worth noting that this, so far, is an academic discussion; at this moment, none of the major hypervisors has had any severe vulnerability reported.

- Security Architecture

  Since applications have traditionally been tied to a specific piece of physical hardware and infrastructure it has been possible to design security around an environment in a fairly static way, making sure that the physical server and environment are secured. When dynamically allocated virtual servers are used it is necessary to track where the application is currently residing and this may require the use of dynamically configured security or, at minimum, the rule that the application only reside on secured host servers.

- Immature and/or incomplete tools

  Dynamic environments also require new or enhanced tools for managing and securing virtualization. This includes the ability to:

  - Ensure the complete environment is successfully patched. This applies to both guest and host systems.
  - Analyze and manage the host OS and the virtual network to find and address bad configurations and other vulnerabilities.
  - Solutions that can plug into the hypervisor’s APIs to manage and secure all hosts on the host servers.
  - Analyze and secure traffic between VMs on the same machine
  - Be aware of and secure environments with Virtual Desktop Infrastructure (VDI) and Mobile VMs
  - Whenever possible/applicable, be policy driven and able to work across the datacenter so that each guest system is managed in an identical way even if it is migrated to another host system.

  Additional details about recommended tools can be found in the "Identifying Requirements for Management Tools" section on page 33.
- **Reorganization / consolidation of servers and applications**
  Any major change to a server environment – reorganization, consolidation, modification – is disruptive and, by its very nature, a risk. However, if the change is managed in a controlled and well planned way, this risk can be managed as well and kept to a minimum.

- **Loss of logical servers**
  Unless the images are well managed (see “Identifying Change Control Methods” section on page 35) it is easy to mistakenly delete a complete logical server (or set of logical servers) in a virtualized environment.

- **Consolidated datacenters**
  While consolidating many servers into one big datacenter can provide a great advantage it also creates a huge single point of failure. Unless this datacenter is extremely secure, events, such as a natural disaster (fire, flooding, etc.), power failure or sabotage, can cause a major disruption to all (or at least a significant part of) your IT infrastructure.

  In addition when you combine multiple, smaller datacenters into a single datacenter, you need to ensure that the supporting infrastructure can handle the additional load under normal situations, as well as disaster recovery scenarios. This includes providing sufficient network infrastructure, power requirements, storage and backup requirements, cooling and floor space.

- **Real time or near real time requirements**
  Care needs to be taken with applications that require real time or near real time response since the system clock on some virtualized systems can temporarily lag as much as 5-10 seconds if virtual machines are under heavy load. This is typically not a big problem, but it might be an issue in a system that requires real time or near real time response.

  For more information see the following:
  - VMware whitepaper “Timekeeping in VMware Virtual machines”
    [http://www.vmware.com/resources/techresources/238](http://www.vmware.com/resources/techresources/238)
  - Timekeeping best practices for Windows
    [http://kb.vmware.com/kb/1318](http://kb.vmware.com/kb/1318)
  - Timekeeping best practices for Linux guests
    [http://kb.vmware.com/kb/1006427](http://kb.vmware.com/kb/1006427)
  - Virtual machine seems slow when running a particular program (Clock Issue)
    [http://kb.vmware.com/kb/892](http://kb.vmware.com/kb/892)
  - VMware KB 1006113 - “Time in Linux 2.6 guest operating system runs faster than real time due to lost tick overcompensation”
    [http://kb.vmware.com/kb/1006113](http://kb.vmware.com/kb/1006113)
  - VMware KB 2219 - “Linux guest clock runs slowly on ESX Server 3.0”
    [http://kb.vmware.com/kb/2219](http://kb.vmware.com/kb/2219)
Why Use Virtualization

  [http://kb.vmware.com/kb/1000072](http://kb.vmware.com/kb/1000072)

- Microsoft KB 918461
  “The system time runs too fast on a Linux-based virtual machine that is hosted in Virtual Server 2005 R2”

Although these papers mostly focus VMware hosts, similar problems exist for other solutions as well.

Performance

- **Overhead on resource consumption**

  All virtualization technologies impose a performance penalty. If there are multiple virtualized machines (VMs) running at the same time, the amount of resource consumption - including the overhead – increases cumulatively and, often, non-linearly, due to contention for resources that are simultaneously being used by multiple VMs.

  The level of overhead depends on a large number of factors, however the typical increase for a hypervisor based system is around 10%. In the December 18/25, 2006 issue, *InformationWeek* estimates this could be as high as 15%, and a test reported in the April 2, 2007 issue of *Network Computing* estimates a 10% overhead (low of 6% and highs of 20%). Engines without hypervisor technology or other hardware assists have significantly higher overhead. Higher end blade solutions or high end hardware-based solutions (including LPAR or Containers) have relatively low overhead.

  The penalty might be especially large in situations where:

  - Multiple applications require heavy disk-access.
    - When multiple applications on the same host try to use any limited resource (typically, I/O), this will significantly affect performance. In disk I/O situations, this can often be handled by off-loading each application’s data storage to a dedicated storage subsystem or by using a high end dedicated storage solution (including fibre channel, FCoE or iSCSI based SAN systems).

  - Applications are performing many small transactions
    - Performing many small transactions (or combinations of large and small transactions) such as disk I/O, or network traffic, creates a significantly higher overhead than performing a few large transactions.
- **Resource Allocation**

One advantage of virtualization is better utilization of existing resources. This is because, when correctly planned and managed, the virtualization engine can handle a certain degree of over-utilization, thereby allowing applications to use resources that currently aren’t in use by other applications. However, when mismanaged, this is also one of its biggest disadvantages since, under heavy load, the response time from virtual machines becomes unpredictable.

Another way in which virtualization can help you use your existing resources more efficiently is by enabling component level fault tolerance that is implemented for the host server (such as redundant power supplies, teamed NICs, etc.) to be used by all or multiple guest systems.

- **Bottlenecks/Queuing Delays**

Poorly managed resource allocation can lead to bottlenecks. Although bottlenecks are not a new problem, they escalate more quickly in a virtualized environment since you may have multiple logical servers potentially hitting the same resources.

There are few rules regarding what resources will be strained by which application. Bottlenecks depend, to a large degree, on what resources are available and how the application is used in a specific environment. However, typical examples include:

  - **CPU constraints**: A common technique for managing application CPU constraints in a non-virtualized environment is to allocate additional CPUs to the application. In a virtualized environment, however, this is not necessarily a good idea since the virtualization host typically waits until it has *all* allocated CPUs available before it can assign *any* resources to the virtual machine. In other words, in a virtualized environment it may be better to assign fewer fast CPUs to each virtual machine than to over-allocate CPUs. Of course, if you virtualize an application that is designed for multiple CPUs you should specify that number of vCPUs for the virtual machine and ensure you have that many physical CPUs available to the virtualization host. For example, if you run an application and its dedicated database on one virtual system it often adds value to define two CPUs to permit both to be active. If you simultaneously run several virtual guests, each defined with multiple CPUs, then you should have, at least, the sum of defined CPUs free on the virtualization host to avoid a serious performance impact.

  **Note:** This strict co-scheduling algorithm has been improved somewhat in later versions of VMware; however, it is still recommended that you use as few vCPUs as possible. For additional details refer to “Virtual Machines with Multiple vCPUs (SMP)” on page 55.
- **Disk I/O constraints**: DBAs know that databases often perform a large number of small read/write transactions to disk. This can seriously affect performance unless you separate various functions onto different physical disks/stripe sets. For the very same reason, basic storage tuning is very important in a virtualized environment. In fact, because disk intensive applications often compete for access to shared disks, it is common to have dedicated disk space on separately allocated disks/stripe sets. SANs can provide disk resource virtualization and are commonly employed for virtualized applications. Properly sizing SAN cache and managing disk allocation effectively is critical.

- **Memory constraints.** Web servers and database servers often take advantage of available memory for caching. This can significantly improve performance by reducing disk I/Os.

  Virtual machines, however, often have a problem sharing memory in an efficient and fast way and it is critical, therefore, that you provide enough memory for each application. The challenge is to do this without extensively over allocating resources, and making the solution more expensive than necessary.

  This can be handled by using a management tool that monitors the application’s memory requirement and using this knowledge to decide which applications fit together on a specific host.

  **Note:** A limited over allocation of memory is often desirable since modern enterprise level virtualization hosts have advanced memory management functions that allow applications to share memory between different virtual machines and can dynamically borrow memory between the virtual machines. For additional details, see “Memory (RAM) Concerns” on page 50 as well as the “Memory Resource Management in VMware ESX Server” (http://www.vmware.com/pdf/usenix_resource_mgmt.pdf) document.

- **Network constraints**: Client-Server type applications, along with network management tools, often place a large number of small packets on the network. Even if these packets don’t add significant overall load, they may severely affect performance of other virtual machines sharing a NIC if the round trip latency is poor. Dedicating NICs to production virtual machines is typically required to avoid wide swings in response time of network dependant applications.

  Most of these constraints can be managed by adding more resources and/or reorganizing which virtual servers are running on which hosts.

  It is also highly recommended that you carefully read the performance tuning and best practices documents and white papers that are available from host system vendors. For example, the “Performance Best Practices for VMware vSphere 4.0” document, which is available from VMware (http://www.vmware.com/pdf/Perf_Best_Practices_vSphere4.0.pdf) focuses primarily on VMware’s vSphere, however many of its performance tips are applicable to other solutions as well.
Why Use Virtualization

**Note:** Poorly written applications often over consume many different types of resources. Therefore, whenever possible, review in-house applications to determine if they can be enhanced to better use available resources. For example, a database engine given poorly written SQL will likely put unnecessary stress on CPU, Network, Disk I/O and Memory. CA Wily CEM and CA Wily Introscope can rapidly identify resource bottlenecks in web applications.

### Management

- **Support**

  Although the ability to isolate applications through virtualized appliances or by testing patches on identical clones can significantly simplify support, the disadvantage is that many software vendors do not fully support virtualized environments or else require that the issue be reproduced in a non-virtualized environment.

- **Multiple Servers on one physical server**

  Having multiple virtual machines on a single physical machine can introduce the potential for:
  
  - Security vulnerabilities (see the previous “Security / Risks” section on page 12).
  
  - Increased failure impact. A single HW failure now affects multiple logical/virtual servers. This risk can be reduced through use of resilient server hardware and good disaster recovery routines. In fact, some clients choose resilient server hardware for virtualization to reduce risk of failure when comparing multiple failure prone small servers with a single large resilient server.

  - Any reboot/maintenance to the host system interrupts all guest OS, however this can be managed using “hot migration” technologies (such as VMOTION, XenMotion or Live Migration).

  - Bottlenecks (see details in the “Performance” section above):
    
    - CPU cycles, Memory capacity and Network are typically relatively easy to handle by analyzing the typical load of the various applications and proactively allocating the resources. The resources can be dynamically allocated but this should be avoided, whenever possible, since it typically slows down the applications to repeatedly reallocate resources.

    - I/O bottlenecks are a tougher and a growing problem with multiple virtual machines (especially if they are often heavily used at the same time). However, understanding the usage pattern will allow you proactively allocate dedicated physical resources or additional shares of existing resources to the virtual machines.
Why Use Virtualization

- **Specialized skill set required**

  Even though management of a virtualized environment can often be streamlined and simplified it still requires new, and currently unusual, skills.

  Personnel that don’t fully understand the specific requirements for virtualized environments can cause severe damage to the infrastructure. Therefore it’s important to allocate time/resources for training both before and throughout any virtualization project.
Planning is an important part of any project - even more so with virtualization. The key to a good plan is to understand, from the outset, what the goals are, in order to ensure that those expectations can, in fact, be met by the implementation. Before undertaking a virtualization project you should clearly identify the following:

- **Reason** for the project (i.e., what are the business drivers?)
- **What** you are trying to virtualize (e.g., specific functions or applications?)
- **How much** the project is expected to cost (and to save)
- **What risks** – both functional and financial – are expected and, more importantly, acceptable.
- **Scope** of the implementation (i.e., is it a single, focused project, or will there be multiple phases and milestones)
- **Other changes** that are anticipated in the environment and how they might impact or be impacted by virtualization

This is, by no means, an exhaustive list, nor does it apply to all projects, however if you don’t have a good understanding of the answers to those questions *before* you start the project you are more likely to encounter some unexpected bumps during the deployment.

Whatever the answers to these questions may be, it is important to carefully assess the tasks at hand and to plan out the action steps accordingly. Keep the project plan open particularly when dealing with a larger scale project. This enables you to incorporate any lessons learned during the first steps/milestones when it is time to start subsequent steps and sub projects.

**For example:** If the first major milestone in one virtualization project is to implement a library of different virtualized test environments for the Quality Assurance (QA) team, it would then be beneficial to analyze the results from that experience before proceeding with the next milestone, which may be to incorporate various lightly used business critical applications into the environment.
Taking Advantage of the Advantages

As you can see there are many advantages to virtualization – but you need to understand the realities of those advantages, as well as how to counter the potential, and often related, disadvantages. The following sections help you take advantage of those advantages by:

- Deciding where to start
- Analyzing the marketplace/identifying who the players are
- Deciding on the appropriate virtualization engine
- Identifying requirements for management tools
- Identifying change control methods
- Identifying data storage resources and limitations
- Defining pertinent maintenance tasks
- Identifying the advantages and disadvantages of using Virtual Appliances
- Taking a look at Virtual Desktops
- Determining costs, as well as return on investment

Also included are a few helpful thoughts on virtual appliances and virtual desktops, detailed discussions of which are currently beyond the scope of this document.

Deciding Where to Start

There is no simple answer to this question since every situation is unique and every project requires an analysis of the organization’s specific situation to realize the pertinent facts for that situation. Consult the previous “Areas Where Virtualization Provides Quick Value” section on page 5 for tips on where virtualization quickly adds value.

Often the best place to start is to look at those situations where a library of different environments is required to be accessible on demand – for example, development, quality assurance, support and demo centers. Keep in mind the list of “Common Advantages” and “Common Disadvantages” identified earlier in this document (see page 7) and consider how these apply to your organization.

The next step is to carefully analyze the list of current (and potential) business applications to determine which would make a good fit for consolidation - for example, File and Print Servers, Web Servers and some carefully selected Business Applications. Whenever possible, it is best to start with servers that have low activity levels.
A few high-level pointers that you should consider when selecting your candidates for virtualizations are:

- Ensure that the applications are supported in your virtualized environment.
- Can you get buy-in and cooperation from executive management as well as the owners and other stakeholders of the involved applications.
- Ensure you have sufficient hardware (CPU, RAM, Network and Disk I/O) for the virtualized applications.
- Ensure that the applications are using centralized storage for its storage needs.

If you are planning to virtualize and existing application that currently are using locally attached storage you should consider to first make the application use a centralized storage pool. It is highly recommended to do this as a foundation to the virtualization project, doing this at the same time would be more complex and introduce unnecessary risks.

**Note:** Careful planning is especially critical for I/O intensive applications such as high end databases and/or email servers. Although these are generally not ideal candidates for virtualization, if you must virtualize them you should plan to use one or more dedicated physical disks (preferably implemented through SAN).

### Analyzing the Marketplace/Identifying Who the Players are

The following list represents some of the more interesting players in this area – either from a market share and/or a technology point of view. It is not intended to be a complete list. Information about additional companies working in this area can be found on [http://www.virtualization.info/radar/](http://www.virtualization.info/radar/) and [http://www.cio.com/article/349577/Virtualization_Vendor_Matrix](http://www.cio.com/article/349577/Virtualization_Vendor_Matrix).

- Amazon EC2 ([http://aws.amazon.com/ec2](http://aws.amazon.com/ec2))
- Citrix Systems ([http://www.citrix.com](http://www.citrix.com))
  - XenServer/XenSource ([http://www.xensource.com](http://www.xensource.com))
    - Acquired by Citrix in August 2007.
- Linux KVM ([http://kvm.qumranet.com/kvmwiki](http://kvm.qumranet.com/kvmwiki))
- Microsoft ([http://www.microsoft.com](http://www.microsoft.com))
- Open Source Xen ([http://www.xen.org](http://www.xen.org))
- Open VZ ([http://wiki.openvz.org/Main_Page](http://wiki.openvz.org/Main_Page))
Taking Advantage of the Advantages

- Oracle (http://www.oracle.com/technologies/virtualization/)
  - Virtual Iron (http://www.oracle.com/virtualiron/index.html)
    Acquired by Oracle in May 2009.
  - Sun Microsystems (http://www.sun.com/solutions/virtualization/)
    Acquired by Oracle in January 2010.
    - InnoTek (http://www.virtualbox.org)
      Acquired by Sun Microsystems in February 2008.
- Parallels (http://www.parallels.com)
  Earlier sometimes referred to as SWsoft
- VMware (http://www.vmware.com)

Based on market share and market recognition, however, only a handful of these solutions carry significant weight. However, this is a large and growing market so we can expect a lot of activity.

**Note:** Although a majority of the references and examples in this document refer to VMware, that should not be interpreted as an endorsement of VMware over any other vendor. It is merely a reflection of the author’s experiences.

Multiple analysts firms and trade magazines have done surveys to gauge industry trends and to understand how clients are using and are planning to use virtualization in their environment. This includes questions on which vendor(s) they prefer, if they are considering using solutions from multiple vendors, etc. A few examples are:

- http://searchdatacenter.techtarget.com/news/article/0,289142,sid80_gci1516863,00.html
- http://itic-corp.com/category/virtualization

It is obvious that VMware and Microsoft are perceived as the major players when it comes to the software virtualization tools, however it is also worthwhile to include Citrix XenServer (formerly called XenSource, Note: August 15th 2007 Citrix Systems Inc announced a definitive agreement to acquire XenSource) in the discussion.
Taking a closer look at VMware ESX, Microsoft Hyper-V and Citrix XenServer

Although VMware is clearly the market leader and the front-runner at this point, other solutions, such as Microsoft Hyper-V and Citrix XenServer, are gaining momentum and are definitely options well worth looking at. Also in some situations, Hyper-V could potentially be more efficient than VMware and Xen solutions for Window guests OS – due to their detailed knowledge of the Windows OS.

