CAPACITY: THE KEY INGREDIENT OF AN AGILE CLOUD INFRASTRUCTURE

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Executive Summary

Demand for IT resources is always linear. We are more familiar with where organization's IT resources grow; not the other way around. However, IT must ensure that there is sufficient capacity to serve. When IT departments focus on IT as a Service, it needs to satisfy one important goal—to 'serve' precisely when needed.

Worldwide companies have been adapting to the cloud computing era. Companies now extensively leverage the 'As a service' model—one of the basic fundamentals of cloud computing. With as-a-service, the consumer is given the option to 'use-when-needed' which translates to pay-as-you-go.

Service providers must ensure that there is sufficient resource capacity to meet cloud computing's on-demand, rapid elasticity, and resource pooling characteristics. In other words, service providers and IT departments that host a private cloud need to have a different approach while managing capacity for the cloud.

Managing capacity in the cloud is not the usual stop-gap measure to mitigate a resource crunch, as that would defeat the definition of cloud computing. However, we cannot fully rule out the possibility of scenarios where the cloud infrastructure could actually run out of capacity.

It can be argued that, after security, capacity management is the most important factor contributing to the functionality of cloud computing.

This Knowledge Sharing article explores the potential dangers of overlooking capacity when dealing with cloud computing. It identifies the components in the cloud infrastructure that require continuous attention, trending, and analysis. These steps satisfy the definition of cloud by creating a resource pool that is on-demand and elastic. Doing so helps cloud service providers or a company's virtualized infrastructure create specific capacity management plans for sustainability and ensure proper deliverables.

Introduction

"65% of typical x86 servers are doing nothing"[1]

(Gartner)

Virtualization was the answer to the findings cited above when the research was conducted in 2009. The goal of server virtualization was to increase hardware utilization. To some extent this has been achieved by the ratio between the number of operating systems and the physical server. But the most intriguing fact is that most organizations average just 18% utilization even after virtualization. This means virtualization didn't truly increase hardware utilization.

The most difficult task in maintaining IT resources is striking a balance between having enough resources to satisfy existing and future demands and not having excessive resource idle for a long time. While a return on investment (ROI) should ideally be realized as soon as the investment is made, this might not be realistic because of global economic challenges, delays due to customer engagement, and various other delays.

Before the Cloud or Virtualization era, new hardware had to be purchased when deploying a new application. It was simple and easy. That's not the case today. Today we can have a virtual machine (VM) built almost instantaneously. Though it's much faster and easy, at the same time the systems become complex. Did we really solve the problem of hardware under-utilization? See Figure 1.
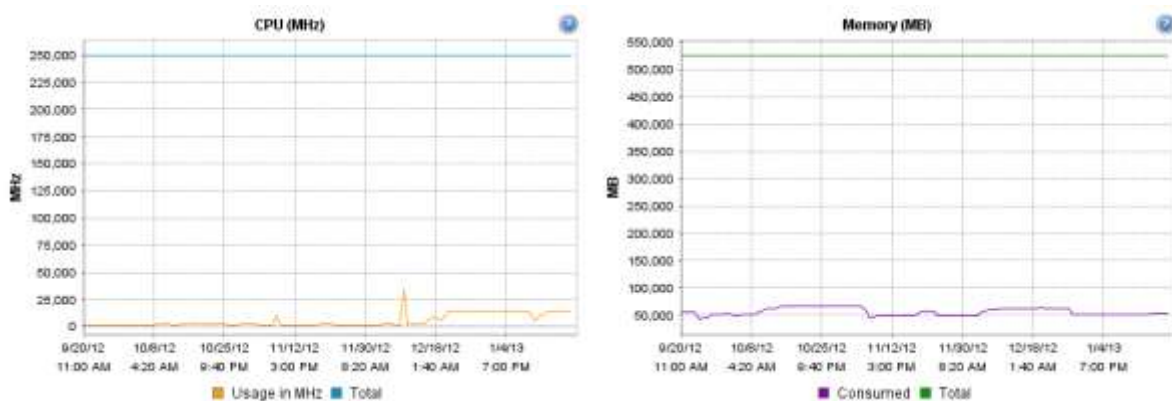
Figure 1: CPU and Memory utilization of an 8-node ESX cluster. Notice the utilization is minimal throughout its 5 months of lifetime.