A lab test conducted between ESX 3.5, Hyper-V and XenServer 5 (published in the February/March 2009 issue of Virtualization Review”) showed that each one of these Hypervisors has some advantages and disadvantages. The article also states that “What is entirely clear, is that all three hypervisors are legitimate virtualization platforms, and that no single company has a monopoly on virtualization any longer”.

The chart below compares some important technical features between the three solutions:

<table>
<thead>
<tr>
<th>Feature</th>
<th>ESX/ESXi 4.1</th>
<th>Hyper-V™ Server 2008 R2</th>
<th>XenServer 5.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypervisor</td>
<td>64-bit</td>
<td>64-bit</td>
<td>64-bit</td>
</tr>
<tr>
<td>Cores¹ / Host</td>
<td>128 (512 Virtual CPUs)</td>
<td>64 (EE²/DE³) 32 (SE⁴)</td>
<td>64</td>
</tr>
<tr>
<td>vCPUs / VM</td>
<td>4 / 8⁵</td>
<td>4</td>
<td>8 / 32²</td>
</tr>
<tr>
<td>RAM / Host</td>
<td>1 TB</td>
<td>1 TB (EE²/DE³) 32 GB (SE⁴)</td>
<td>256 GB</td>
</tr>
<tr>
<td>RAM / VM</td>
<td>255 GB</td>
<td>64 GB (EE²/DE³) 31 GB (SE⁴)</td>
<td>32 GB</td>
</tr>
<tr>
<td>Active VM / Host</td>
<td>320⁶</td>
<td>384 (EE²/DE³) 192 (SE⁴)</td>
<td>50</td>
</tr>
<tr>
<td>Virtual NIC / VM</td>
<td>10</td>
<td>12 (whereof 4 legacy adapters)</td>
<td>7</td>
</tr>
<tr>
<td>AMD-V / Intel-VT</td>
<td>Supported (Required for 64-bits VMs)</td>
<td>Required</td>
<td>Required for Windows VMs</td>
</tr>
<tr>
<td>AMD-RVI / Intel EPT</td>
<td>Supported</td>
<td>Supported</td>
<td>Supported</td>
</tr>
</tbody>
</table>
Taking Advantage of the Advantages

1: Additional requirement on CPU configurations.
2: Windows 2008 Server Enterprise Edition
5: vSphere Enterprise Plus is required to use more than 4 vCPU in a VM
6: Specific solution limits may be lower
7: 8 vCPU for Windows, 32 vCPU for Linux. XenCenter support max 8 vCPU

Additional details about these solutions are provided in the more specialized sections on the next few pages.

Note: All product-specific data is subject to frequent update. Please see the vendor’s websites for the latest information.

VMware vSphere 4 - VMware ESX/ESXi 4.1

VMware has been a clear market leader since virtualization first became a hot topic in the distributed world. VMware provides a number of different solutions including VMware Workstation and VMware Server, however, this document focuses on production environments where the VMware solution of choice is the VMware vSphere 4.1 which includes ESX 4.1 or ESXi 4.1. Following are a few important facts about VMware vSphere 4.1:

- It is a true Hypervisor, using a bare metal architecture with a virtualization layer implemented directly on the server’s hardware.
- Supports dynamic volume resizing.
- Supports a large number of different storage technologies, such as: Direct Attached Storage (DAS), Storage Area Networks (SAN) through iSCSI, Fibre Channel & Serial Attached SCSI (SAS) as well as Network Attached Storage (NAS). Including the option to boot from SAN.
- Boot from SAN, vSphere 4.1 allows booting directly from both iSCSI, FCoE and Fibre Channel SAN. See details and hardware compatibility list on the VMware site.
- Virtual Network including Virtual NICs and Switches. Advanced functionality such as IPv6, NIC teaming and virtual VLAN.
- Support of 10Gb Ethernet network cards and network performance optimization in the form of TCP Segment offload (TSO) and Jumbo Frames.
- Advanced memory management, such as RAM over commitment, Memory Compression, Page sharing and Memory ballooning.
- Supports a large number of OS as guests, including Windows, Linux, Solaris and Novell NetWare.
- VMware VMsafe™ provides APIs that enables 3rd party security product to gain visibility into the Virtual Machines hardware resources (such as memory, CPU, disk and I/O systems) to eliminate malware.
- Power Management using Intel SpeedStep® and AMD PowerNow!
VMDirectPath allows select virtual machines to directly access underlying hardware devices. This enhances CPU efficiency for applications with frequent access to I/O devices; however it will disable certain VMware virtualization features.


For additional information on VMware ESX/ESXi 4.1, see the following documents:  

**Microsoft Hyper-V Server 2008 R2**

In June of 2008, Microsoft released the first official version of a major new virtualization engine, called Hyper-V (formerly referred to as "Viridian" or "Windows Server Virtualization (WSV)"). Hyper-V 2.0 (part of Windows Server 2008 R2) was released to manufacturing (RTM) in July 22, 2009.

Following are some important facts about Hyper-V 2.0:

- Hyper-V host requires the x64 edition of Windows Server 2008. However, it is a true hypervisor and operates directly on the hardware.
- Support for up to 64 logical CPUs (8-socket physical systems with up to 8 physical cores each).
- Support for up to 384 running VM guests per host (up to 512 vCPUs).
- Hot pluggable virtual storage (VHD) (add and remove).
- Supports a large number of different storage technologies, such as: Direct Attached Storage (DAS), Storage Area Networks (SAN) through iSCSI, Fibre Channel & Serial Attached SCSI (SAS) as well as Network Attached Storage (NAS).
- Live Migration, which enables migration of active machines to new hosts without any downtime. This also includes Processor Compatibility Mode which allows the live migration of virtual machines to a different generation of CPUs within the same processor family (i.e., "Intel Core 2 to Intel Pentium 4" or "AMD Opteron to AMD Athlon").
- Support for host clustering technology for failover
- Support for multiple VHD volumes sharing a single LUN - Clustered Shared Volumes (CSV). This greatly simplifies migration between host servers.
Second-Level Address Translation (SLAT) takes advantage of AMD RVI and Intel EPT technology to improve performance by providing an indirection layer from the virtual machine memory access to the physical memory access.

Advanced power control of individual CPUs and cores (Core Parking).

Support for TCP/IP Offload Engines (TOEs) and Jumbo Frames.

Support for Virtual Desktop Infrastructure (VDI).

Ability to take “snapshots” of running machines so that the user can easily revert to previously saved snapshots.

Can be managed through Windows Management Infrastructure (WMI) and/or a published HyperCall API. This simplifies integration with 3rd party management tools.

Seamless Citrix XenServer interoperability allows you to move a VM image from a XenServer host to a Hyper-V host without any reconfiguration of the virtual machine.

Hyper-V R2 has also been improved in a number of ways such as enhanced performance and scalability optimization in a number of areas of the OS. This includes improved scheduling on NUMA architectures, support for solid state disks, various power management improvements, more efficient memory algorithms, generic networking improvements, and improved file transfer speeds on LAN


It is also noteworthy that, in July 2006, Microsoft announced that they were cooperating with XenSource to allow Xen-enabled guest operating systems, including Linux, to run on Windows Server 2008 “Longhorn” and that this will be supported by Microsoft.

Citrix XenServer & Citrix Essentials

Citrix XenServer is based on the open source virtualization Xen® Hypervisor and Citrix Essentials is an advanced virtualization management toolkit. As mentioned above Microsoft and Citrix started a partnership on virtualization in 2006, this partnership has since then been further extended to so that Citrix Essentials integrates with Hyper-V and XenServer will be supported by Microsoft System Center. Below are few important facts about XenServer:

- XenServer 5.6 itself is freely downloadable but, to obtain all the features listed below you need to get the Platinum or Enterprise edition of Citrix Essentials.
- Based on a 64bits hypervisor which supports 32 and 64 bits operating systems.
- Support a large number of 32 & 64 bits Windows and Linux OS.
- XenMotion allow migration of virtual machines between hosts for maintenance or load balancing with zero downtime.
- XenServer supports automated high availability that allows failed virtual machines to restart on a secondary physical server.
- Support a large number of different storage technologies, such as: Direct Attached Storage (DAS), Storage Area Networks (SAN) through iSCSI, Fibre Channel & Serial Attached SCSI (SAS) as well as Network Attached Storage (NAS). XenServer also supports a wide range of host bus adapters (HBA) technologies.
- XenServer is compatible with Hyper-V in a way that workload can be moved between the two platforms.

Additional information about XenServer can be found on
http://www.citrix.com/xenserver and
http://docs.xensource.com/XenServer/5.6.0

Citrix Essentials is a suite of management and automation tools from Citrix that supports XenServer and Microsoft Hyper-V and support management of heterogeneous environments using both solutions. From a high level point of view the suite covers five areas:

- Automated Lab Management
- Advanced Storage Integration (featuring Citrix Storage Link™)
- Dynamic Provisioning
- Workflow Orchestration
- High Availability

Additional information about Citrix Essentials can be found on
Deciding on the Appropriate Virtualization Engine

In determining the best tool for your project and environment you need to carefully consider what you are trying to accomplish, what type of functionality is required and what the related total cost of ownership will be.

For any larger scenario you need to consider the following items:

- Organization Requirements
- Required functions and protocols
- Virtual Disk Formats
- Hypervisor-based Architecture
- Hardware Virtualization Engines and Applications

Each of these areas is covered in some detail in the sections below.

Organizational Requirements

Organizational or tactical requirements can often be as important as technical requirements and it is important to look at these and how they can affect the success and cost of the project. For example:

- Is a particular solution already in use in a part of your organization?
- Is there a particular solution with which you and/or other members of your team already have existing knowledge and experience?
- Do any of your preferred partners have existing knowledge/experience with one of the potential solutions?
- What solutions have been tested or can easily be tested with the existing hardware platform and your most critical applications?

Required functions and protocols

It is important to clearly identify what functions you require from your virtualization engine because there is a big difference in the types of functions that various vendors ship with their different offerings.

Some of the more commonly required functions include:

- Support for Hot Migration, which allows you to move a virtualized environment to another physical server easily, and without interruption.
- Support for the hardware/infrastructure that you have or are planning to use in your environment.
- Support for SAN solution (Fibre Channel, FCoE and/or iSCSI based). It is critical that the virtual images can reside on a SAN. If you are planning to use diskless systems you also need to make sure that the virtual engine can boot from the SAN.
Support for multiple storage repositories which allows you to minimize the risk of storage contention.

Support for all applications that you are planning to virtualize. This includes an acceptable level of support provided by the software vendor when the application is implemented in this specific virtual environment.

Support for all operating systems that are required by your organization (16/32/64 bits versions of Windows, UNIX and/or Linux).

Ability for the system to access, utilize and distribute all required resources (including sufficient amount of RAM, CPU types, CPU count etc).

Management tool or support for a management tool that can monitor performance and availability. These tools should, preferably, also integrate with your existing Enterprise Management System.

Built in functions, APIs and interfaces to manage additional advanced native and 3rd party tools in the areas of security, energy saving schemas, high availability and fault tolerance.

Virtual Disk Formats

Virtual Disk formats allow you to easily move a virtual disk between physical disks, however it is important to understand that there are different standards available and that Microsoft and VMware are both using their own ‘standard’.

Both Microsoft (VHD) and VMware (VMDK) have made their specifications for Virtual Disks open and free to use.

- VMware made the specification for its VMDK available in April 2006, however, they reserve the right to revise or rewrite it.
  Developers who are creating Virtual Disk Management applications are encouraged to use the VMware Virtual Disk Development Kit which can be found on http://www.vmware.com/download/sdk/virtualdisk.html.

- Microsoft made its “Virtual Hard Disk Image Format (VHD)” freely available to the public in October 2006. (However, like VMware, they kept the right to revise or rewrite it).
  Additional details, as well as access to the standard, can be found on http://technet.microsoft.com/en-us/virtualserver/bb676673.aspx

It is also noteworthy that XenSource uses Microsoft’s VHD format.

**Note:** Since these formats now are open, tools have been developed to convert between the formats. This typically works well for data disks however you need to be careful with system disks since different VM Engines emulate the system in different ways.
Hypervisor-based Architecture

The hypervisor (sometimes also called the “Virtual Machine Monitor”) is the virtualization software that allows multiple virtual machines to share a single host server. Hypervisors are often classified into the following two categories:

- **Type I hypervisors** both run on and communicate directly with the hardware. Unless otherwise noted, all references to “hypervisors” later in this document refer to Type 1 hypervisors.

- **Type II hypervisors** run on top of a conventional operating system operating system, such as Windows, Unix or Linux. Even though these solutions may be good options for workstations, or for development and testing purposes, Type I solutions are strongly recommended for server/data center virtualization. For the purposes of this document, Type II hypervisors are not classified as “true” hypervisors.

A hypervisor-based (Type I) architecture employs technology that communicates more directly with the hardware without exchanging calls with an intermediary operating system. This means that the virtualization software requires fewer hardware resources (e.g., memory and storage) and also has a smaller overall footprint.

- Architectures with true Hypervisors makes the communication with multiple virtual machines significantly more efficient.

- Hypervisor-based solutions, to a larger degree, tend to take advantage of specific hardware functions that support virtualization (available for both Intel and AMD chips).

All major virtualization vendors either have or are planning to have a version based on hypervisor technology.

- VMware ESX and ESXi Server is based on hypervisor architecture

- VMware Server and VMware Workstation both run on top of a conventional operating system, and are, therefore, Type II hypervisors.

- The open source project Xen (including XenSource Enterprise 3.x) has been a hypervisor based solution from its start.

- ”Microsoft Virtual Server 2005 R2” runs as a service on top of the guest OS (WinXP, Win2003) and is not a true hypervisor based solution.

- Microsoft Hyper-V includes a hypervisor-based Virtualization Engine. Each Hyper-V hosts does require a root partition running Windows Server 2008 that manages machine level functions. Child partitions only have access to hardware through the root partition or the Hypervisor.

Windows Server 2008 x64 was shipped with a beta version of Hyper-V and an update to a final (RTM) version (released in June 2008) can be downloaded from [http://support.microsoft.com/kb/950050](http://support.microsoft.com/kb/950050).
Note: after this Hyper-V 2.0 (part of Windows Server 2008 R2) was released to manufacturing (RTM) in July 22, 2009

Hardware Virtualization Engines and Applications

Virtualization often pushes the limits of resource consumption and the level of parallelism significantly further than most normal OS application combinations and these technologies are not yet highly standardized. Therefore, we can expect that the various virtualization engines will be optimized to handle the potential scenarios in different ways.

Different guest OS and application combinations - or even differences in how these are used - can stress different functions that a particular virtualization engine might be able to take advantage of and, therefore, make this scenario run efficiently on this specific engine. Another scenario might stress other functions that a different engine might be able to handle more efficiently.

The specific combination of hardware, virtualization engine and application can often affect scalability and, just because a solution scales in a certain way on Server A, does not guarantee that it will scale the same way on Server B.

Identifying Requirements for Management Tools

As previously noted, the ability to manage your environment becomes even more critical when virtualization is employed. The individual Hypervisor vendors are providing more and more management tools and functions; however, just like with classic physical environments, it is important to have a solution that can holistically manage/monitor your environment - across all technologies and with your company’s business services in focus. The tool needs to be able to track services and the components and relationship that each service depends on.

The components of a service should be able to be efficiently and transparently managed regardless of whether they are implemented using specialized hardware, physical server(s), virtual server(s) or if they are implemented somewhere in a cloud. To provide a complete solution you typically need multiple, well integrated views into the environment that assist you by providing:

- High level views that provide accurate overall information about the status of the business services in your environment. This has to scale so that can efficiently support your complete infrastructure.
- Virtual “magnifying glass” that allows you to zoom in on and manage different aspects of the service and its related components and relationships.
- Methods to both manually and automatically turn on and/or tune how the systems (hosts, guest systems and/or business processes), are monitored. This allows you or an automated management tool to enable detailed monitoring that you normally don’t want to have active.
- Ability to automatically and manually take actions and manipulate the existing environment. This includes: classic management of OS and applications or dynamic reconfiguring of the servers (blade servers, virtual machines and/or instances in the cloud) along with control of available resources or location of the logical server.

- Tools that simplify management of the complete lifecycle of your servers, service and applications. Amongst others this includes configuration and change management of the flexible environment that virtualization and cloud computing allow.

The individual vendors often provide tools that are very good at managing their own systems in a deep and detailed way. However, it’s important to ensure that your toolbox also includes a broader support that enables you to see the complete business processes. In order to understand that a problem with component X affects the services Y and Z, the solution also need to transparently support both your current and future environments, including physical servers and different Hypervisor technologies as well as servers, applications and/or services implemented in the cloud.

Some of the more common management issues directly related to virtualization and virtualized environments include the need to:

- Simplify creation of new virtual servers and migration of existing systems into a virtualized environment (for example, VMware Converter or P2V in Microsoft Virtual Machine Manager).

- Lifecycle management and workflow orchestration tools that help you control development of new guest systems, the process of patching, configuring and testing existing systems, provisioning new or additional systems etc.

- Predict and track virtual environments that compete with each other for server and storage resources. This includes real time access to the physical host on which a specific application or guest system is running, and, from there, analysis of the performance data from the host systems and all of its guest systems.

- Predict and track performance utilization in real time as well as noting historical trends. This has to be done for individual environments, the host system as well as the SAN system, and preferably, in a way that allows correlation between these components.

- Manage "VM sprawl" By tracking where, why and how virtual applications are running and what resources they are using.

- Provide tools for backup and disaster recovery of the virtual environment.

- Provide tools and procedures to manage security.
Intelligently utilize Active Management Assistance based on policies, measured performance and events. This added flexibility can be one of the great advantages of virtualization. A few examples are:

- Dynamically changing resources available to virtual machines
- Moving virtual machines between different host servers as needed.
- Dynamically provisioning and configuring servers on demand or when triggered by policies.

If these capabilities aren’t appropriately managed, these otherwise great features can present some very significant risks.

Many of these and other similar tasks also need to be managed in non-virtualized environments, but it is especially important to understand the specific challenges that are presented in a virtualized or cloud based environment.

If your management tool can handle most of these issues and includes a simple method to do hot migration (VMOTION, Live Migration or similar) you will have a good environment in which to do efficient load balancing between the servers. Although some management tasks can be automated, it is important to be able to predict, whenever possible, the amount of resources that are required before they are actually required. To accomplish this you will need a strong understanding of the business systems and occasional human intervention.