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[1] Drakos, Nikos and Paquet, Raymond *"Technology Trends you can't afford to Ignore"*,
http://my.gartner.com/it/content/1031300/1031312/july1_technology_trends_you_cant_afford_ignore.pdf

The challenge today is to optimize the graph in Figure 1 by bringing utilization to par with the available resources but not at the cost of performance. Over-procuring hardware ties up capital whereas under-procuring impacts revenue. For cloud infrastructure, actual resource forecasts are critical to ensure continuous operations.

Answers to the following questions provide the key piece of information needed for capacity planning:

1. How much infrastructure (resources) do I have? (Measurement)
2. How have I distributed the available resources? (Measurement)
3. Which resources are generating revenue and how much are non-revenue? (Measurement)
4. When will I run out of capacity? (Measurement and Forecasting)
5. What efficiency techniques (Virtualization, Thin provisioning, de-duplication, etc.) are in place? (Plan)
6. How am I monitoring over-subscription (overcommitted memory, oversubscribed CPU, over-provisioned storage)? (Measurement, analysis, and planning)
7. Am I compromising performance while allowing more allocation? (Measurement and Analysis)
8. What is my over-subscription limit? (Forecasting)
9. How has the capacity grown over the months? (Trending)
10. How are we planning to accommodate new clients? (Forecasting and Planning)
11. How long can my customer wait for capacity? (Service level)
12. When is my company planning to invest more on capital expenditure? (Business)

Cloud characteristics that challenge classic capacity management

A study conducted by Forrester Consulting stated that managing capacity has been the biggest operational challenge along with security.[2] In this section, we try to understand why capacity planning is a critical aspect while managing cloud infrastructures.

The three essential characteristics of cloud that are directly dependent on capacity planning are Rapid Elasticity, On-Demand Service, and Resource Pooling. Let's review each of these characteristics and understand how each depends on capacity.

[2] Forrester Consulting (2010). *Virtualization Management and Trends.*
http://www.ca.com/us/~/media/files/industryanalystreports/virtual_mgmt_trends_jan2010_227748.aspx
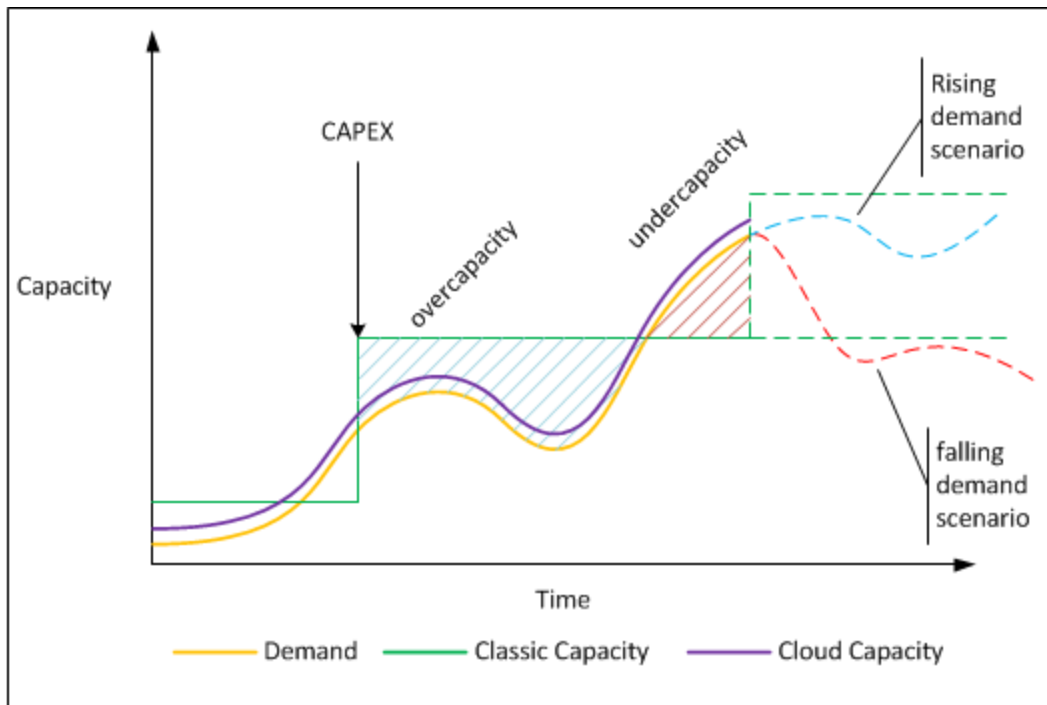
Figure 2: The 'Elasticity' expectation of Cloud capacity is to be in line with demand. Source: chades.net

Rapid Elasticity

"Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time."[3]

Consumers get an opportunity to expand their resources on-the-fly and hardware resources should be able to support this. Elasticity equates to dynamic growth and resources must be available to satisfy demand. This means that resources must be *available in excess* to satisfy the sudden surge, e.g. days following Christmas until first week of New Year. The challenge that cloud service providers (CSP) face is when the resources have been released after the surge. Large public CSPs use commodity hardware to maintain profit margins. Enterprise CSPs or IT organizations do not usually invest in commodity hardware due to lack of expertise and management overhead to maintain it in-house.

This situation illustrates a typical problem where one has to maintain resources without spending too much capital.

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[3] Mell, Peter and Grance, Timothy(2011). *The NIST Definition of Cloud Computing*. National Institute of standards and Technology. http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

On Demand self-service

"A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider."

Resource pooling

"The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g. country, state, or data center). Examples of resources include storage, processing, memory, and network bandwidth."

Capacity planning for the cloud basically revolves around Elasticity. However, the other two characteristics indirectly depend on the resources that constitute the cloud. If a user has been provided the privilege to execute a self-service portal to consume resources, the backend cloud infrastructure must be able to deliver the resources when needed.

It must be made clear that a CSP makes revenue when capacity is sold. Customers unable to receive the resources represent sheer loss of revenue for the CSP. Moreover, in a world where news reaches us much faster via social media, damage to the CSP's reputation can be long lasting.

Resource pool Elasticity

Resource pools are the fundamental components of a cloud infrastructure. While the customer-facing layer—virtual data centers (VDC)—provides the freedom to expand on-demand, the backend hardware must be able to grow elastically as well. Cloud operations would need to monitor the resource utilization closely to ensure that the infrastructure does not break. The first step in capacity planning is to _measure precisely_ the current available capacity. In the next section, we will cover the important 'resource pool' data that must be tracked, monitored, and trended.

Measurement and Analysis

The three levels of ITIL V3 Capacity management are:

- Component

- Service

- Business

Requirements most often flow "top-down" and data and information flow "bottom-up". There is no drastic change as the model changed from traditional IT to IT as a service. However, the data that needs to be gathered and its analysis needs to take a different approach since, due to virtualization, there are many layers of abstraction involved to improve hardware utilization. In the cloud or even IT for that matter, capacity planning is all about understanding the following in order:

1. Know your infrastructure inside-out (Component).

2. Know your service level agreements – your commitments to the customer (Service)

3. Understand business strategy, goals, new deals, future clients, and capital investment in infrastructure (Business)

Data Gathering and Documentation

When purchasing more goods one must know the exact amount of goods currently available and determine how long will they last. To a CSP in IaaS, goods are resources such as compute and storage. There are various ways in which we could measure them based on their use.