Note: Make sure the tools you are using for your virtualized environment can cooperate and integrate with the existing enterprise management software.

Identifying Change Control Methods

Virtualization’s ability to quickly define and deploy new logical servers can be useful in many situations – particularly when you need to access a large number of configurations for a limited time. It can also be useful in situations where you might need to deploy additional servers for scalability reasons.

Note: Virtualization makes it easy to quickly create a large number of different images; however, unless there is a compelling reason to do so, you should minimize the number of variations of the base systems. This will greatly simplify the process of keeping these images up-to-date and secured.
Regardless of the reasons for building an image directory, it is important to introduce the appropriate change controls in order to best manage those images. Although there are many approaches to take, you should plan to incorporate mechanisms for the following states:

- **Development**
  Phase/library where the images are developed. This could include completely new images or updates to existing images.
  When the image is ready for QA it is transferred to **Test / Quality Assurance**.

- **Test / Quality Assurance**
  Phase/library where the newly updated/developed images are tested and verified. If further modification is needed they are transferred back to **Development**; otherwise they are subject to an approval process and, if approved, are transferred to the next stage - **Available Images**.

- **Available Images**
  Library where the Gold Master images are stored when they are approved for usage. In a VMware environment these Gold Master Images are typically implemented as VMware Templates.
  When the image is to be deployed as a server, a clone or an image based on this template should be transferred to **Configuration**. If any changes need to be done to an existing image, a copy should be made and transferred back to **Development**. Finally, if an image is replaced by an updated version or if, for any other reason, it should not be used, it should be transferred to **Archive**.
  This is purely a storage area for the Master images of potential servers. These images should never be active or modified.

- **Archive**
  Library for Gold Master images that have been marked as “End of Life”

- **Configuration**
  Phase where Gold Master images are configured before they are deployed for production.
  This configuration step might be as simple as renaming the server and making sure it has the latest approved maintenance or it may include an automated step to apply additional software or prepare it to connect to existing external data. The use of automation for this task can help ensure a well defined baseline, and be sure that the automation also documents the exact state of the configured server. Once the server is configured it is moved into **Production**.
Taking Advantage of the Advantages

- **Production**
  
  Phase where the images are deployed. This is normally the last stage for any specific image. If you decide to upgrade an image it should be based on the Gold Image located in the *Available Images* phase.

  The only updates that should be done to images in the *Production* phase are those that are the result of normal production. This typically includes minor OS and application patches that don’t require a reboot; however these should first be applied and verified on the gold master image.

  If additional change control is required you might consider implementing staging areas in between one or more of the stages.

Identifying Data Storage Resources and Limitations

As previously noted, one of the more important areas to analyze during a virtualization project is how to manage the data storage problem. When you introduce a project like this it is critical that you have a data storage infrastructure to support it. In many ways, this can be considered a separate project, however, it is a requirement for any successful virtualization project and it is likely that it will both save money and, more importantly, make it easier to secure your business critical data.

A few challenges to look into in this area include:

- **Multiple I/O intensive applications using the same physical disk**
  
  When multiple data-streams try to communicate to the same physical disk at the same time you are likely to run into severe delays. This is a well-known problem within specific applications (such as databases), but you will most definitely run into this problem if multiple virtual machines share the same physical disk.

  This risk can be managed by making sure each virtual machine (or better yet, each expected concurrent major data stream) has its own physical disk – preferably by implementing a SAN solution (based on fibre channel, FCoE or iSCSI) where the disks are correctly allocated to the various virtual machines. Implementing a SAN solution with many smaller disks is preferable in these situations since multiple disks normally provide faster overall performance due to the larger number of heads that can do simultaneous read/write operations.

- **Make disk space accessible from multiple host systems**
  
  To simplify migration of virtual machines between different physical machines it is important that the data is stored in such a way that it is accessible in the same way from each one of the host systems.

  This can be easily managed by moving the data storage from the host server to a SAN solution.
Allocate enough storage for each virtual machine

Like most other resources it is important to have enough data storage available for the application – and to account for both maintenance as well as expected growth.

On a traditional disk system this has been managed by allocating the server significantly more space than it really requires and, thereby, wasting huge amounts of disk space. With an external disk system it is easier to manage this by allocating additional space for a specific virtual machine when required. This can be managed manually, through the storage manager on a SAN solution, however, in some situations, it might also be worthwhile to look into a more formalized system for thin provisioning of storage assets.

True thin provisioning is a very interesting and efficient technology when you have a large number of users who might need access to a lot of storage that they often aren’t going to use. Since you also have to give up control, to some degree, over who has access to a certain disk you also give up what may have earlier been predictable performance. Therefore, this needs to be carefully analyzed when I/O intensive applications are using the disk. With that in mind, this type of technology can be very efficient since read/write operations from one application might be spread out over multiple disks and, in this way, able to perform parallel I/O operations.

It is worth noting that sites, like mySpace (http://www.myspace.com), are successfully using thin provisioning to allow a large number of users to have access to a large amount of disk - in a controlled manner.

Defining Pertinent Maintenance Tasks

One of the major advantages with virtualization is how it can, with the appropriate planning, minimize the amount of downtime required for hardware and software maintenance. Another advantage is that it can greatly simplify any maintenance tasks since they can be performed on an offline system while the production systems are running on another host.

To truly minimize the downtime associated with maintenance, it is important to have a solution that provides “hot migration”, such as VMware VMOTION, Microsoft Live Migration or Citrix XenMotion. Hot migration allows you to move virtual machines between hosts while they are still active. Using this functionality, you can move all applications to a secondary system and then, without any interruption or stress, upgrade and test on the now offline original hardware. Once the upgrade is performed and tested, the application can be migrated back to the original system and you can move on to the next system that needs to be upgraded. All of this can be done without any interruption of the production system.
Taking Advantage of the Advantages

There are also significant advantages with virtualized environments for software maintenance tasks. Any updates to the production environment should go through a change management process to ensure that this update works as expected and to minimize the risk of any interruption of production.

In a traditional environment, this can be a complex task to tackle in a robust and secure way. In a virtualized environment with a change management infrastructure implemented, however, the degree of complexity drops significantly. Although there may still be a brief interruption in production while the production system is switched over to the new and updated image, since this has been carefully tested, the risks are minimized. In addition, if something does go wrong you can switch back to the original system relatively easily.

Minor updates that do not interrupt production processing (e.g., security patches that do not require a reboot) can be applied directly to the production system once they have been tested and applied to the corresponding gold image. This will keep the gold image synchronized with the production copy and, at the same time, minimize disruption of the production system. However, even in this situation, it is highly recommended that you first take a snapshot\backup so that you can quickly revert to the original state should a problem occur.

Identifying the Advantages and Disadvantages of Using Virtual Appliances

One of the great advantages with this technology is that, since the virtualized image should typically only be used for a very specialized application, it can be tuned to specifically support that application in the best possible way. This is called a Virtual Appliance – and, in the process, the OS and the environment often might be crippled so that it only supports this specific task.

As with most other solutions there are both advantages and disadvantages with this approach. A few advantages are:

- Tuning or disabling functions to optimize them for the specific task can enable the OS to run more efficiently and, therefore, lead to a faster application that uses fewer resources.
- Disabling certain features that the application does not require can result in a significantly more secure system since it minimizes the potential security holes.
- Support and maintenance may be simplified since:
  - Smaller, less complicated modules typically simplifies troubleshooting and maintenance.
  - Each module has fewer components that might interfere with each other (e.g., incompatible DLLs or Java versions).
Taking Advantage of the Advantages

- If the virtual appliances have a good, well thought out design it will greatly simplify the work required to accommodate any future growth.

  The basis for this is that, since you know exactly what each module/virtual machine is responsible for, a good architecture will allow you to scale out simply by plugging in new modules.

On the other hand, disadvantages are:

- Unless the developer/administrator of the virtual appliance completely understands the requirements, it is easy to cripple the application’s functionality by disabling a service that it requires for certain functions.

- Although Virtual Appliances may simplify support and maintenance, with a highly customized environment it can also be very hard to get support from the application and/or OS provider. Being asked to first reproduce the problem on a standard OS is not unusual.

- Breaking up applications into really small appliances might add a significant cost since common components, such as operating systems and security products, typically require a license for each appliance.

- If the operating system is highly customized it might be complicated to maintain and support since critical operating system patches might need careful testing before they are deployed.

Taking a Look at Virtual Desktops

Although this document focuses on server virtualization it is worth mentioning the increasing push for virtual desktop infrastructure (VDI) as well.

It is a well known fact that most user desktops have extremely low utilization and, in fact, may not be used at all during many hours. However, since they do require quite a few resources when they are used, they still need to have access to those resources. At first glance, this sounds like a perfect scenario for virtualization (and in some situations it might be) but there are a number of challenges to consider:

- Are the resources commonly used at approximately the same time?

  As with server consolidation you need to analyze the resource usage patterns to determine if users commonly use their desktops at approximately the same time (for example, at the beginning and/or end of day or around standard lunch hours)

- I/O contention

  As with server utilization, I/O contention is a very real concern in VDI environments. In a typical scenario each VDI client uses much fewer resources than a typical server, however this will encourage people to have a large amount of desktop instances hosted on each server.

  To provide acceptable performance it is important to calculate and plan for the peak I/O requirements for these virtual desktops.
Taking Advantage of the Advantages

- What is the network connectivity between the planned clients and the datacenter?
  
  A solution like this obviously requires good low latency in the network connectivity between the clients and the datacenter. This is typically not a problem in a campus environment; however it might be a significant issue in a more distributed environment.

  It is worth noting that this is not always a disadvantage. In fact, under certain circumstances (such as with client-server based applications) it can even be an advantage since the computing power is closer to the rest of the server infrastructure.

- This is new technology
  
  Although similar solutions have been around for quite a while, they have not been widely accepted as a desktop standard. Since the concept is currently receiving new attention, we can probably expect to see significant enhancements in this area in the coming years. This is obviously an advantage, but it is also a risk since your investments might be leapfrogged by new technology.

Again, this document is not intended to dive into the depths of VDI, but it is important to be aware of it and to realize that many (but not all) of the advantages/disadvantages with server consolidation are also valid for desktop virtualization.

Determining Costs, as well as Return on Investment

All analysts and major trade magazines are in agreement that the number of x86 workloads running on virtualized environments will accelerate rapidly over the next few years. There is a multitude of business drivers for this, everything from lowering cost, to providing better support for the business. If the main driver is to save money, this can be accomplished by lowering cost of hardware, saving space in the datacenter and/or limiting the energy costs, however there are a lot of obstacles in the way and this gain is far from obvious.

A virtualization project can be an expensive exercise unless the business has proper control over the additional costs that may be incurred for additional licenses, newer, more advanced server environments, and infrastructure changes needed to support this new environment and make it coexist with the existing environment. In addition, it is very important to have a clear and well thought out strategy on how to manage this new technology.
Taking Advantage of the Advantages

Following are some of the key factors to consider when analyzing the total cost for a virtualization project:

- **New high end servers to support virtualization**
  In most situations the virtualized environment needs new and more costly hardware to handle multiple concurrent virtual servers. Such new servers need sufficient NICs with sufficient bandwidth, additional memory, and CPUs.

- **Storage solution**
  Unless the company has already invested in a storage solution that supports this environment (such as a high performance fibre channel, FCoE or iSCSI based SAN solution) this might be a significant additional investment.

- **Adequate infrastructure**
  You may need to review the datacenter infrastructure to determine if it contains adequate backbone bandwidth (especially where VMotion is part of the solution or where one of the goals of virtualization is enhanced fault tolerance or disaster recovery) and adequate power/cooling for the dense rack(s) used for virtualization servers.

- **Education and/or new hire**
  To build, manage and support the virtualized environment in an efficient and secure way requires specialized knowledge that is currently unusual and in high demand.

- **Redeploying existing working infrastructure into Virtual Machines**
  There is always the risk that you may be fixing something that does not need to be fixed and, if at all possible, this should be avoided, especially in the beginning of any virtualization project.
  
  Based on earlier discussions (see “Areas Where Virtualization Provides Quick Value” on page 5) it is generally a good idea to start with a situation where you need to house a library of servers (for example Development, QA, Support and/or Demo scenarios).

- **Need for new management tools**
  Good management tools are more important than ever when it comes to managing virtualized environments, since you need to be able to track (and, when possible, predict) resource consumption by individual virtual machines. This knowledge will allow you to redirect resources and move virtual machines to underutilized hosts before you experience performance problems. To provide a management solution with a holistic view of your environment it is important to ensure that the new tools are or can be integrated with your existing enterprise management solution.
Taking Advantage of the Advantages

- **License cost for virtualized applications**
  Depending on the application and how virtualization is used, the licensing costs for OS and third party applications might be considerable.
  It is important to make a careful analysis, based on the applications that should be virtualized. A few things to consider are:
  - In a virtualized environment it is common to have many smaller servers (Virtual Appliances), each one of these likely needing an operating system, as well as a number of common applications such as antivirus, backup clients, back office connectivity etc...
  - Some software licenses are bound by how many physical CPUs the hosting server has and not how many vCPU are assigned to the virtual machine. This often makes the licensing more expensive since the host in a virtualized environment likely is to be a larger server.
  - Some software is licensed to run on a specific physical server. This might reduce the advantages with the virtualization since you either need to invest in a license for each potential host or disable the VM load balancing functionality.

- **License cost for virtualization engine and management tools**
  Even though the Hypervisor itself is often relatively cheap (or free) the total cost of licenses for virtualization software is typically significant and should be taken into account when you are evaluating the tools. When you investigate prices make sure that the solution you are looking at includes all the tools and technologies you need. The price might differ depending on a large number of factors; a few of the more important are listed below.
  - Support for SAN (iSCSI, FCoE or Fibre Channel based)
  - Hot migration support (VMOTION, Live Migration or similar)
  - Size of Host server (commonly measured by number of CPUs or sockets)
  - Included Upgrade and Support agreement
Estimating Hardware Requirements

Once you have determined that virtualization is the right approach for your environment and business requirements, the next step is to determine the amount of hardware that will be needed to support this effort. For the most part, hardware sizing calculations for a virtual environment are similar to those used in planning for a physical environment. In fact, it is recommended that you first calculate sizing as though the installation was being done on physical hardware. Since those calculations will be application-specific, they won’t be covered in detail in this document.

In terms of the differences, there is both good news and bad news. The **good news** is:

- The virtual environment allows much more flexibility and, within certain limits, it is much easier to move resources between various VMs hosted on the same host.
- If you need additional resources and have built a good infrastructure it is easy to ‘plug in’ a new host server (or new storage resources) and transfer some of the load to this server. With the right infrastructure this can even be completely automated.

On the other hand, the **bad news** is:

- The Virtualization environment introduces an overhead on the available resources.
- Since the various VMs running on the same host share many resources they might significantly affect each other’s performance. This is especially true if any of the resources are overutilized. If your solutions require predictable performance you need to ensure that their required resources are always available and waiting for them.

  This is further complicated if VMs are dynamically moved between hosts.

However, in larger environment, where virtualization is gradually implemented in a series of controlled steps, the benefits of virtualization’s flexibility clearly outweigh the potential drawbacks of this type of added complexity. For a more detailed discussion of advantages/disadvantages see “Why Use Virtualization” on page 3.

This section examines a number of common questions and concerns regarding hardware planning for virtualization. Much of this information – and more – is presented in checklist format in “Appendix B: Virtualization Checklist”.

**Note:** This information is also useful for tuning and optimizing existing virtualized environments. For more details, see Chapter 3.
Initial Server/Application Sizing

The first step is to take a closer look at the applications that will be virtualized to establish both a rough estimation of the required hardware as well as an initial analysis of the performance profile.

Initial Sizing Estimations for Individual Virtual Machines

Start by reviewing existing best practices and sizing guidelines for the application that will be virtualized to create a classic estimate of hardware requirements. This should initially be done in the same way as if it was to be implemented directly on physical servers, with the exception that you should ignore minimum requirement imposed by available hardware. In other words, if the basic sizing calculations suggest one CPU, this suggestion should be used even if the minimal recommended physical server has a QuadCore CPU).

To simplify future steps it is important to gather the most critical information in a format that makes it easy to analyze multiple applications and their needs, side-by-side. For example:

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<tr>
<th>Name</th>
<th>Software</th>
<th>CPU</th>
<th>RAM</th>
<th>Storage</th>
<th>Network</th>
<th>Comments</th>
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This information, when combined with the following more specific guidelines and load estimations, can help you determine which virtual machines can be co-located on the same host and/or in the same resource pool and which should be divided into multiple virtual machines. For example, a database is typically installed on its own virtual machine.

The sizing exercise is typically an iterative process and based on later findings it is likely that the information that you gathered in this step will be updated frequently during the planning phase. It can also be used as the basis for future updates throughout the lifetime of the environment.
Estimated Hardware Requirements

Expected Peak Load (CPU/RAM/NIC/Storage)

In order to effectively allocate virtual machines to the appropriate host servers it is critical to understand their performance profile. If you are moving an existing application into a virtual environment it is highly recommended that you carefully analyze any prior performance reports to understand when and how this application uses resources.

If you are analyzing a new application it is still important to do a best effort analysis of the expected performance profile based on existing best practices, experiences with similar products and knowledge on how this product is expected to be used.

The resources that are especially important to look at are: CPU, memory (RAM), network and storage. With network and storage it’s important to consider both the number of I/O transaction, as well as the total amount of space/bandwidth that is needed. To ensure that the numbers you are using are meaningful it is important to measure these values over the course of a month or more. This will allow you to identify periods of peak resource demand.

The intent is to establish an estimate of how many resources the application will need at different times in order to simplify scheduling of resources. Depending on the application, the performance profile could be time-based and/or event based and multiple virtual machines can also be closely connected and affect each other.

Consider the following examples:

- **Restart of the environment.**
  This type of event can typically be controlled through process and automation, but, if not done correctly, it is likely to cause a significant peak in resource consumption.
  
  **Note:** This is likely to cause a significant performance hit when just one server is restarted. If multiple servers are restarted at the same time it is critical that this is carefully planned.