Virtualization adds complexity in understanding the amount of the resources and its need.
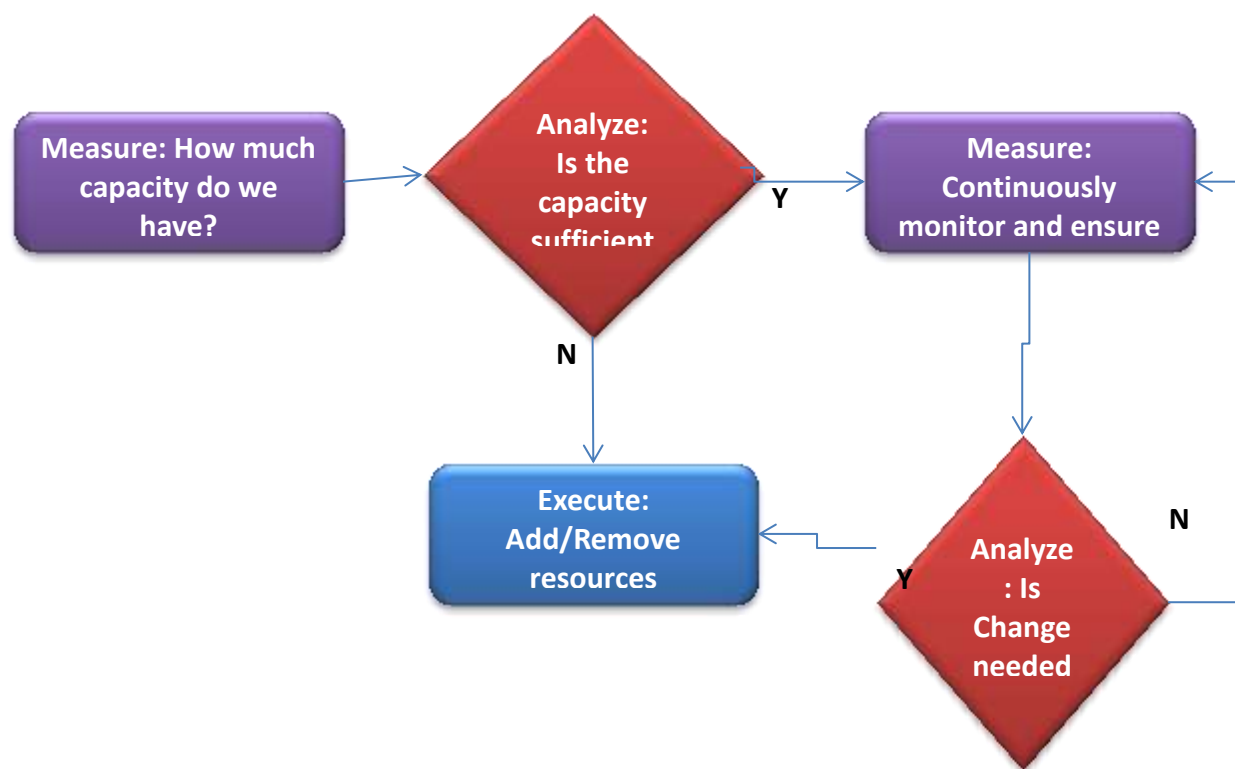

Figure 3: Typical process for capacity planning

Compute Capacity

In a typical private cloud environment, compute resources are usually blade servers. However, there are no restrictions that they must not be rack-mount or commodity servers[4]. In any model, the level of granularity should be based on the number of servers and its properties.

Location	Blade type	Total Blades	Blades in use	Unreserved/free Blades
Data center 01	Cisco UCS B200 M2	32	20	12
	Cisco UCS B440 M1	4	3	1
Data center 02	Cisco UCS B200 M2	40	20	20
	Cisco UCS B440 M1	4	3	1

Table 1: Sample server inventory which summarizes the number of blades in each Private Cloud

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[4] Commodity hardware: Public CSPs, large companies hosting data on the Internet such as Facebook and Google use low-cost hardware to satisfy their compute needs. This helps lower the cost needed for hardware investment. With low cost, in the event of hardware failure, the single server unit can be discarded without impacting the hosting. Companies hosting a private cloud would generally avoid this model as they would want to avoid the need for maintaining the hardware themselves. Hence, they depend on hardware produced by a reputed vendor. Further reading on commodity hardware: opencompute.org

Table 1 gives a picture of the amount of blades that are available in each data center for a particular private cloud or Vblock®5. The data can be obtained by using blade management software used to manage a particular blade type.

Next, understand each blade/server's detailed characteristics. The key piece of information in capacity planning is found in granularity. This could be achieved by extracting information about all the blades that constitute the infrastructure.