- **Expected and reoccurring events**
  These are different types of processes that are expected to be triggered at the same moment in time. These do not necessarily need to be connected to each other in any other way but that they are likely to be triggered at the same time. For example:
  - Multiple users logging into various systems and checking the status of various application/projects in the morning.
  - Multiple users running reports, printing out documents, verifying status of their projects, checking in and saving files, as well as logging out from various systems before going home in the evening.
Estimating Hardware Requirements

- Reports, Backup, and other batch updates are executed during otherwise off-peak hours.
- Complex reports are generated, printed and emailed during end of month, quarter or year processing.

**Events triggering multiple functions at the same time**

A prime example of this is the events that occur in a management infrastructure in response to an exception. Such as:

- Network & System Fault Management peaks due to incoming events.
- Automatic Root cause analysis and automation tools peaks since they are trying to analyze and correct the cause of the problem.
- Service Desk & Knowledge Tools peak while users try to find out if it’s a known problem and, if not, open issues.
- Service Desk Analysts use a number of tools to troubleshoot the issue. For example High Level Portals, CMDB, Asset Management, Network and Systems Fault Management, etc...

Since virtual machines in the same host and/or resource pool affect each other it is important to identify and plan for when multiple machines might experience simultaneous peak demands for resources – particularly the same resources.

**Moving to a Virtual Environment**

Although most modern enterprise class virtualization hosts include intelligent methods for sharing over-allocated resources among guests, there are a number of physical limitations to take into consideration. In situations where resources are known bottlenecks, but where predictable response times are required, it is a good idea to dedicate hardware for individual virtual machines – or, at least, to make sure that there are always resources available.

To best take advantage of the hardware, it is often possible to over allocate resources so that various guest OSs share a limited set of resources. In these situations the host system is responsible for scheduling currently available resources between the logical systems.

As noted previously, it is best to proceed cautiously if any of the virtual machines are resource intensive and you require predictable response times. However, when there are resources available, the hosts/hypervisors are typically fairly good at efficiently sharing the over allocated resources.

Furthermore, it is critical to ensure that no single virtual machine can have dedicated access to all of a host system’s resources of a certain type as this would block anyone else, including the host kernel, from accessing those resources. For example, never allow a virtual machine to have 4 vCPU on a 4 CPU host or have private access to 4 Logical Network cards on a host system with 4 physical NICs.
In general, if you have a large host server with a significant amount of available resources and a guest system that uses these resources at different points of time, it is likely that the hardware will be able to efficiently host a large number of VMs. If there is a risk that all the VMs will peak at the same time, however, this can be a risky strategy.

Following are some considerations to keep in mind for various resource types.

**CPU Concerns**

It is more and more common to have servers with a massive amount of available CPUs, particularly with modern hardware where Quad-, and Hexa-core CPUs (and beyond) are becoming standard.

One question that is frequently asked is whether there is a difference in performance between systems with, for example, 2 Quad-Cores CPU compared to a system with 4 Dual-cores. The answer is “yes” – in the same way as there are differences between all CPUs with different architectures this will also introduce differences. In this case, the difference depends mostly on access to the other resources, such as other cores, cache and external resources such as memory. However, since these types of sizing estimates by their nature are rough estimates, these differences can be ignored and a Hexa-core CPU considered roughly comparable to 6 single-core CPUs. For this reason, references to “CPU” going forward will refer to a single core within a CPU.

Hyper-threaded CPUs do add value since they have two instruction pipelines, however, since there is only one execution pipeline and, therefore, only one instruction that can be executed at any given point, you should only count this as one CPU for the purposes of establishing rough sizing calculations.

Fast CPUs are obviously good, but you cannot focus too much on the CPU frequency rating. Since different generations of CPUs, or CPUs from different vendors are often able to perform different tasks during one clock cycle, CPU frequency can be a very misleading performance indicator. While it is important to have fast CPUs it is also important to ensure that the CPU has large L2 and/or L3 processor caches. In fact, in a virtualized environment a large cache is often more important than the CPU frequency. In addition remember that modern CPUs often have features that allow them to better utilize each clock cycle. In an environment with different types of CPUs, however, these features are often disabled to allow hot migration between different CPUs.

Aside from the type of CPU in use, it is equally important to ensure that it is connected to a high performance server class motherboard. The performance of the bus that connects the CPUs with memory, other CPUs on the same motherboard and other peripheral component is critical to provide system with high performance.
In a virtual environment, the CPU is a resource that is almost always shared between virtual machines. The VMkernel is responsible for scheduling the available CPUs between the active virtual machines so that each VM has exclusive access to a CPU for a short time before offering it back to the scheduler. If a VM requests a CPU and they are all busy serving other VMs, this VM will have to wait until one is released. For this reason, it is critical to ensure that there is a sufficient amount of CPUs available in the host system.

In determining the number of required CPUs (cores) for a host server there are a few important things to consider:

- The host server always adds an overhead to the CPU usage. This overhead, which is likely to be between 6-20% (commonly less than 10%), must be taken into consideration during the sizing.
- In extreme cases where most virtual machines located on the same host are likely to peak at the same time, you might need to have as many physical CPUs available as the number of vCPU that are allocated to the virtual machines located on this host.
- If you, with certainty, can expect the guest OS to use resources at different times of the day you can use this information to co-locate them on an otherwise oversubscribed system.
- Low end virtual machines, such as file and print servers, can often massively oversubscribe to available resources, however you should exercise caution when tuning these machines and carefully monitor the system under expected peak load.
- Most virtualization platforms support virtual machines with multiple vCPU (SMP), however it is critical to realize that this often causes a significant overhead due to the additional need for organized scheduling.

For more details, see "Virtual Machines with Multiple vCPUs (SMP)" on page 55.
- Fast CPUs with large L2 and L3 cache can often be used efficiently to minimize the need for multiple CPUs. Keep in mind that comparing clock frequencies between different CPU families can be misleading.

When multiple Virtual Servers share CPUs another concern is that the different guest systems will affect the CPU cache and cause a worse cache hit ratio than what would be expected in a physical environment. As a result, the performance can be expected to become worse when the number of guest OS’s per host system and CPU increases. Advanced hypervisors are aware of this problem and their scheduling algorithms are trying to combat the effect of this in various ways. This can be partially addressed by using CPUs with larger CPU cache.
BIOS Configuration

Hardware vendors are adding more and more functions to support the efficient use of virtualization. Some of these functions are always enabled, however many are also configurable in the host system’s BIOS. Commonly controlled functions include direct Virtualization functions such as AMD-V / Intel-VT and AMD Rapid Virtualization Indexing (RVI) / Intel Extended Page Tables (EPT), as well as generic functions for cache and timers.

Typically, it is recommended that you enable all virtualization specific functions that are supported by your hypervisor (such as AMD-V / Intel-VT and AMD-RVI / Intel-EPT) and, in some cases, these may be required. In addition, unless the documentation provided with your hypervisor or virtualization guidelines for your specific applications recommends otherwise, you should also enable functions such as Hyperthreading and DCA (Direct Cache Access).

It may also be beneficial to enable HPET (High Precision Event Time). Depending on hypervisor and implementation of HPET, however, this can sometimes cause time drifts in virtual machines. If the HPET is significantly misreporting its frequency, you must disable it.

Finally, it is also recommended that you disable any power saving functions as well as any unneeded devices, such as serial and USB ports.

**NOTE:** Detailed guidelines for BIOS configurations depend on both the actual hardware in use, the Hypervisor that are being used and to a lesser degree what OS and types of applications that are being virtualized. It is highly recommended to find solution specific recommendation for your environment.

Memory (RAM) Concerns

Even though some modern virtualization hosts have a very intelligent memory management system, it might be unwise to extensively over-allocate memory if your applications are memory constrained.

A few important things to consider when it comes to memory utilization in a virtualized environment are:

- The virtualization always adds an overhead, both for the host system itself as well as for each one of the virtual machines.

For VMware this is:

- 272 - 800 Mb for the Service Console
  - Note: Service Console is not present in an ESXi environment.
- 100-200 Mb for VMkernel (estimate)
  - Depending on the required drivers.
Estimating Hardware Requirements

113 – 10328 Mb for each virtual machine

The actual requirement depends on factors such as OS, number of vCPU and allocated RAM. A guest system with up to 2 vCPU and 4 GB of RAM consumes 113 - 243 MB as overhead. See the vSphere Resource Management Guide for additional details.

For Microsoft Hyper-V this is:

- 512 MB or more for the root partition
- For each virtual machine you should assign 32 MB memory for overhead for the first GB of virtual RAM and another 8 MB for each additional GB.

Note: Since Hyper-V first allocates memory to the child partition, it is critical that you have additional memory available for the root partition. If you over-allocate memory the root partition will slow down all I/O and other operations performed by the root partition.

- Linux uses a different and more expensive technique of memory mapping when it has more than 896 MB of physical memory available. Therefore, when possible, try to limit the memory to a maximum of 896 MB when using Linux as the guest operating system.

- Some virtual engines are able to recognize if an identical page is already loaded in memory. Since this also applies between VMs it allows virtual machines with a similar profile (for example same OS) to share static memory pages.

- Through paravirtualization (drivers in the guest system that allow it to communicate with the host) some virtualization hosts can also borrow already allocated RAM from one virtual machine and re-allocate it to another virtual machine. An example of this is called “ballooning” within VMware.

- A significant risk with heavily oversubscribed memory is that it can cause double paging - where the host server swaps out memory to disk that has already been swapped out inside the virtual machine.

  This will significantly affect the performance of the system when this memory is once again addressed.

These points lead us to conclude that memory (RAM) can often be oversubscribed. However, the degree to which this is possible depends highly on the virtualization engines that are in use as well as the profiles of the guest systems. Therefore, memory allocation should be approached with great caution. For additional details on memory management see the following:

- Memory Resource Management in VMware ESX Server

- Performance Best Practices for VMware vSphere 4.0
Estimating Hardware Requirements

- vSphere Resource Management Guide
- Performance Tuning Guidelines for Windows Server 2008 R2
  http://www.microsoft.com/whdc/system/sysperf/Perf_tun_srv.mspx

Memory profiles can often be further tuned when you have access to the actual system and its performance statistics during simulated or real peak load. Details on how this can be done for Windows guests can be found in the section “Correct Memory Sizing for Child Partitions” in Performance Tuning Guidelines for Windows Server 2008 R2.

Network Bandwidth, I/O Concerns

NICs are often shared between virtual machines and, from a fault tolerance and performance point of view, this can provide an advantage since the VMs have access to a pool of teamed NICs. If a guaranteed response time is required, however, you should consider allocating dedicated NICs to your critical and network intensive applications.

Following are some important considerations regarding Network infrastructure and NICs:

- For efficient sharing of network resources it is recommended to use multiple, server class rated NICs (typically multi port NICs) with good performance.

- Using multiple NICs can also provide another layer of fault tolerance. If one of the teamed NICs, or the related Switch port, go down it does not necessarily block any of the VMs from accessing the network. Therefore, it is a good idea to have at least two physical cards. In other words, two dual port cards might be preferable to one single Quad Port card.

- The network interface cards/ports can typically be significantly oversubscribed in the sense that multiple virtual machines can share a smaller set of NICs.

- It is critical to ensure that the sum of the required/expected network I/O performance is available for all virtual machines at any given time. To get a complete picture you need to look at both the amount of available bandwidth as well as the number of transactions that can be handled per second.

Each pool of required NICs should also include an extra NIC for the purposes of redundancy.
Estimating Hardware Requirements

- Having access to multiple (often teamed) NICs also allows the Host to schedule peak load efficiently over multiple NICs and, therefore, give individual VMs better performance than they would have in a typical physical environment.

- Unless management traffic and hot migration events are infrequent, it is considered best practice to have dedicated NICs for the iSCSI traffic, the Service Console, and hot migration tools, such as VMOTION or Live migration.

- To minimize the CPU overhead in the host system it is recommended to verify what offload mechanisms are supported by your virtualization engine and network cards.

  Typically, stateless features such as Large Send Offload (LSO) and, Checksum Offload (CSO) and VLAN tagging (IEEE802.1Q), can be supported by virtualization engines, while stateful features, such as TCP Offload Engine (TOE) and Intel I/O Acceleration Technology (I/OAT), are not typically supported in virtualized environments.

  For more information see:
  - Performance Tuning Guidelines for Windows Server 2008 R2
    http://www.microsoft.com/whdc/system/sysperf/Perf_tun_srv.mspx
  - What is a TOE NIC and does ESX support any TOE NICs?
    http://kb.vmware.com/kb/1006143/

Storage Concerns

Disk I/O is a common bottleneck and it is highly recommended that you have dedicated physical high performance disks (preferably through SAN, based on FCoE, iSCSI or fibre channel infrastructure).

Certain technologies for 'thin provisioning of data storage assets' can efficiently spread the load over multiple physical discs; however, this needs to be carefully analyzed before use with business critical applications.

Following are several important arguments for using a SAN system:

- Additional flexibility for the storage administrator enables easier allocation of disk-space when it actually is needed.
  
  This is, of course, much more efficient than a traditional model where all disks that might be needed in a foreseeable future are allocated up-front.

- Separating the disk system from the physical server allows the VMs to quickly move between physical host servers. This can be used both for dynamic load balancing as well as high availability solutions.

- A high end SAN system is likely to have an advanced, large and quick cache system that can significantly enhance the disk I/O.
A common problem in smaller/simpler server configurations is the lack of I/O performance to the disk when multiple I/O intensive virtual machines are trying to access the same or a few disks at the same moment in time.

- It is critical that each disk intensive virtual machine have private access to at least one disk/Logical Unit Number (LUN).

- When using a high performance disk systems and applications with limited requirements on disk I/O you can often technically share LUNs between a few VMs. In VMware ESX, this is done with one shared VMFS per LUN. However, when doing this it is critical to carefully monitor the performance since poor disk I/O quickly can cause serious performance issues for the complete system.

- Applications that have extremely high requirements for good disk I/O often recommend multiple LUNs to provide optimal performance. This does not change in a virtual environment and, to guarantee the performance, it’s important that the logical disks actually end up on separate and private LUNs.

A typical example of this is high end MS-SQL installations, where a common recommendation is to have separated private LUNs for:

- Operating System
- Application (can often be co-located with the OS)
- MS SQL data files
- Transaction Logs
- Temp Database

For more detailed information about the requirement consult the best practice guide for your specific disk intensive application.

Finally, nearly all operating systems use page files on disk to complement the available memory (RAM). On a slow disk this can significantly slow down the performance of the virtual machine. Paging can be optimized through appropriate placement of the pagefile. Following are some recommendations for high performance systems:

- Locate the pagefile separately from other I/O intensive applications, such as OS and frequently accessed data stores.

- Do not locate the pagefile on a fault tolerant drive as this will typically slow down the write access to the data. Either way if the disk fails you are likely to have a system crash.

- Use multiple physical disks or a disk array for paging.
Advanced Configurations

The fact that virtual machines often share resources means that you need to take this in account when planning the environment, as well as when configuring the system for optimal performance and scalability. The primary considerations during the design phase focus on the creation of a sufficient infrastructure but it also includes ensuring that the individual virtual machines are optimized. One factor that can make a significant impact is how virtual machines handle and are assigned multiple vCPU.

In addition, there are also a number of methods for controlling how resources are shared between the guest systems. This document will only discuss a few examples. For more detailed information on this it is highly recommended that you review the documentation provided for the virtualization engines that you are planning to use. For VMware see http://www.vmware.com/pdf/Perf_Best_Practices_vSphere4.0.pdf, http://www.vmware.com/pdf/vi_performance_tuning.pdf and http://www.vmware.com/pdf/esx3_best_practices.pdf. For Microsoft Hyper-V see http://technet.microsoft.com/en-us/library/cc534980.aspx.

Virtual Machines with Multiple vCPUs (SMP)

In general, when using guest systems with multiple vCPU you should use as few virtual CPUs (vCPUs) as possible and, if reliable/repeatable performance is critical, ensure that you always have physical CPUs available for all scheduled vCPUs. Applications/virtual machines that require multiple CPUs for optimal performance can create specific challenges for virtualization. The underlying reason for this is that operating systems and applications that take advantage of multiple CPUs typically rely on them being readily and quickly available at all times. If not handled correctly, delays in inter CPU communication can cause either significant performance degradation or produce kernel panics/blue screen of death (BSOD) in the guest systems.

One of the most basic and common methods for handling this is to make sure that all vCPU that are allocated to a virtual machine are always scheduled together as a group (co-scheduled) and, therefore, always accessible for the virtual machine. This works fine if there is no or very limited oversubscription to the CPUs and a sufficient number of waiting CPUs. In a more realistic scenario, however, this will introduce a queue since the host will wait until it has all allocated resources available before dispatching them. For example, if a virtual machine is assigned 4 CPUs, the host cannot assign any additional CPUs until all 4 CPU are available. In addition, a guest system that has been assigned many vCPUs will tie up all of those CPUs even if it is only efficiently using one or two of them.
This is a well known problem that virtualization vendors have attempted to resolve through tuning and other approaches. For example, In ESX 3.x, VMware changed their scheduling from strict co-scheduling to what they call a relaxed co-scheduling algorithm. This made the performance hit smaller, but still significant and multiple vCPU should still only be used when the application truly take advantage of them. For additional details see http://www.vmware.com/files/pdf/perf-vsphere-cpu_scheduler.pdf, http://communities.vmware.com/docs/DOC-4960 and http://blogs.vmware.com/performance/2008/06/esx-scheduler-s.html.

Some important points to consider regarding the use of multiple vCPUs are:

- When applicable, consider implementing multiple, smaller VMs, rather than a few huge logical virtual servers.
  
  A prime example of this is placing the database on a separate server instead of including it on the same virtual machines as the application using the database.

- Only use multiple vCPUs when the application can truly take advantage of this, and even then, use as few vCPU as possible.

- If possible, test with one vCPU first and only add vCPU when needed.

- Uniprocessor (UP) versions of the HAL/kernel have less overhead than the corresponding SMP version. Always use the Uniprocessor version if you only have one vCPU.

  **Note:** Some of the newer operating systems, such as Windows Vista, Windows 7 and Windows Server 2008, use the same HAL for UP and SMP installations.

- If using VMware hosting virtual machines with multiple vCPU it is highly recommended to use the most recent version of ESX/ESXi. ESX 3.x / ESX 3i had some major updates, but the scheduler is constantly being enhanced.

- If reliable/repeatable performance is critical ensure that you always have physical CPUs available for all scheduled vCPU (this cannot be repeated often enough!).

- SMP often scale better in a 64bits environment. Consider using this if your application supports this type of environment.

  A typical example of this is MS-SQL 2005 which, when tested with multiple vCPU and high load, consistently scales better in a 64bits environment. For more details see http://www.vmware.com/files/pdf/SQLServerWorkloads.pdf
Controlling How Resources are Shared

Finally, we will also briefly cover a few common configuration options for virtualized environments. Unless otherwise noted, the specifics mentioned below pertain to VMware ESX / ESXi; however, most enterprise class virtualization engines are likely to have somewhat similar functionality.

Many of the settings discussed below can be controlled for both individual virtual machines as well as resource pools. Whenever possible, it is recommended that you use resource pools since the management of individual VMs can otherwise quickly get very complicated and hard to track.

- **CPU**
  
  In addition to the number of vCPUs allocated for a virtual machine this resource can be controlled in the following ways:
  
  - **Shares**
    
    Through shares you can define the priority for a virtual machine or a resource pool. The shares only matter when CPUs are a sparse resource.
  
  - **Reservations**
    
    Reservation allows you to reserve (guarantee) a certain amount of CPU cycles for specific business critical systems.
  
  - **Processor Affinity**
    
    Through processor affinity you can control on which physical CPU(s) the virtual machine will running.
    
    **Note:** Avoid using this option this unless you have compelling reasons to do so. Affinity introduces additional overhead and it does not work with VMotion.

- **Memory (RAM)**
  
  You can similarly control how RAM is shared between resources. It is the VMkernel that allocates a specific amount of physical RAM to the VMs. The allocations represent at least the reserved amount and not more than the defined limit.
  
  The VMkernel will often grant a virtual machine all of its configured RAM when it is started and then dynamically reclaims some of its memory if/when it’s not needed.
  
  The administrator can control the behavior using the following controls:
  
  - **Configured RAM**
    
    The amount of RAM the virtualized machines OS reports
  
  - **Limit**
    
    The maximum amount of RAM the VMkernel will allocate to this VM. By default this is “unlimited” or, in other words, the same as Configured RAM.
Reservation
Using reservation the administrator can guarantee that a certain amount of memory always is allocated.
This can be useful, for example, for databases that have significant performance hits when there is insufficient memory.

Shares
As with CPUs, memory shares controls which priority this VM or resource pool should have when the VMkernel need to prioritize who should get a limited amount of RAM.

Network
Network cards are often shared between multiple VMs. However it is important to be aware that the virtual network infrastructure is highly customizable in a number of ways:
- Traffic Isolation – send various types of traffic to separated subnets.
- Enhanced I/O performance and redundancy through NIC teaming
  By using NIC teaming you can give a virtual NIC access to multiple physical NICs to enhance performance and fault tolerance. If these physical NICs are also connected to different switches you can architect a very robust, fault tolerant solution.
- Dedicated NICs to administrative functions such as iSCSI, Service Console and VMOTION.
- Consider to dedicate Teamed NICs to network intensive VMs or resource groups.
- Note that VMware Tools/Paravirtualization (especially the vmxnet driver) can significantly enhance performance.
- Enhanced VMXNET can be used to support Jumbo Frames. Note, this also require specific version of OS (Windows 2003 EE or DE) and additional configuration in this guest OS.

Storage
Configuring the storage system depends on a large number of factors, including expected load, network, type of hardware, RAID system, cache, and more. You are strongly encouraged to read the following documents for additional details:
- Performance Best Practices for VMware vSphere 4.0
  http://www.vmware.com/pdf/vi3_301_201_san_cfg.pdf
Estimating Hardware Requirements

- **Server Configuration Guide** ("Advanced Networking" section for NFS Best Practices and "Configuring Storage" section for iSCSI information)

- For Hyper-V see the chapter "Performance tuning for Virtualization Servers" in the *Performance Tuning Guidelines for Windows Server 2008*

- For XenServer see the "Storage" chapter in the *XenServer Administrator's Guide 5.6.0*.
  See [http://support.citrix.com/product/xens/v5.6/#tab-doc](http://support.citrix.com/product/xens/v5.6/#tab-doc)

- The hardware vendor’s documentation of the specific disk/SAN system.
Chapter 3: Maintenance Considerations

It is important to track the performance profiles of the individual machines, as well as the virtualization hosts, both before and during the lifecycle of any virtualized environment in order to identify potential peak requirement periods. During the design phase this information can help you determine the most appropriate architecture for your solution. Continued analysis after deployment can help pinpoint when tuning is required and when adjustments need to be made to improve performance.

For example, consider a typical environment in which, at the end of every workday, a majority of the users:

- Send an email, synchronize email folders and then logout from the mail server.
- Run reports to prepare for the following day’s activities.
- Print out these reports and, perhaps, additional supporting documents to bring with them and study from home.
- Make backup copies of a number of important files to a folder on a file server.

Another example is when unplanned events/faults occur which then trigger activity on multiple systems:

- A fault trigger fault management systems to alarm, do root cause analysis and likely to handle event storms and certain automation tasks.
- The end users notice the problem and uses knowledge tools and Service Desk to find out if the problem is known and otherwise report it.
- The operations and the helpdesk team get the alert from the fault management and service desk system and connect to the Service Desk, CMDB, Asset Management, Network and System Management Tools etc to troubleshoot and correct the issue.

If the applications all share a common host system whose requirements are based on ordinary usage you might expect that these VMs would slow down substantially in response to the higher peak load resulting from the near simultaneous performance hit from these activities by hundreds or thousands of users.

By tracking the consumption of critical resources over time it is possible to identify patterns of resource usage by servers and use that knowledge to pair virtual machines that stress different types of resources or that stress the system at different points in time.
These performance profiles should be used to establish a baseline that can be monitored so that you can see how resource utilization changes over time. This knowledge can be used to:

- Identify which virtual machines are requiring more or less resources over time. This can be used for both strategic as well as tactical resource allocation.
- Pinpointing servers that potentially aren’t in use and, in this way, assist in minimizing Virtualization Sprawl.

Most of the major virtualization vendors, including VMware, Microsoft and Citrix, tend to focus more and more on tools to assist with management of the virtualized environment and their performance; however, you often need additional tools to correctly manage the bigger picture. Regardless of the tools you select, you should be sure to incorporate careful planning, along with personal experiences with how certain applications are likely to require additional resources. This is especially important since many applications often experience peak load at the same time and having multiple machines request more resources at the same might put significant load on the host machine.

Combining performance profiles with knowledge about the company’s activities allows the system manager to optimize the resources for individual virtual machines as well as to make sure they are paired on hosts with other virtual machines that, if at all possible, are using different resources or experience peak load at different times.

It is important that the system manager have a deep understanding of the overhead of various virtual machines and how tuning options affect the overall health of the environment. Typical options for optimizing virtual resources include:

- Allocating dedicated and shared resources
- Re-allocating existing resources between VMs
- Moving an existing VM to a new host
- Optimizing and tuning the individual VMs

There are several documents available on this topic and it is highly recommended that the system manager become familiar with them. Following are a few useful links to consider:

Optimization Strategies

- Performance Best Practices and Benchmarking Guidelines (ESX/ESXi 3.5)  

- “Performance Tuning Best Practices for ESX Server 3”  
  (http://www.vmware.com/pdf/vi_performance_tuning.pdf). This document references an additional document which includes further details.

- VMware Resources (Whitepapers, Technical Papers, Documentation etc.)  
  http://www.vmware.com/resources/

Allocating Dedicated and Shared Resources

Although most modern enterprise class virtualization hosts include intelligent methods for sharing over-allocated resources among guests, there are a number of physical limitations to keep in mind. In situations where resources are known bottlenecks, but where predictable response times are required, it is wise to dedicate hardware for individual virtual machines – or, at least, to make sure that there are always resources available.

It is important to identify which virtual machines require which type of dedicated hardware and in what way shared resources can be controlled in order to manage resource consumption. Important resources to monitor include Storage (Physical Disks), CPU, Memory (RAM), Network Cards (NICs).

For more information on considerations for these resources, consult the section “Moving to a Virtual Environment” on page 47.

Re-allocating Existing Resources Between VMs

Although similar to what is mentioned above, reallocating existing resources between VMs requires a more thorough analysis of the ongoing and expected resource consumption of the logical servers. VMware includes utilities to handle this automatically but, typically, this requires intelligent automation tools and/or manual intervention – and this is where performance profiles and baselines can be truly useful. The key here is that we are talking about re-allocating resources. If you add resources to one virtual machine you typically need to remove the corresponding resource from another logical machine on the same host.

Move an Existing VM to a New Host

After analyzing the performance profiles for both virtual machines and the actual host system you might consider reorganizing which virtual machines are running on which host systems - or you may decide to move all virtual machines to a new host to allow for maintenance.
If you have systems with “hot migration” (such as VMOTION, XenMotion, Live Migration or similar) and a well planned out disk storage system on a SAN this is not a very complex task. However, it should normally not be done to handle a short term peak. Rather, the ideal is to be proactive and to plan ahead to see when a guest OS needs to be transferred to a new system.

Regardless of the optimization approach you take, it is important to realize that virtualization always adds overhead. You cannot simply add the resource requirements for the individual guests to derive an estimate for the host system. You also need to consider peak period requirements and remember that applications hit their peaks at the same time or during similar situations.

Other important items to consider are:

- According to Network Computing (April 2nd 2007) the overhead of VMware ESX is typically less than 10% (low of 6%, highs of 20%).
- Make sure you provide sufficient memory for memory intensive applications (such as IIS, and SQL depending on the query type). However, avoid over-allocating it on applications that do not use it.
- Having multiple applications which employ intensive disk-access (where the bottleneck is I/O) will significantly affect performance unless you can off-load each application’s data storage to a dedicated physical disk.
- To be able to efficiently manage the VMs you need to have the virtual disks on separate disk systems using high performance SAN solutions based on iSCSI, FCoE or fibre channel. This will significantly simplify your management of virtual machines and their disk requirement, both by allowing you to grow/shrink required disk space and, more importantly, to simplify any migration of virtual machines between host systems.

Optimizing and Tuning the Individual VMs

Although all of these measures are important, you should not overlook the importance of analyzing the actual VM machine to determine if it would benefit from basic internal tuning steps.

In a non-virtualized environment this type of tuning is recommended, but often not critical; however, since any unnecessary usage of resources in a virtualized environment penalizes other applications it becomes critical to ensure this if the virtualized environment is to run efficiently.
A few examples are:

- **Disable/uninstall screensavers and other unnecessary applications**
  
  During the creation of any server system you should avoid installing, or even uninstall, any applications that are not going to be used. This applies to all types of application and utilities since this minimizes the risk for security exposures. However, it is especially important for tools that might perform heavy calculations, such as 3D screensavers or multimedia tools.
  
  **Note:** No server needs a 3D screensaver and very few servers require a mediaplayer. This is true for both virtualized and non-virtualized servers.

- **Disable services and daemons that aren’t in use and/or required**
  
  One of the great advantages with virtualized servers is that it is easier to have complete control over the system and, therefore, it is easier to remove unused services and daemons from a virtual machine so it becomes more like a “Virtual Appliance”. If this is done correctly it can enhance both security and performance significantly.
  
  Note that this does require quite a good understanding of both the application as well as the guest operating systems and, any changes that are made require a significant quality assurance effort.

- **Disable/disconnect unnecessary devices in host and guest systems**
  
  Devices connected to the guest and/or the host system consume various types of resources and should, therefore, be disabled or disconnected on systems that aren’t using them.
  
  A few examples of resources that might be considered for this are:
  
  - Serial (COM) and Parallel (LPT) ports
  - Floppy/CD/DVD drives
  - USB / FireWire Adapters
  - Network Interface Cards
  
  Disabling these devices frees up IRQ resources and eliminates conflicts. Many of these resources also consume CPU through polling especially in a virtualized environment. Finally, having multiple virtual machines polling the same physical device can sometimes cause delays due to contention.
  
  **Note:** When these changes are made on a host that is part of a load balancing scheme it is important to make sure that none of the potential guests requires the specific resource. If not, the migration of this guest will likely fail.
- **Schedule supporting back office jobs during off-peak hours**

  This is something that is likely to have been done long before any virtualization project was implemented so the chances are good that a lot of the basic data on when to run various procedures is already available. However, this task is significantly more complex in a virtualized environment since you now need to take into consideration the load from all other virtual machines running on the same host. And, to complicate this further, since the organization is also likely to be using some type of dynamic load balancing (such as “hot migration”) this is a moving target.

  As a result, scheduling procedures, such as antivirus scanning, software updates and backups, in a virtualized environment is not a trivial task. However, a good performance reporting tool can provide a huge advantage when it comes to estimating the load on both the individual virtual machines as well as the host system while the various back office procedures are running.
Appendix A: References and Links

The following resources were used in this document:

Vendors Whitepaper, Homepages, technical notes etc…

- **3PAR Thin Provisioning**
  [http://www.3par.com/library.html](http://www.3par.com/library.html)

- **Citrix**
  - Citrix Essentials
    [http://citrix.com/essentials](http://citrix.com/essentials)
  - Citrix XenServer
    [http://citrix.com/xenserver](http://citrix.com/xenserver)
  - XenServer 5.6 Documentation
    [http://docs.vmd.citrix.com/XenServer/5.6.0](http://docs.vmd.citrix.com/XenServer/5.6.0)
  - XenServer 5.5 Documentation
    [http://docs.vmd.citrix.com/XenServer/5.5.0](http://docs.vmd.citrix.com/XenServer/5.5.0)
  - XenServer 5 Documentation
    [http://docs.xensource.com/XenServer/5.0.0](http://docs.xensource.com/XenServer/5.0.0)
  - XenServer Knowledge Center

- **IBM Virtualization**

- **Microsoft**
  - Microsoft Virtualization Home Page
  - Introducing Windows Server 2008 Hyper-V
  - Microsoft Hyper-V Server 2008
  - Hyper-V: Guest Operating System Support
Microsoft Technet on Hyper-V

Microsoft Technet: Hyper-V Hardware Consideration

Windows 2008 Server Update: Release Version of Hyper-V
http://support.microsoft.com/kb/950050

Windows Server 2008 R2 Resources (including the Reviewers Guide)

Microsoft System Center Virtual Machine Manager
http://www.microsoft.com/systemcenter/virtualmachinemanager/

Managing SQL Server 2005 Peer-to-Peer Replication
http://www.microsoft.com/technet/technetmag/issues/2006/07/InsideMSFT/
by David Lindquist

Microsoft KB 918461
“The system time runs too fast on a Linux-based virtual machine that is hosted in Virtual Server 2005 R2”

Oracle VM
http://www.oracle.com/technologies/virtualization/

Sun Microsystems Virtualization Solutions
http://www.sun.com/solutions/virtualization

SWSof Virtuozzo - White Paper
“Top Ten Considerations for choosing a server virtualization technology”

VMware Whitepapers, technical notes etc...

Overview VMware specific technical resources
http://www.vmware.com/technical-resources/

VMware Technical Resource Center – Technical Papers
http://www.vmware.com/resources/techresources/

VMware Documentation
http://www.vmware.com/support/pubs/

Performance Best Practices for VMware vSphere® 4.0
References and Links

- VMware vSphere 4 – the CPU Scheduler in VMware ESX 4

- Configuration Maximums – VMware vSphere 4.0

- What’s New with VMware vSphere 4
  http://www.vmware.com/products/vsphere/upgrade-center

- Performance Tuning Best Practices for ESX Server 3, available at

This includes:
- Mismatched HALs – KB Article 1077
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=1077
- IRQ Sharing – KB article 1290
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=1290
- Idle Loop – KB article 1730
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=1730
- CPU Utilization – KB Article 2032
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=2032
- Network Throughput between Virtual Machines – KB article 1428
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=1428
- Queue depth on QLogic – KB article 1267
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=1267
- Guest Storage Drivers - KB article 9645697
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=9645697
- Disk Outstanding commands parameter - KB article 1268
  http://kb.vmware.com/selfservice/microsites/search.do?cmd=displayKC&externalId=1268
- Timekeeping in VMware Virtual Machines
  http://www.vmware.com/resources/techresources/238
  http://www.vmware.com/resources/techresources/240
- VMFS partitions – “Recommendations for aligning VMFS Partitions”
  http://www.vmware.com/resources/techresources/608
References and Links

- Esxtop – Using esxtop to Troubleshoot Performance Problems” (http://www.vmware.com/resources/techresources/436)
- Details of What's New and Improved in VMware Infrastructure 3 version 3.5
- Configuration Maximums - VMware Infrastructure 3
  “Time in Linux 2.6 guest operating system runs faster than real time due to lost tick overcompensation”
  http://kb.vmware.com/kb/1006113
- VMware KB 2219
  “Linux guest clock runs slowly on ESX Server 3.0”
  http://kb.vmware.com/kb/2219
- VMware KB 1002742
  “Time is Running Ahead/Too Fast in a Windows 2003 Virtual Machine”
  http://kb.vmware.com/kb/1002742
- What is a TOE NIC and does ESX support any TOE NICs?
  http://kb.vmware.com/kb/1006143/
Research and Reports

- **Clabby Analytics Research**
  “CA's Unicenter Advanced Systems Management: Virtualization Cluster Management for Heterogeneous Environments”
  http://whitepapers.windowsecurity.com/whitepaper2540/

- **Forrester Research, Inc**
  “Server Virtualization Reaches A Majority Of Firms, Spurring Initial Adoption Of Cloud Computing”

- **Gartner Inc.**
  - Workloads Running in Virtual Machines
    http://www.gartner.com/it/page.jsp?id=1211813
  - Virtualized Servers and security
    http://www.gartner.com/it/page.jsp?id=1322414
  - Virtualization Trends
    http://www.gartner.com/it/page.jsp?id=638207

- **Information Technology Intelligence Corp.**
  http://itic-corp.com/category/virtualization

- **USENIX Association**
  Proceedings of the 5th Symposium on Operating Systems Design and Implementation (Memory Resource Management in VMware ESX Server) by Carl A. Waldspurger, VMware, Inc., available at:

Virtualization Magazines and Articles

- **Baseline** *(Where leadership meets technology)*
  - March 2007 (issue 070) "Virtualization Beyond the Buzz" by Michael Vizard
    http://www.baselinemag.com/article2/0,1540,2100143,00.asp
• April 2007 (Issue 071)
  http://www.baselinemag.com/article2/0,1540,2113063,00.asp
  – “Virtualization: For Servers, a Disappearing Act” (Less hardware is good, but immature technology isn’t. With new products on the way, companies may find better methods to speed up virtual server deployments and cut costs.) by Brian P. Watson
  – “Microsoft: Ramping Up” by Brian P. Watson
  – “VMware: Speeding Ahead” by Brian P. Watson
  – “XenSource: Aiming High” by Brian P. Watson

• Channel Insider
  • February 27, 2009
  “Free Citrix XenServer for Everybody” by Sharon Linsenbach
  http://www.channelinsider.com/c/a/Networking/Free-Citrix-XenServer-For-Everybody/

• CIO – Business Technology Leadership
  • June 15th 2007
  “Thinking Inside the Boxes” or “How Server Virtualization Tools Can Balance Data Center Loads” by Katherine Walsh
  http://www.cio.com/article/117256/
  – “ABC: An Introduction to virtualization”
    http://www.cio.com/article/40701/
  – “Taking Virtual Servers to the next level”
    http://www.cio.com/article/122950/
  – “Server Virtualization Snapshot”
    http://www.cio.com/article/106950/
  – “The Virtues of Virtualization”
    http://www.cio.com/article/11855/
  – “The Benefits of Consolidation and Virtualization”
    http://www.cio.com/article/21970/

• July 15th 2007
  “Virtual Possibilities” or “Taking Virtual Servers to the Next Level” by Thomas Wailgum
  http://www.cio.com/article/122950/ - same article as “Taking Virtual Servers to the next level” from June 15th
**CommunicationsNews** May 2007:

- “Virtualization Takes Hold” (Enterprise data centers embrace new/old technology to better utilize resources, but security, compliance and mobility issues must be addressed.) by Jeff Jilg
  

- “The Namespace Option” by Panos Tsirigotic:
  
  [http://comnews.com/stories/articles/0507/0507namespace_option.htm](http://comnews.com/stories/articles/0507/0507namespace_option.htm)

- “Virtual machines go mobile” (Optimization software shrinks files to improve portability and performance.)
  