Name	Chassis ID	PID	Model	User Label	Cores	Cores Enabled	Memory	Adapters	NICs	HBAs	Overall Status	Operability	Power State	Assoc State
sys/chassis-1/blade-1	1	B440-BASE-M2	Cisco UCS B440 M2	DC1-Exchange-01	40	40	262144	2	4	2	ok	operable	on	associated
sys/chassis-1/blade-3	1	B440-M1	Cisco UCS B440 M1	DC1-XYZ_Corp_SQL_1	32	32	262144	2	4	2	ok	operable	on	associated
sys/chassis-1/blade-5	1	B200-M2	Cisco UCS B200 M2	DC1-XYZ_Corp_Oracle	12	12	98304	1	4	2	ok	operable	on	associated
sys/chassis-1/blade-6	1	B200-M2	Cisco UCS B200 M2	DC1-XYZ-ESX01	12	12	98304	1	4	2	ok	operable	on	associated
sys/chassis-1/blade-7	1	B200-M2	Cisco UCS B200 M2	DC1-XYZ-ESX02	12	12	98304	1	4	2	ok	operable	on	associated
sys/chassis-1/blade-8	1	B200-M2	Cisco UCS B200 M2	DC1-XYZ-ESX03	12	12	98304	1	4	2	ok	operable	on	associated
sys/chassis-2/blade-1	2	B440-BASE-M2	Cisco UCS B440 M2	DC1-Exchange-02	40	40	262144	2	4	2	ok	operable	on	associated
sys/chassis-2/blade-3	2	B440-M1	Cisco UCS B440 M1	DC1-XYZ_Corp_SQL_2	32	32	262144	2	4	2	ok	operable	on	associated
sys/chassis-2/blade-5	2	B200-M2	Cisco UCS B200 M2	DC1-XYZ-ESX04	12	12	98304	1	4	2	ok	operable	on	associated
sys/chassis-5/blade-1	3	N20-B6625-1	Cisco UCS B200 M2	DC1-XYZ-ESX05	12	12	73728	1	6	2	ok	operable	on	associated
sys/chassis-5/blade-2	3	N20-B6625-1	Cisco UCS B200 M2	DC1-XYZ-ESX06	12	12	73728	1	6	2	ok	operable	on	associated
sys/chassis-5/blade-3	3	N20-B6625-1	Cisco UCS B200 M2	DC1-XYZ-ESX07	12	12	73728	1	6	2	ok	operable	on	associated
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Table 2: A sample excerpt from Cisco UCS Manager blade export, detailing the properties of each blade

Using blade management tools such as UCS manager (for Cisco UCS blades) or HP Integrity Server Blade management software (for HP blades), detailed information related to blades can be gathered and documented. Using the information as seen in Table 3, blade characteristics such as the number of CPU cores and amount of memory can be noted. This will help in understanding the capability of each blade and its availability when there is a need for capacity elsewhere in the environment.

Compute Virtualization – Measurement and Analysis

Managing blade server inventory gives a detailed picture of the compute hardware that constitutes the Private Cloud. In the world of virtual servers, they play the role of aggregating the resources and presenting a large pool of resources of compute capacity in the form of processing capability and memory. Managing this pool is the task of bare-metal embedded hypervisors such as VMware ESX.

Virtual Machines are created on clusters which are a group of hosts. This helps in resource aggregation, better hardware utilization, mobility, high availability, and fault tolerance. From a Cluster perspective, hosts are the only key characteristic that contribute to capacity. Knowing the cluster and the VM limits help in knowing the ceiling (limit). Refer to Table 3.

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[5] Vblock: A compute, storage, and network system that is purposefully integrated into a common platform by the VCE Coalition.

Physical Building Block	Logical Building Block	Limitation
Cisco UCS B200 Blade	Virtual machines	30
Cisco UCS B200 Blade	Performance (CPU)	75%
Cisco UCS	Layer 2 separation (VLAN)	1024
ESX Cluster	Virtual machines per ESX cluster	1280
ESX Cluster	Hosts per cluster	32

Table 3: Understanding the limitations of a given compute model

There are a number of ways that cluster configurations can be monitored. Various monitoring tools are available in-house that can be leveraged to closely watch the ESX cluster. In scenarios where there are multiple clusters across multiple data centers, tools such as Zenoss, Nimsoft, or custom scripts (based on VMware PowerCLI) can be made. The information expected would be:

Number of Clusters in the data center	'n'
Number of hosts in the Cluster	'm'
Total Usable CPU capacity of the Cluster	In Ghz
Total Usable Memory of the Cluster	In GB
Number of VMs in the Cluster	'x'
Total Number of CPU cores of VMs that are powered on	'y'
Total Allocated CPU of all VMs that are powered on	In Ghz
Total allocated memory of all VMs that are powered on	In GB
CPU usage of the cluster	Ghz (Average)
Memory usage of the cluster	GB (Average)

Table 4: List outlining the important characteristics that needs to be noted for a given cluster

Cluster Name	Total Hosts	Total CPUs	Raw CPU (Ghz)	Usable CPU(Ghz)	Raw Memory(GB)	Usable Memory(GB)	Number of VMs	Total VM CPUs	Total VM CPUs(Ghz)	Total VM Memory(GB)
Cluster A	9	108	358.99	325.58	863	817	123	251	417.16	499

Table 5: Statistics of a cluster with nine hosts. Notice that the VM CPUs (Ghz) is slightly oversubscribed against the Usable CPU (Ghz)