  [http://comnews.com/stories/articles/0507/0507v_machines_go_mobile.htm](http://comnews.com/stories/articles/0507/0507v_machines_go_mobile.htm)

- “Security Rules Have Changed” (New solutions are necessary to protect virtualized networks.) by John Peterson
  

- “The phantom menace: Security (Protecting the virtualized network is different from previous network security practices)” by Allwyn Sequeira
  
  [http://comnews.com/stories/articles/0507/0507the_phantom.htm](http://comnews.com/stories/articles/0507/0507the_phantom.htm)

- Related Online material:
  
  - “Virtualized versus traditional blade platforms” (Server consolidation has become a key strategy for reducing data center costs.)
    

  - “Virtualization and IT service assurance” (Proper monitoring and management of virtualized environments is essential to address performance problems.)
    

  - “Virtually insecure” (Address the security implications of a disruptive technology.)
    

  - “Common mistakes when consolidating servers” (Avoid potential pitfalls by planning ahead.)
    
    [http://comnews.com/stories/articles/0507web/0507cirba.htm](http://comnews.com/stories/articles/0507web/0507cirba.htm)
- **ComputerWorld**
  November 2007 "CA Launches virtualization management tool" by Matt Hambleon

- **Custom Systems Magazine**
  March 2007 "Fitting More Apps into fewer boxes” by David Gilbert.

  - November 27th 2006
    "Unicenter Goes Virtual” By Paula Musich
    [http://www.eweek.com/article2/0,1759,2064622,00.asp](http://www.eweek.com/article2/0,1759,2064622,00.asp)
  - March 12th 2007
    - “Competition heats up” (VMware, Virtual Iron, Parallels roll out enhanced virtualization offerings) by Scott Ferguson
    - “Isilon boosts storage management” (Data migration between multiple tiers of clustered storage) by Chris Preimesberger
  - April 2nd/9th 2007
    "Xen Expansion” (Open Source Virtualization project moves from bleeding edge to deployment ready) by Jason Brooks
    [http://www.eweek.com/article2/0,1895,2107810,00.asp](http://www.eweek.com/article2/0,1895,2107810,00.asp)
    - “Iron-clad server virtualization” (Virtual Iron 3.5 offers a flexible low cost solution)
      [http://www.eweek.com/article2/0,1895,2107811,00.asp](http://www.eweek.com/article2/0,1895,2107811,00.asp)
    - Linux Kernel to add VMI
      [http://www.eweek.com/article2/0,1895,2107818,00.asp](http://www.eweek.com/article2/0,1895,2107818,00.asp)
  - May 7th 2007
    "Stretching your resources” – (Amazon.com elastic compute cloud allows ad-hoc VM deployments) by Jason Brooks
    [http://www.eweek.com/article2/0,1895,2124973,00.asp](http://www.eweek.com/article2/0,1895,2124973,00.asp)
    - Enomalism helps manage VMs
      [http://www.eweek.com/article2/0,1895,2124901,00.asp](http://www.eweek.com/article2/0,1895,2124901,00.asp)
    - esxRanger ably backs up VMs
      [http://www.eweek.com/article2/0,1895,2124944,00.asp](http://www.eweek.com/article2/0,1895,2124944,00.asp)
References and Links

- May 21st 2007
  http://www.eweek-digital.com/eweek/20070521_stnd/
  “Virtualization comes into focus” (desktop users look for better pc management) by Scott Ferguson
  http://www.eweek.com/article2/0,1895,2131524,00.asp
  - VMware adds Linux’s Paravirt-ops Virtualization
    http://www.eweek.com/article2/0,1895,2128344,00.asp
  - Virtual Iron, provision networks take on desktop virtualization
    http://www.eweek.com/article2/0,1895,2114414,00.asp
  - uXcomm Takes on Virtualization with acquisition
    http://www.eweek.com/print_article2/0,1217,a=204426,00.asp
  - XenSource prepares latest Virtualization Release
    http://www.eweek.com/article2/0,1895,2109856,00.asp
  - Novell adds Virtuozzo Virtualization to SLES
    http://www.eweek.com/article2/0,1895,2104847,00.asp

- June 11th 2007
  http://www.eweek-digital.com/eweek/20070611_stnd/
  “Expanding Virtualization’s reach” or “Vendors are attempting to expand the reach of virtualization” – (VMware rolls out utility computing for hosting companies) by Jeffrey Burt & Scott Fergusson
  “VMware expands Virtualization Options” by Jason Brooks
  http://www.eweek.com/article2/0,1895,2142436,00.asp
  - “VMware releases full version of ACE 2 Software” by Scott Ferguson
    http://www.eweek.com/article2/0,1895,2130437,00.asp
  - “VMware tries it hands at utility computing” by Scott Ferguson
    http://www.eweek.com/article2/0,1895,2142149,00.asp
  - “ClearCube, VMware partner on Virtualized Desktops” by Scott Ferguson
    http://www.eweek.com/article2/0,1895,2136424,00.asp
  - “VMware latest Virtualization Software supports Vista” by Scott Ferguson
    http://www.eweek.com/article2/0,1895,2128067,00.asp
  - “VMware’s VI3 Suite Delivers on Virtualizations promise” by Jason Brooks
    http://www.eweek.com/article2/0,1895,2095585,00.asp
- “IBM Launches new Virtualization Tools” by Scott Ferguson
  http://www.eweek.com/article2/0,1895,2094523,00.asp
- “Adoption of Virtualization Continues to grow: Report” by Scott Ferguson
  http://www.eweek.com/article2/0,1895,2094148,00.asp

- May 7th 2008
  Virtualization Evolves into Disaster Recovery Tool
  http://www.eweek.com/c/a/IT-Infrastructure/Virtualization-Evolves-into-Disaster-Recovery-Tool/

- November 25th 2008
  “Cross-Platform Tools Needed to Combat Virtualization Sprawl” by Cameron Sturdevant

- December 2nd 2008
  “Server Virtualization: A Five-Year Roadmap” by Chris Preimesberger

- February 23rd 2009
  “Citrix, Microsoft Aim to Corner Virtualization Market” By Nicholas Kolakowski

- March 5th 2009

- **Federal Computer Week**
  Dec 04, 2008 “6 tips for server virtualization”
  http://fcw.com/articles/2008/12/04/6-tips-for-server-virtualization.aspx
References and Links

- **Information Week**
  - Dec 18th/25th 2006 “Virtual Payoff In the Real World” by Charles Babcock
    - “Making the best of Both Worlds (Virtualization software brings the same management challenges as physical serves to virtual machines)” by Charles Babcock
      http://informationweek.com/1119/virtual.htm
    - “Microsoft Opens Virtualization Standard in Gambit Against VMware (Microsoft has previously opened specs in only Web services arena, where it faces tougher open standards competition.)” by Charles Babcock
      http://informationweek.com/1119/vmware.htm
    - “Microsoft And Xen Team For Virtualization (With this move Microsoft is expanding its support of virtualization in its most advanced software, and it’s doing so in a way that uses fewer system resources than past approaches)” by Charles Babcock
      http://informationweek.com/1119/xen.htm
  - March 12th 2007 “Desktop Virtualization: VMware Eyes New Pastures” (Virtualizes hundreds or thousands of PCs and Notebooks, sends a set of virtualized files over the network-executed locally, Remote Control, Pocket ACE allows virtual desktops to be loaded on iPods or flash drives…) by Charles Babcock
    - “VMware Accuses Microsoft of Restricting its Customers (Microsoft’s virtualization technology shuts out third parties, the vendor claims)” by Charles Babcock (March 10 2007)
      http://informationweek.com/1128/vmware.htm
  - April 9th 2007 “Citrix Seizes The Moment For Desktop Virtualization” (VMware ACE 2, Citrix Desktop Server to serve desktops for the end users) by Charles Babcock
    - “VMware Looks To Virtualize The Desktop (Virtualization may make desktops and laptops more secure and easier to manage)” by Charles Babcock (March 10 2007)
      http://informationweek.com/1129/vmware.htm
  - June 11th 2007
    “How 9 Hot Technologies can blow up in your face” / “Virtualization Threats Ahead” and VMwares new equation (Virtualization + SAAS)by Charles Babcock (cbabcock@cmp.com)
    http://www.informationweek.com/software/showArticle.jsp?articleID=199902576
References and Links

- June 25th 2007 “Virtual Desktop May Take Awhile To Become Real” by Charles Babcock
  http://www.informationweek.com/story/showArticle.jhtml?articleID=200000171
  - VMWARE’S APPROACH
    http://informationweek.com/1129/vmware.htm/
  - HP, VMware Teaming Up To Use Server Virtualization To Replace PCs
    http://www.informationweek.com/showArticle.jhtml;jsessionid=FT44IMWWJZSXSQSNDLRSKHSCJUNN2JVN?articleID=193600083

- July 16th 2007 “A Virtualization Bargain” by Joe Hernick (jhernick@nwc.com)
  http://www.informationweek.com/1146/xenenterprise.htm
  - Full Assessment: Find our testers notebook.
    http://www.informationweek.com/1146/notebook.htm
  - More Numbers: Get the complete result of our tests:
    http://www.informationweek.com/1146/benchmark.htm
  - Take a Look: Screenshots at XenEnterprise:
    http://www.informationweek.com/1146/gallery_xen.htm
  - Microsoft Play: Viridian coming soon, short some key features:
    http://nwc.com/go/ms-virtual/
  - What’s next? All eyes are on I/O virtualization technology:
    http://nwc.com/go/iov/

- July 23rd 2007
  “Virtual Machines in motion: Live Migration Adds to Appeal” by Charles Babcock
  http://www.informationweek.com/story/showArticle.jhtml?articleID=201200284
  - It all adds up: The practical realities of virtual data centers:
    http://www.informationweek.com/1146/datacenters.htm
  - Virtual XEN: open Source virtualization software is a bargain:
    (same article as “A Virtualization bargain” from July 16th)
  - Friends in high places: Intel Invests $218 million as VMware preps IPO:
    http://www.informationweek.com/1145/intel.htm
August 13th 2007
“Virtualization: Key To Linux’s Future or a Linux Killer” by Antones Gonsalves (antoneg@pacbell.net)
http://www.informationweek.com/showArticle.jhtml?articleID=201400215

Distribution lists
– http://www.informationweek.com/software/showArticle.jhtml?articleID=199202005&cid=RSSfeed_IWK_News “SUN SEES VIRTUALIZATION WITHOUT VMWARE OR XEN” (The company’s investment in its Live-Star project could translate into improved software and security distribution models.)

InfoStor
March 2007 - "HP Enhances Virtualization, security"
http://www.infostor.com/index/articles/display/284541/articles/infostor/storage-management/virtualization/hp-enhances-virtualization-security.html
By Kevin Komiega

June 2007 – “EMC Unites SRM, VMware” by Dave Simpson

InfoWorld
InfoWorld Virtualization Homepage
http://www.infoworld.com/d/virtualization

Virtualization Report – David Marshall
http://www.infoworld.com/blogs/david-marshall

Network Computing
April 2nd 2007 “The Virtualization Drag (VMware can help you save money and gain flexibility, but there will be trade-offs. We took to the lab to determine where performance hits will come from, and how to minimize them)”
http://www.networkcomputing.com/showArticle.jhtml?articleID=198700359
by Michael Caton
- **Network World**
  - November 27th, 2006
    “CA Unicenter to manage Virtual Servers” –by Denise Dubie
  - June 11th, 2007
    “10 Free virtualization tools worth a look” (including links) by Dennis Connor
    - Why Virtualization is cool - Virtualization is heavily over hyped
      Podcast/MP3 – Ann Winblad interviewed by Beth Schultz
    - Microsoft “Shoot to high” on virtualization, says exec by John Fontana, May 17th, 2007
    - “Microsoft lays out Windows server road map” by John Fontana, (May 16th, 2007)

- **SearchServerVirtualization.com**
  - Archive
  - February 5, 2009
    “Hyper-V vs. VMware: Which is cheaper” by Bridget Botelho

- **Smart Enterprise**
  - The Power of Virtualization
    Virtualization is surging. But only with effective management can the technology accelerate time to market, drive operational excellence, and reduce both IT and business risk.
    [http://www.smartenterprisemag.com/showArticle.jhtml?articleID=223000346](http://www.smartenterprisemag.com/showArticle.jhtml?articleID=223000346)
References and Links

■ Fall 2009 - "Virtualization Takes Shape"
As virtualization expands to take on mission-critical production workloads, CIOs are making sure to manage physical and virtual resources in a unified, integrated manner.
http://www.smartenterprisemag.com/showArticle.jhtml?articleID=220700478

■ Winter 2009 - "Right Time, Right Technology"
http://www.smartenterprisemag.com/showArticle.jhtml?articleID=212902583

■ Winter 2009 - "Data Center 2.0"
http://www.smartenterprisemag.com/showArticle.jhtml?articleID=212902344

■ Fall 2007 - "Virtualization Goes Mainstream"
http://www.smartenterprisemag.com/articles/2007fall/researchwatch.jhtml

■ Spring 2007
“Virtually Efficient” (Virtual servers can bring greater efficiency and flexibility. But CIOs must first have a strategy to effectively manage these new environments.) by Amy Larsen DeCarlo
http://smartenterprisemag.com/articles/2007spring/enterpriseitmanagement.jhtml

■ Virtualization Review

■ February/March 2009
"Lab Experiment: Hypervisors“ by Rick Vanover
http://virtualizationreview.com/articles/2009/03/02/lab-experiment-hypervisors.aspx
Appendix B: Virtualization Checklists

Any virtualization project requires thorough planning and careful consideration of which applications to virtualize, in what order and pace to virtualize them, what hardware to use, how to configure the environment and who should be responsible for various parts of the project.

This appendix presents several checklists that can be used as a starting point for planning your virtualization project. These checklists are far from complete, however, our intent is to highlight some of the more important questions that the project team needs to consider. It is highly recommended that the project team conduct additional brainstorming meetings to further evaluate other factors that are important for your organization’s particular needs.

Identify Virtualization Candidates

A key part of any virtualization project deciding which servers / applications should be virtualized and prioritizing when and in what order they should be virtualized.

It is highly recommended that all of these considerations be included in the plan, but the actual virtualization implementation should be realized in phases using an open project plan that can take advantage of any lessons learned.

List and Prioritize Servers/Applications/Solutions

List all Servers / Applications / Solutions that you are planning to virtualize:

<table>
<thead>
<tr>
<th>Server / Solution</th>
<th>Description</th>
<th>Timeframe</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
For each one of these, answer and/or consider the following questions:

**Generic Questions for Guest Systems**

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>List all applications that will be included in this Virtual Machine.</td>
<td></td>
</tr>
<tr>
<td><strong>Note:</strong> Unless the applications require or benefit significantly from being co-located it is recommended that you separate applications into private guest systems.</td>
<td></td>
</tr>
<tr>
<td>Is the application(s) supported in a virtualized environment and specifically in the virtualization environment that you are planning to use?</td>
<td></td>
</tr>
<tr>
<td>Acceptance from primary application owner/users?</td>
<td></td>
</tr>
<tr>
<td>Status/prior experience with these applications? For Example:</td>
<td></td>
</tr>
<tr>
<td>▪ Is it a new application?</td>
<td></td>
</tr>
<tr>
<td>▪ Will a new release of the application to be installed in virtual environment?</td>
<td></td>
</tr>
<tr>
<td>▪ Will an identical release of the application be moved into a virtualized environment?</td>
<td></td>
</tr>
<tr>
<td><strong>Note:</strong> If possible/applicable gather performance data from an existing implementation of the application. To get a complete load profile, including when peak loads are expected, try to collect this data over a period of time during which such peaks would occur. Also, take note of other caveats and experiences from earlier implementations.</td>
<td></td>
</tr>
</tbody>
</table>
### Item

What are the business drivers for virtualization?