Graphs are one of the best ways to convey stories without requiring detailed reading. While Table 5 is useful for engineers, much more attention can be gained if the same information is transformed into graphs.
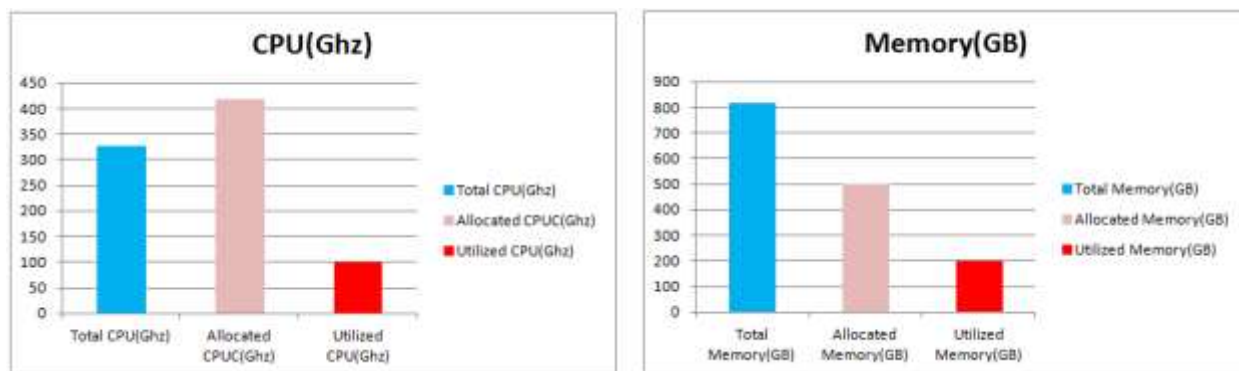
Figure 4: CPU and Memory – Available and allocated capacity. The total capacity represents the total cluster capacity whereas the allocated capacity is the capacity allocated in the form of VMs. The utilized capacity is the physical utilization of the cluster.

Figure 4 shows the CPU and memory allocation of a cluster. The CPU allocated is more than the total CPU available in the cluster. This is possible using oversubscription of the CPU, an accepted way to increase hardware utilization. While virtual machines are created, a CPU core is assigned to it. Usually, a VMs CPU core could be 2, 4, 6, or 8 with the number dependent on the type of application. A web server might require fewer cores while a database server might require more than eight cores. When multiple VMs are created across the cluster, the allocated CPU can increase the actual number of cores available in the physical machine. This helps in better utilization of the hardware.

Measuring the Cloud layer

On top of the hardware and hypervisor layers another software layer is used for abstraction, pooling, and automation of all data center services such as storage, networking, and security. Notable virtual data center (VDC) software are VMware vCloud Director and Eucalyptus Cloud platform. They create a *logical partition* of the underlying hardware resource (pool) that provides all the required infrastructure components such as compute, network, storage, and security to a *tenant*.

Behind the scenes of a VDC, the hypervisor creates a hierarchical partition of the CPU and memory available in the cluster. This corresponds to 'resource pools' of a cluster.
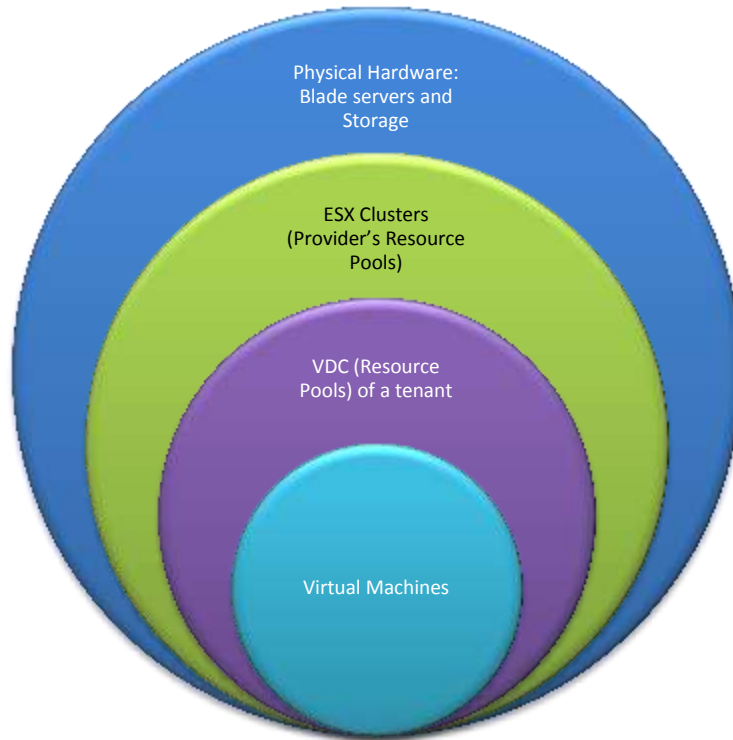
Figure 5: Multiple layers of abstraction in a Cloud infrastructure (Compute)

The resource pools of a VDC depend on the cluster's resources. However, it's bounded by a limit defined by the Allocation model. The allocation models of VMware vCloud Director are:

- Pay-as-you-go: Resources are only committed when users create vApps (a VM) in the organization VDC. You can specify a percentage of resources to guarantee, which allows you to over-commit resources. You can make a Pay-As-You-Go organization vDC elastic by adding multiple resource pools to its provider vDC.

- Allocation Pool: Only a percentage of the resources you allocate are committed to the organization VDC. You can specify the percentage, which allows you to over-commit resources.

- Reservation Pool: All of the resources you allocate are immediately committed to the organization VDC. Users in the organization can control over-commitment by specifying reservation, limit, and priority settings for individual virtual machines.

Challenges

If all VDCs in a provider are configured as Pay-as-you-go, at what point will one have to stop creating new VDCs?

Previously, from the CPU and Memory allocation in a Cluster shown in Figure 4, it was evident that the allocated capacity is part of the total capacity. However, in a Pay-as-you-go model, the allocated value might not exist at all. Notice Figure 6, where the allocated capacity is almost absent. In these scenarios, the utilized capacity plays an important role in knowing the limit. Also, historical data trends provide background information about the way in which the VDC has grown over time.

Figure 6: Absence of allocated capacity in a Pay-as-you-go model

Storage capacity

In today's VDC, storage virtualization is the process of presenting a logical view of the physical storage resources to a host. This logical storage appears and behaves as physical storage directly connected to host. While this is similar to the traditional practice of carving a group of physical disks into a number of logical disks (LUN), storage virtualization takes this concept one step further by increasing flexibility in the provisioning and management process as well as expandability, utilization, and performance. The technologies involved are thin provisioning, deduplication, and data tiering.

Storage efficiency is improved by thin provisioning, the act of using virtualization technology to give the appearance of having more physical resources than are actually available. The technology provides the ability to over provision storage to hosts. Over-provisioning is the act of using thin provisioning to allocate more storage than actually available in the physical storage array. For example, an array with 155 disks of 2000GB (1832GB usable capacity) configured as

RAID 6 provides a usable capacity of 200TB. These set of disks are configured as thin pools and thin LUNs which have been created and presented to various hosts. The total capacity of all the thin LUNs that were created is about 300TB. In essence, the array is over-provisioned by 100 TB or over-provisioned by 50% or the array (or pool) has been subscribed by 150%.

Defining the limit of over-provisioning

Theoretically, over-provisioning can make storage capacity inexhaustible. It might be possible to allocate many times the actual storage available in the array. The problem would arise only if all the hosts started to utilize the allocated thin LUNs and consume the physical space of the arrays. In that case, the hosts would end up having issues pointing to lack of space in the volumes and possibly causing an outage to the applications. Over-provisioning might not cause any problem immediately or even within months of provisioning. It might take a while for the hosts (applications) to consume physical data. However, without close monitoring, the array's capacity will eventually be fully consumed.

To prevent a worst-case scenario, an over-provisioning limit must be defined. This could be defined by:

- The type of array.

- The number of free slots and unused disks (disks that aren't part of RAID groups or spare.)

- The maximum disks supported by the array.

- The type of disks.

- The RAID type of the disks.

Calculating the over-provisioning limit uses predictive analysis. The following data needs to be gathered for assuming the maximum capacity that could be accommodated in the array:

- In the empty slots, predict the number and type of disks that could be installed.

- Know the limit of disks and the enclosures.

  - For example, in an EMC VNX® 5700, the maximum disks are 500. However, if the disk array enclosures (DAE) use a 15-drive enclosure instead of a 25-drive enclosure, the maximum drives become 495 drives[6].