- Saving on Hardware Budget
- Saving Floor Space
- Saving Energy / Green IT
- Maintenance / Management
- High Availability
- Load Balancing / Flexibility
- Improved Service / Agility
- Security
- Other...

**Note:** Document all applicable business drivers, but prioritize them to indicate order of importance.

Classify/describe these applications and identify where they fit into “Areas where virtualization provides quick value” as described in “Virtualization Best Practices”.

Examples could be:

- Test Environments / QA / Support
- Demo Environment
- Low utilized application server
- Worker nodes for applications that can scale out on additional nodes.
- Application Server with predictable load
- Application Server with unpredictable load
- Application Server with consistent high load
- Other...

Specify expected load on the system:

- If possible reference back to historic data
- Specify peak period and expected fluctuation during off-peak periods
- Specify events that are expected to trigger high load
Will the virtual machine always be active/enabled?

If not, document the expected schema or rules of engagement when it will be active.

Does the application have real time or near real time requirements?

**Note:** Virtual machines are typically not suited for real time applications.

### Configuration of Guest System

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System for the virtual machine</td>
<td></td>
</tr>
<tr>
<td>Ensure that the OS listed above is supported by the host system.</td>
<td></td>
</tr>
<tr>
<td>How many vCPUs should be assigned to the guest?</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> Multiple CPUs can be used; however, it will cause a significant overhead. Do not over allocate the number of vCPUs without a good reason. Also, make sure you have the latest version of your virtualization engine and servers where CPU isn’t a scarce resource.</td>
<td></td>
</tr>
<tr>
<td>Configure virtual machines that only use one CPU to use a Uniprocessor version of the HAL/kernel.</td>
<td></td>
</tr>
<tr>
<td><strong>Note:</strong> Some OS, such as Windows 2008 Server, do have a common HAL for both UP and SMP systems.</td>
<td></td>
</tr>
<tr>
<td>How much RAM will be associated with this guest?</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> If a predictable result is required, ensure that all configured RAM is available when needed (for VMware look at Shares vs. Reservation of resources). Hypervisors often have an intelligent memory management system; however over-allocation of resources introduces a significant risk to affect performance.</td>
<td></td>
</tr>
</tbody>
</table>
If feasible, avoid allocating more than 896 Mb to Linux based guest systems.

This to make the memory management in the Linux kernel more efficient.

How many NICs are needed by this guest and of what speed? Will they be using dedicated or shared physical NICs?

**Note:** Sharing physical NICs between guest systems is often acceptable, but dedicated NICs are recommended for network intensive applications that require predictable performance.

Use a minimalist OS

- If Windows Server 2008 is used, and the virtualized application supports it consider using the CORE version.
- If using Linux/Using consider disabling the windows manager and other components that aren’t required.

Disable or uninstall unnecessary applications.

This can include:

- All screensavers
- Multimedia tools
- Gadgets that are auto started but not required

**Caution:** Make sure these aren’t required for any part of the application.

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>If feasible, avoid allocating more than 896 Mb to Linux based guest systems.</td>
<td></td>
</tr>
<tr>
<td>How many NICs are needed by this guest and of what speed? Will they be using dedicated or shared physical NICs?</td>
<td></td>
</tr>
<tr>
<td><strong>Note:</strong> Sharing physical NICs between guest systems is often acceptable, but dedicated NICs are recommended for network intensive applications that require predictable performance.</td>
<td></td>
</tr>
<tr>
<td>Use a minimalist OS</td>
<td></td>
</tr>
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<td>- If Windows Server 2008 is used, and the virtualized application supports it consider using the CORE version.</td>
<td></td>
</tr>
<tr>
<td>- If using Linux/Using consider disabling the windows manager and other components that aren’t required.</td>
<td></td>
</tr>
<tr>
<td>Disable or uninstall unnecessary applications.</td>
<td></td>
</tr>
<tr>
<td>This can include:</td>
<td></td>
</tr>
<tr>
<td>- All screensavers</td>
<td></td>
</tr>
<tr>
<td>- Multimedia tools</td>
<td></td>
</tr>
<tr>
<td>- Gadgets that are auto started but not required</td>
<td></td>
</tr>
<tr>
<td><strong>Caution:</strong> Make sure these aren’t required for any part of the application.</td>
<td></td>
</tr>
</tbody>
</table>
### Disable Services / Daemons that aren’t required.

A few examples to consider are:

- Web Servers (IIS, Apache, etc)
- Indexing Servers
- SMTP/POP3
- SSH/FTP/TELNET
- File and Printer Sharing
- Messenger

**Caution:** Make sure these aren’t required for any part of the application.

Disables or disconnect unnecessary devices on guest and host systems.

This will free up IRQs and minimize the risk for queuing and collisions. In addition, it will also free up CPU resources since these would otherwise need to be polled by the virtual machines.

### Devices to consider are:

- Serial & Parallel ports
- Floppy/CD/DVD/BlueRay Drives
- USB/Firewire Adapters
- Unused Network Interfaces

**Caution:** Make sure these aren’t required for any part of the application.

Schedule supporting back office jobs during off-peak hours.

**Note:** Off-peak should be calculated globally on the complete host and not just in each individual guest.
Operating System with Tightened Security / Limited Functionality

It is not unusual for Virtual Machines to have a tight lock down schema applied to them or to have certain functionality disabled to save resources and enhance security.

This can be done by blocking certain functions or by disabling functions, such as windows managers or various services /daemons. When this is done it is critical that you verify that this doesn’t adversely affect the applications that are running on this guest system.

To reduce the chances for error, you should gather the following information:

- List all non-standard security lock down settings on the guest server
  
  Examples of this could be:
  - Encryption modules
  - Modified Enhanced File system security
  - Hardened requirement on passwords
  - Limited access to Administrator / root account
  - Local/Private Firewall functionality

- List all Services / Daemons that are not activated on the guest system
  
  Examples of this could be:
  - IIS
  - SMTP/POP3
  - SSH/FTP/TELNET
  - File and Printer Sharing
  - Messenger

- List all other functionality that is disabled on this system
  
  Examples of this could be:
  - Windows manager
  - Multimedia applications
  - USB / Firewire adapters
  - Floppy/CD/DVD/BlueRay Devices

**Note:** The examples listed above are not, in any way, intended to be a complete list. Rather, they are merely representative of the type of changes that are of interest.

For each one of these list items verify that the changes do not affect any part of the hosted applications and that the application still is fully supported after these changes are made.
Summary/Overview of Guest System in the Environment

Summarize the information that has been gathered into a simplified table listing the most critical information in a format that makes it easy to analyze multiple virtual machines and their requirement side-by-side.

For example, consider the following worksheet:

<table>
<thead>
<tr>
<th>Name</th>
<th>Software</th>
<th>CPU</th>
<th>RAM</th>
<th>Storage</th>
<th>Network</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

This list will, to a large degree, match the corresponding list in the section “List and Prioritize Servers/Applications/Solutions” on page 83. Note, however, that is not unlikely that some of the servers have been divided up into multiple virtual machines.
## Guidelines for Host Systems

The following guidelines apply to host systems.

### General Questions for Host Systems

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>What type of virtualization engine is being used?</td>
<td></td>
</tr>
<tr>
<td>Examples: ESX 4, ESXi 4.1, Hyper-V Server 2008 R2, XenServer 5.6, etc...</td>
<td></td>
</tr>
<tr>
<td>What guest systems will typically run on this host?</td>
<td>Note: This should be mapped to the guest system specified in the section above.</td>
</tr>
<tr>
<td>Are the guest-systems statically located on this host or are there plans to dynamically re-allocate them between hosts?</td>
<td></td>
</tr>
<tr>
<td>If so, what methods are planned to be used for this?</td>
<td></td>
</tr>
<tr>
<td>- Manual Steps / Scripts</td>
<td></td>
</tr>
<tr>
<td>- Quick Migration...</td>
<td></td>
</tr>
<tr>
<td>- VMotion, XenMotion, Live Migration</td>
<td></td>
</tr>
<tr>
<td>- Other Tools</td>
<td></td>
</tr>
</tbody>
</table>
## Basic Hardware Configuration

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many CPUs / Cores will be used?</td>
<td></td>
</tr>
<tr>
<td>Total number of simultaneously used vCPUs allocated to guest systems from this host.</td>
<td></td>
</tr>
</tbody>
</table>

**Caution:** Do NOT excessively over-commit process resources.

The acceptable ratio depends on the load on the individual guest system. It is important to remember that the virtualization itself adds a 6-20% overhead.

### BIOS Configurations:

**Note:** Following are some general recommendations regarding BIOS configurations. It is highly recommended that you follow the documented guidelines provided with your specific hypervisor/hardware solution.

*Enable CPU Virtualization Support:*
Depending on BIOS and CPU these settings might have different names, referring to CPU functions such as AMD-V / Intel-VT and AMD-RVI / Intel-EPT. Also note that not all of these options are supported by all hypervisors.

*Enable Hyperthreading:*
Hyperthreading does not provide the same effect as a separate CPU/Core but it will provide a performance improvement.

*Enable DCA – Direct Cache Access:*
This method enables delivery of inbound I/O data directly into processor caches.

*HPET – High Precision Event Timer:*
Enabling this might provide better performance for certain applications, however one disadvantage is that time drifts in virtual machines can sometimes be caused by HPET misreporting its frequency. If the HPET is significantly misreporting its frequency, you must disable the use of the HPET.
<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are all hosts in a single Hot Migration pool (VMotion, Live Migration, XenMotion) using the same CPU architecture?</td>
<td>Consult the documentation provided with the specific virtualization engine to determine the exact limits. Typically, the CPU requires the same architecture, but minor details, such as clock frequency, can differ. <strong>Note:</strong> Some host systems can be configured for compatibility mode where the servers are grouped up front and only those functions that are available on all CPUs are enabled on these systems.</td>
</tr>
<tr>
<td>How much RAM will be available on this host?</td>
<td>For predictable performance make sure the host has more RAM than the total amount of memory that will be used by the host system plus the sum of the guests systems. <strong>Note:</strong> Hypervisors have intelligent memory management techniques; however, over-allocation of memory can force swapping which significantly reduces the performance.</td>
</tr>
<tr>
<td>How many NICs are available and with what performance specification?</td>
<td>Having multiple high performance server class NICs available is highly recommended. Dedicated NICs are highly recommended for guest systems with significant network requirements in order to guarantee a predictable performance. Ensure the NIC drivers in the host and guest are correctly configured when it comes to:  - Auto-negotiated speed or the set speed  - Half or full duplex mode Multiple network adapters configured for NIC teaming provides increased performance and failover.</td>
</tr>
</tbody>
</table>
Configure the system to have dedicated NIC for the host systems management part (for example the Service Console in VMware)

To ensure best performance the recommendation is to use network adapters supporting the following hardware features:

- TCP Checksum offload
- TCP segmentation offload (TSO)
- Handling of high memory DMA (i.e. 64-bit DMA addresses)
- Handle multiple Scatter/Gather elements per Tx frame
## Disk Configuration

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>What type of disk system will be used?</td>
<td></td>
</tr>
<tr>
<td>For example: Fibre Channel, FCoE or iSCSI based SAN, NAS or Direct Attached Storage.</td>
<td>Note: A SAN solution is highly recommended in order to take full advantage of the virtualized environment.</td>
</tr>
<tr>
<td>If an iSCSI based SAN is used:</td>
<td></td>
</tr>
<tr>
<td>- Use Gigabit network- if possible, 10 Gigabit Ethernet.</td>
<td></td>
</tr>
<tr>
<td>- Multiple server class network adapters with good I/O performance ensure better speed and redundancy.</td>
<td></td>
</tr>
<tr>
<td>- Use iSCSI TOE NIC or an iSCSI HBA. The TCP/IP Offload Engine (TOE) or Host Bus Adapter (HBA) offloads the iSCSI and TCP/IP encapsulation from the CPU. An HBA also allows the system to boot from the SAN.</td>
<td>Note: A software-only initiator should be avoided since it consumes a significant amount of CPU.</td>
</tr>
<tr>
<td>- If iSCSI HBA is used, configure it for maximum queue depth.</td>
<td></td>
</tr>
<tr>
<td>Tune the cache for the disk subsystem</td>
<td></td>
</tr>
<tr>
<td>- Ensure that Write through cache is enabled</td>
<td></td>
</tr>
<tr>
<td>- Identify amount of available cache?</td>
<td></td>
</tr>
</tbody>
</table>

**Caution:** Write back or other write caching mechanisms are a potential point of failure which can, in a worst case, corrupt a database.
<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>What level of RAID are you using?</td>
<td></td>
</tr>
<tr>
<td>• None</td>
<td></td>
</tr>
<tr>
<td>• RAID 0: Data Striping</td>
<td></td>
</tr>
<tr>
<td>• RAID 1: Data Mirroring</td>
<td></td>
</tr>
<tr>
<td>• RAID 5: Block Striping with distributed parity</td>
<td></td>
</tr>
<tr>
<td>• RAID 1+0: Mirrored sets in a striped set</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** A RAID 5 or RAID 1+0 system is recommended for any mission critical system. RAID 0 is sufficient for a cache or other systems that require high speed but for which reliability isn’t critical.

Make sure any disk intensive applications or subsystems have access to a private disk (or, more precisely, a private disk arm). In general, it is often better to have many small disks than a few huge ones.

Examples of application/sub-applications that should have private disks are:

- Operating System
- Any major application (Depending on the application this might be separated onto multiple disks)
- Temp areas / cache areas with high I/O
- Database data files
- Database Transaction logs
- Database TempDb
- Database table with high load

**Note:** Implementing a SAN is good and it makes managing this easier, but it’s not a magic bullet. You still need to follow the recommendation listed above.

Make sure the virtual machine’s swap files are located on a high speed storage system.

**Note:** Memory swapping should be avoided, whenever possible; however, when required, this step minimizes the performance hit.
For each of these application/sub-applications identify the following:

- How many I/O per second (IOPS) is required?
- What is the maximum acceptable response time?

Ensure that the provided disk system can guarantee these requirements - even in a failover situation.

Ensure that sufficient storage is allocated – or even better, can be easily added when required.

**Note:** Plan so that you never utilize more than 80% of the available disk space.

Ensure all devices included in a Hot Migration Pool (VMotion, Live/Quick Migration, XenMotion) with good performance can reach all required disk systems.

### Management Infrastructure

Management of business critical applications has always been important. In a virtualized environment, however, it is even more important since each system can affect the others’ scalability and since an unplanned interruption of a host system now can affect multiple business critical applications.

With good management practices you can minimize these downtimes by finding out when you need more resources and quickly provisioning a new server or making sure the critical application gets all the resources it needs.

The first step is to list the management products you are planning to use to manage your virtual environment. The following checklist only lists a few common examples; specify any other tools where applicable.

<table>
<thead>
<tr>
<th>Products / Management area</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA Virtual Assurance for Infrastructure Managers / CA Virtual Systems Performance for Infrastructure Managers (formerly CA Virtual Performance Management)</td>
<td></td>
</tr>
<tr>
<td>CA Virtual Assurance</td>
<td></td>
</tr>
<tr>
<td>Products / Management area</td>
<td>Comments</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>CA Virtual Automation</td>
<td></td>
</tr>
<tr>
<td>CA Virtual Configuration</td>
<td></td>
</tr>
<tr>
<td>CA Spectrum Automation Manager</td>
<td></td>
</tr>
<tr>
<td>VMware Virtual Center</td>
<td></td>
</tr>
<tr>
<td>Microsoft Virtual Machine Manager</td>
<td></td>
</tr>
<tr>
<td>Performance Management Tools</td>
<td></td>
</tr>
<tr>
<td>These are tools that manage performance of guest systems as well as the complete host and, preferably, have the functionality to correlate this information.</td>
<td></td>
</tr>
<tr>
<td>CA Technologies has several performance management tools, including;</td>
<td></td>
</tr>
<tr>
<td>• CA Virtual Assurance for Infrastructure Managers</td>
<td></td>
</tr>
<tr>
<td>• CA Virtual Systems Performance for Infrastructure Managers</td>
<td></td>
</tr>
<tr>
<td>• CA Spectrum Automation Manager</td>
<td></td>
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<tr>
<td>• CA Nimsoft</td>
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<tr>
<td>• CA Spectrum Infrastructure Manager</td>
<td></td>
</tr>
<tr>
<td>• Wily Introscope &amp; Wily CEM</td>
<td></td>
</tr>
<tr>
<td>Change Control / Change Management Tools</td>
<td></td>
</tr>
<tr>
<td>• CA Service Desk</td>
<td></td>
</tr>
<tr>
<td>• CA Cohesion</td>
<td></td>
</tr>
<tr>
<td>• CA Harvest CCM\CA Software Change Manager (SCM) for Distributed Systems</td>
<td></td>
</tr>
<tr>
<td>Tools to manage Virtual Machine Sprawl</td>
<td></td>
</tr>
<tr>
<td>• CA CMDB</td>
<td></td>
</tr>
<tr>
<td>• CA Virtual Performance Management</td>
<td></td>
</tr>
<tr>
<td>• CA Spectrum Automation Manager</td>
<td></td>
</tr>
<tr>
<td>• Client Management Solution</td>
<td></td>
</tr>
<tr>
<td>Other Tools...</td>
<td></td>
</tr>
</tbody>
</table>
Just as important as which tool you use are the procedures you use to control and manage your environment and how the virtual images are created and used. Make sure you have a well defined process for this, including several distinct stages for Development, Test/QA, Gold Images, Archive of older images, Configuration and, finally, Production.

Cost Analysis

Last, but not least, you need to consider the true costs connected to the virtualized environment. A complete analysis requires a close look at your organization’s situation and specific requirements; however, the following checklist represents a good starting point and highlights several key points that you need to consider:

<table>
<thead>
<tr>
<th>Cost Area</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Server Hardware</td>
<td></td>
</tr>
<tr>
<td>Storage Solution / Infrastructure</td>
<td></td>
</tr>
<tr>
<td>Education and potential new hire</td>
<td></td>
</tr>
<tr>
<td>Redeployment of existing and working solutions</td>
<td></td>
</tr>
<tr>
<td>New Management Tools (license, hardware, services)</td>
<td></td>
</tr>
<tr>
<td>Virtualization Engine and Tools</td>
<td></td>
</tr>
<tr>
<td>License Costs</td>
<td></td>
</tr>
<tr>
<td>• Need for additional licenses for Operating System and back office products (such as security and other management tools/agents). This since virtualization often leads to the deployment of more, but smaller logical servers.</td>
<td></td>
</tr>
<tr>
<td>• Application licenses that are bound to the number of physical CPUs on the hosting server.</td>
<td></td>
</tr>
<tr>
<td>• Licenses that are limited to a single named physical server. If you have any of these, determine if you need additional licenses to handle load migration between host systems.</td>
<td></td>
</tr>
<tr>
<td>• Licenses required to support life cycle management, images stored in environments such as development, test/QA etc.</td>
<td></td>
</tr>
</tbody>
</table>
Glossary

Application Virtualization
There are several definitions for “Application Virtualization” some of which are significantly different from each other. Following are two common interpretations:

- A technique that aims to improve stability and security of the systems by using abstraction layers between the application and the actual hardware. This technique is used in most modern operating system to enable protection of the operating system, as well as other applications, from an application that has been poorly written.
- Application service virtualization is also referred to as Application Virtualization and refers to running software on a central server rather than distributed to each of the users’ computers. Except for a very thin generic client and communication protocols (that often can be a standard web browser) no changes are made to the local computer’s file system or registry.

Containers (Solaris Zones / Containers)
Sun Microsystems have their own implementation of operating system virtualization abstraction that is called “Solaris Zones.” Although the term “Containers” is often used interchangeably with “Zones”, the correct definition of a container is a zone that is also using the OS resource management facility. Each systems have a global-zone that has a dual role. It is the default zone for the system as well as the zone that is used for all administration (configured, installed, managed, or uninstalled) of non-global zones.

There are two types of non-global Zones (often referred to as just Zones):

- Whole Root Zone, where the complete OS and all related packages are implemented in the zone. This provides maximum flexibility since the administrators have access to and can customize all of its soft resources/file system.
- Sparse Root Zone, where only a subset of the packages is installed directly in the zone. Other operating system functions are shared through read only loopback file systems.

DLPAR (Dynamic LPAR)
See LPAR.

DPM (VMware Distributed Power Management)
VMware Distributed Power Management (DPM) is an experimental component that works together with DRS to reduce power consumption by intelligently balance the workload and automatically power off servers whose resources aren’t needed and return power to these when they later are needed.

DRS (VMware Distributed Resource Scheduler)
VMware Distributed Resource Scheduler (DRS) allows dynamic allocation/reallocation of resources and shares based on rules and policies. DRS is included in vSphere 4 Enterprise and Enterprise Plus (as well as VI3 Enterprise).

Emulated device
A virtualized device that is designed to behave like a physical device and, therefore, can be used by native device drivers that typically are shipped with the guest operating system.
Essentials (Citrix Essentials)
Citrix Essentials provides extended enterprise level management of XenServer and Hyper-V environments including lab automation, storage management, provisioning services, workflow automation and high availability.

ESX (VMware ESX)
VMware’s production class “bare metal” hypervisor that partition physical servers into multiple virtual machines. In most cases ESX/ESXi uses Full Virtualization and runs unmodified versions of the Operating systems in the virtual machines. In a few cases (such as Ubuntu) paravirtualization are required and therefore some minor updates to the guests operating systems have to be done.

ESXi (VMware ESXi)
VMware ESXi has the same basic functionality as the ESX server, however the Linux based service console has been removed and replaced with a new remote command line interface and adherence to systems management standards. This has reduced the size of the hypervisor to 32MB.

FCoE (Fibre Channel over Ethernet)
FCoE is a storage networking protocol which encapsulates native Fibre Channel frames into Ethernet packets. This mapping allows native fibre channel traffic to pass over an Ethernet infrastructure.

Hot Migration
Generic name for technologies that allow virtualized environments to move between host systems while they are still running. This functionally greatly enhances the advantages of virtualization by minimizing (or even eliminating) application downtime when environments are moved to manage load balancing or during hardware maintenance.
The VMware solution for this is VMOTION and for Citrix XenSource it is XenMotion. Microsoft’s hot migration solution is called Live Migration.

Hypervisor
A hypervisor is a basic virtualization component that provides an abstraction layer between the hardware and the “guest” operating systems. A hypervisor has its own kernel and is installed directly on the hardware. It can be considered as a minimalist operating system that controls the communication between the guest OS and the hardware. Hypervisor are sometimes also called “Virtual Machine Monitors”.
A virtualized environment without a true hypervisor (sometimes referred to as Type 2 Hypervisors) needs to have a primary OS in between the hardware and the Virtualization Engine, which can add significant overhead.

Hyper-V
Hyper-V is Microsoft’s latest virtualization product. A beta version (RC0) of Hyper-V was shipped with Windows Server 2008 x64. An updated final version was released in June 2008 and is available for Windows Server 2008 x64 users.
It supports up to 4 CPUs per virtual machines, has a true Hypervisor architecture, support for Quick Migration and support for 32 and 64 bit guest systems running Windows or Linux.
A future version is expected to support host systems with up to 64 CPUs and will include features such as Live Migration and hot-add of resources such as storage, networking, memory and CPUs.
iSCSI
iSCSI is a network protocol standard (transport layer) that allows use of SCSI protocol over TCP/IP networks. Building iSCSI based Storage Area Networks (SANs) using this protocol, together with Gigabit Ethernet, is a significantly cheaper alternative to the traditional Fibre Channel based SANs.

Live Migration
Live Migration is Microsoft’s solution for Hot Migration (See Hot Migration above).

LDOM (Solaris Logical Domains)
Logical Domains (LDOM) is a Sun Microsystems technology that divides the physical hardware into logical domains. Each domain is allocated a reconfigurable set of the existing hardware and has its own operating systems running inside the domain. The logical domains are associated with one or more roles, which included: Control Domain, Service Domain, I/O domain or, finally, Guest Domain. The Guest domains include the actual virtualized environments while the other roles provide supporting infrastructure. The Control and Service function can be combined in one domain, however, to protect stability and performance it is not recommended to run user applications within Control or Service domains.

LPAR (Logical Partition)
Logical Partitions (LPAR) are a hardware/firmware function that divides the existing hardware into completely separate partitions (LPARs), with each one of these partitions housing its own Operating System. This was first developed for IBM mainframe but is now also available on many of IBMs non-mainframe servers, such as pSeries and iSeries servers. Typically, hardware resources cannot be shared between partitions, however memory chips can be shared as long as the allocated memory addresses don’t overlap. With the later introduction of micro-partitioning (sometimes called “mPAR”) one CPU can be shared between multiple partitions. An extension to this is Dynamic LPAR (DLPAR) where resources (RAM, CPU capacity & I/O interfaces) can be dynamically reallocated between LPARs without shutting down or restarting the operating systems running in them.

Micro-partition (mPAR)
See LPAR.

NIC Teaming
Multiple Network Interface Cards (NIC) can be configured to work in parallel and be addressed like it was one single NIC. Since this “virtual” NIC now can have access to multiple cables, ports and even can be connected to different switches this will both increase the network bandwidth as well as providing redundancy for high availability.

Other terms for this includes "EtherChannel", "Ethernet trunk", “Link Aggregation", "Link Bundling", "Multi-Link Trunking (MLT)", "NIC bonding", "Network Fault Tolerance (NFT)", "Port Channel", "Port Teaming", "Port Trunking”.

Operating System (OS) Virtualization
OS virtualization allows isolated partitions, or virtual environments (VE), to be located on the same physical server and operating system. Multiple VEs share a common operating system that they communicate with through an “OS virtualization Layer”, This layer is responsible for ensuring security and complete isolation of dedicated resources and data owned by a specific VE. VEs are sometimes called “virtual private servers (VPS)”, “jails”, “guests”, “zones”, “v servers” or “containers”, to name a few.
P2V (Physical to Virtual)
P2V is a short name commonly used for tools that are used to convert physical servers into corresponding virtual servers.

Paravirtualization
Paravirtualization is a technique where the "guest" operating systems utilize software interfaces through the hypervisor that aren't identical to the underlying hardware (though, typically, similar). This can make certain calls more efficient and it can certainly simplify the role of the virtual engine; however, it requires the operating system to be aware of and to use the specific Virtualization Engine interfaces.

Passthrough disk access
A physical disk or LUN that is directly connected to the virtual machine. The data and instructions to the disk are sent directly to the physical disk without any intervening processing by the hypervisor.

Quick Migration
A Microsoft solution that enables migration of guest systems to other Hyper-V servers. This is not the same as Live migration since this solution requires some downtime. This downtime is typically short but it depends on factors such as I/O performance to the SAN and the size and usage of the virtual machines.

SAN (Storage Area Network)
A Storage Area Network (SAN) is an architecture that allows remote storage devices to be attached to servers in such a way that the operating system perceives it to be a locally attached device. This significantly enhances the virtual environments since you can now easily separate the storage of the virtual images from the rest of the hardware and, thereby, simplifies any type of Live Migration. Traditionally, SAN was implemented with Fibre Channel, however lately it has become more and more common with to see cheaper iSCSI or FCoE solutions being used in this capacity.

Server Core
A Server Core installation of Microsoft Windows Server 2008 is a minimal installation that avoids extra overhead. This greatly limits the roles that can be performed by the server but it also improves security and reduces management costs. The Server Core is trimmed down in a number of ways but the most obvious is that the Graphical User interface is removed. It is, instead, administered from the command prompt or a remote administrative interface.

SMP – Symmetric Multiprocessing
Symmetric Multiprocessing is a computer architecture where two or more CPUs are connected to a common shared memory. Since the processors share memory the operating system can easily balance the workload by moving tasks between them. SMP is currently the most common architecture used by multiprocessor machines. Examples of competing architectures include NUMA (Non-Uniform Memory Access), ASMP (asymmetric multiprocessing) or computer clustered multiprocessing (e.g. Beowulf).

CA Spectrum Automation Manager (CA Spectrum AM)
CA Spectrum Automation Manager (formerly CA Data Center Automation Manager) is a policy-based solution that automatically monitors, reconfigures and provisions virtualized as well as physical resources to dynamically meet the load demands of the modern data center.
Storage Virtualization

Storage Virtualization refers to various technologies that allow you to present logical pools of data so that it seems like one single physical disk even though it might be physically located across a large numbers of servers. In fact, the actual disk space might not even be available as long as the solution can guarantee that it will be available when needed.

Storage VMotion (VMware)

VMware Storage VMotion simplifies maintenance of the storage arrays by allowing live migration of virtual machines disk files across heterogeneous storage arrays without any interruption in the service for business critical applications.

Synthetic Device

A virtualized device without a specific physical analog. This is a form of paravirtualization since the guest system typically requires a specific driver to access this device. The synthetic device can often be made more efficient than an emulated device since it is aware of the virtualized environment.

System Center (Microsoft System Center)

Microsoft System Center is Microsoft’s umbrella suite for managing physical and virtual network and Windows Servers and desktops. One of the tool included in the suite are “Virtual Machine Manager” that manages virtual environment.

Thin Provisioning (of storage resources)

Thin provisioning is a technique that allows disk space to be allocated to servers or users on a “just enough” as well as a “just in time” basis. This addresses a problem where servers and users often exaggerate their current need to account for the need for additional space in the near future.

vCenter

vCenter Server (formerly Virtual Center Server) is VMware’s management tool for its VI3 and vSphere infrastructure. It also provides a toolset for the end user that includes a number of interfaces for 3rd party tools and is, therefore, required to support many 3rd party integrations.

vCPU – Virtual CPU

Virtual CPUs (vCPUs) are used to allocate computing power in the form of CPU to a virtual machine. The Hypervisor typically schedule private access to one CPU-core for each allocated vCPU for a short time slice when a virtual machine requests this resource. Virtual machines with multiple vCPUs allocated often need to have them co-scheduled to enable access to all of its CPU at the same moment in time.

VDI – Virtual Desktop Infrastructure

Virtual Desktop Infrastructure (VDI) utilizes virtualization techniques to provide end users with their desktop environments. This technique is similar to server virtualization, however it also presents its own unique set of advantages and challenges.
VI / VI3 – VMware Infrastructure

VI3 is the former generation of VMware vSphere 4. See the entry on vSphere for information about the latest version.

VI3 consists of a VMware ESX/ESXi Server 3.x and related distributed services. The VMware Infrastructure 3 (VI3) is divided into three different editions that each include the ESX/ESXi server and all functionality in the more basic editions. VI Foundation includes Consolidated Backup, Update Manager and Virtual Center Agent. VI Standard also includes the High Availability Option and VI Enterprise adds VMotion, Storage VMotion, Distributed Resource Scheduler (DRS) and an experimental version of Distributed Power Management (DPM).

Virtual Appliance

Similar to ordinary software appliances virtual appliances are minimalist packages with everything you need to provide a specific service. A virtual appliance is delivered in the form of a pre-configured virtual machine that includes an OS and application that are optimized. This simplifies the install and can greatly enhance security, since unnecessary services, daemons, protocols, etc. can be disabled.

Virtual Machine Manager (Microsoft System center Virtual Machine Manager)

Virtual Machine Manager is a Microsoft’s virtual management solution optimized for Windows Server 2008, Microsoft Virtual Server, and VMware infrastructures (through VMware Virtual Center). Amongst other the tools include features for performance and resource management, tools to convert VMware VMDK to VHD format and assistance for provisioning new virtual machines.

Virtual Machine Monitor (VMM)

See Hypervisor.

CA Virtual Assurance

CA Virtual Assurance is a comprehensive stand-alone, lightweight Systems Management solution, designed to provide; Streamlined appliance deployment and configuration, Automatic discovery and visualization of virtual environments through an topology map, Comprehensive performance management of virtual components, Rich visibility into application traffic responsiveness in the virtual environment, Real-time detection of dynamic resource changes in virtual environments and Intuitive workflows to help facilitate increased operator productivity as well as reduced mean time to repair.

CA Virtual Assurance for Infrastructure Managers (formerly Performance Management)

CA Virtual Assurance for Infrastructure Managers (includes Systems Performance for Infrastructure Managers) is an add-on product to CA Assurance and Automation Managers that delivers an integrated physical and virtual management for multi-platform, multi-vendor server technologies such as VMware. Support for Clusters, Sun, Citrix and IBM virtual platforms forthcoming.
CA VPM includes features such as Real-time Discovery and topology mapping, Single Pane of Glass for virtual and physical environments, dynamic optimization of virtual resources to proactively respond to changing business demands, performance management and reporting and the ability to drive security compliance through role-based management.
CA Virtual Automation
CA Virtual Automation is designed to make it easier for administrators to centralize computing resources, eliminate virtual sprawl, reduce time to deploy new systems and optimize utilization of existing hardware infrastructure. Some of its important features are Policy-based management of resource pools, Discovery and tracking of virtual machines, Self service portal for user initiated provisioning, Capacity management of your virtual environment, Chargeback and showback reporting and finally the ability to burst to public Amazon EC2 clouds.

CA Virtual Configuration
CA Virtual Configuration is a comprehensive configuration discovery and change management solution designed to provide; Discovery of your virtual hosts and their applications so as to identify, inventory and baseline application dependencies and relationships, Change management and configuration control that allows you to validate configurations and establish policies and "gold standards" for your environment, Monitoring of your established gold standards to help identify configuration drift and automation capabilities to take action to remediate it and finally CIS based compliance checking and reporting against predefined industry best practice standards as well as your corporate policies.

CA Virtual System Performance for Infrastructure Managers
See CA Virtual Assurance for Infrastructure Managers above.

VHD (Virtual Hard Disk)
A virtual machine encapsulates an entire server or desktop environment in a file. The Microsoft VHD file format specifies a virtual machine hard disk that can reside on a native host file system encapsulated within a single file. Microsoft has made the VHD Image Format Specification available to third parties under a royalty-free license, however they still own the standard and they reserve the right to revise or rewrite it.

Viridian
Viridian was the codename Microsoft used for Hyper-V before it was released. For additional details see “Hyper-V” above.

Virtual Machine
A virtual machine is a self contained software environment that works on top of a host operating system through a set of well defined interfaces. These interfaces can either be specific to this virtualization (see Paravirtualization) or can use an abstraction layer that catches the calls the virtualized software environment normally would communicate with its operating system and/or underlying hardware infrastructure.

VMFS (Virtual Machine File System)
VMFS is VMware’s cluster file system and it is used only with ESX server. VMFS allows multiple virtual machine disk images to be stored in a way that can be accessed (read/write) by multiple servers simultaneously (currently up to 32). VMFS is required for VMOTION to work.

VMDK (Virtual Machine Disk Format)
A virtual machine encapsulates an entire server or desktop environment in a file. VMware’s VMDK specification describes and documents the virtual machine environment and how it is stored. VMware has made the specification for VMDK available to the public; however they retain the right to revise or rewrite it.
**VMOTION**
VMOTION is VMware’s solution for Hot Migration (See Hot Migration above).

**Windows Server Virtualization (WSV)**
Windows Server Virtualization (WSV) is the name Microsoft previously used for its server virtualization product Hyper-V. For additional details see “Hyper-V” above.

**vSphere 4**
vSphere is VMware’s virtual server infrastructure and it consists of a VMware ESX/ESXi Server and related distributed services. VMware vSphere 4 is available in 7 different editions ranging from the free ESXi Single Server to an Enterprise Plus edition that includes the full spectra of functionality that vSphere offers. See [https://www.vmware.com/products/vsphere/buy/editions_comparison.html](https://www.vmware.com/products/vsphere/buy/editions_comparison.html) for a comparison of the different editions. The former generation of this infrastructure was called VI3.

**vSphere Client**
The VMware vSphere Client (formerly called Virtual Infrastructure Client) is VMware’s Windows based graphical user interface for interactive configuration of VMware vSphere. It is the primary interface to the VMware infrastructure and it allows the user to connect to the guest system’s console, individual ESX hosts or the VMware vCenter™ for multi-host management.

**XenCenter**
XenCenter is a Citrix management platform that, together with and in parallel with the CLI, allows you to manage all aspects of the Citrix XenServer environment.

**XenMotion**
XenMotion is XenSource solution for Hot Migration (See Hot Migration above).

**Zones (Solaris Zones)**
See Containers.