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[6] In VNX, the enclosure 'slots' even empty add up to the count of the

Take the same example as above of an array with 155 disks of 2000GB drives. Let's predict the over-subscription limit:

Considering that all enclosures are composed of 15 drive slots, 155 disks would have consumed 11 enclosures in the VNX 5700. It might be possible that the first enclosure would have consumed just the 5 SAS 300 GB drives with the remaining slots empty. With limited storage space, it might be critical to use all the empty slots. Let's fill the slots with disks and predict the capacity:

Type	Raid Type	Raw capacity/ drive	Usable capacity/ drive	Total Disks	Raid Groups possible	Capacity per Raid group	Total Capacity (GB)	Total Capacity (TB)
SAS	RAID-5	300	268	10	2	1072	2144	2.09
EFD	RAID-5	200	182	20	4	728	2912	2.84
SAS	RAID-5	600	535.33	55	11	2141.32	23554.5	23.00
NL-SAS	RAID-6	2000	1832.53	240	30	10995.18	329855	322.12
				325			358466	350.06

Table 6: Predictive drive configuration and capacity projection for a storage array

In the above example, we consider that there would be 15 drives used for various hot spares; hence, the calculation:

155 existing drives + 15 hot spares + 325 projected drives = full capacity of 495 drives.

We also derive the maximum possible growth of the array for the above configuration of up to 350TB which helps to deduce the over-provisioning limit.

From the above example we could know the limits of a storage array which helps in capacity planning of the cloud environment.

Recommendations

Understand the storage technology and hardware limits well in the design phase of the environment. Every storage array has its maximum limits; choose the storage array and model with capacity in mind. Focus on detail such as usable capacity, precise maximum disk counts, and overheads due to RAID and drive formatting.
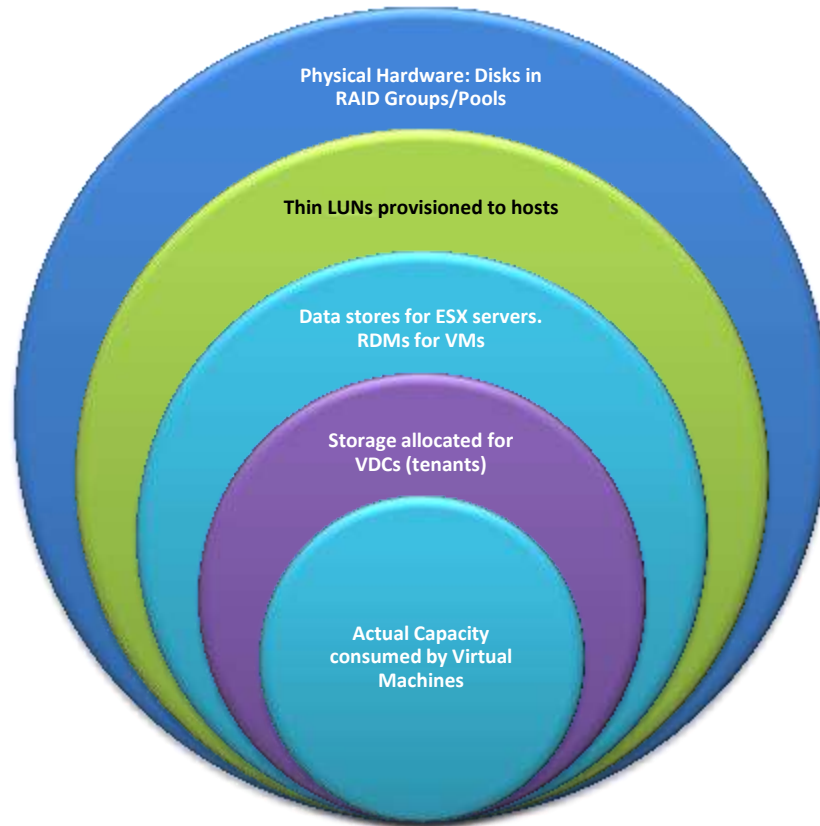
Figure 7: Multiple layers of abstraction in a Cloud infrastructure (Storage)

vStorage Thin provisioning

A virtual disk used by a VM can either be thin or thick provisioned. Thin provisioning of virtual disks in the compute layer improves storage efficiency. Similar to the concept in the storage arrays, vStorage thin provisioning increases storage utilization and reduces application downtime by emulating larger disks throughout the lifetime of the application. However, similar to the storage array pools, utilization must be closely monitored. The 'pool' in this case is the data store.

For example, if there are 10 VMs with thin disks of 50GB, initially, they would consume just a few Megabytes of space. But eventually, as the application data grows, it might consume up to 40GB of physical space of the data stores, equal to 400GB of the data store. There could be an outage if the capacity of the data store was just 350GB.
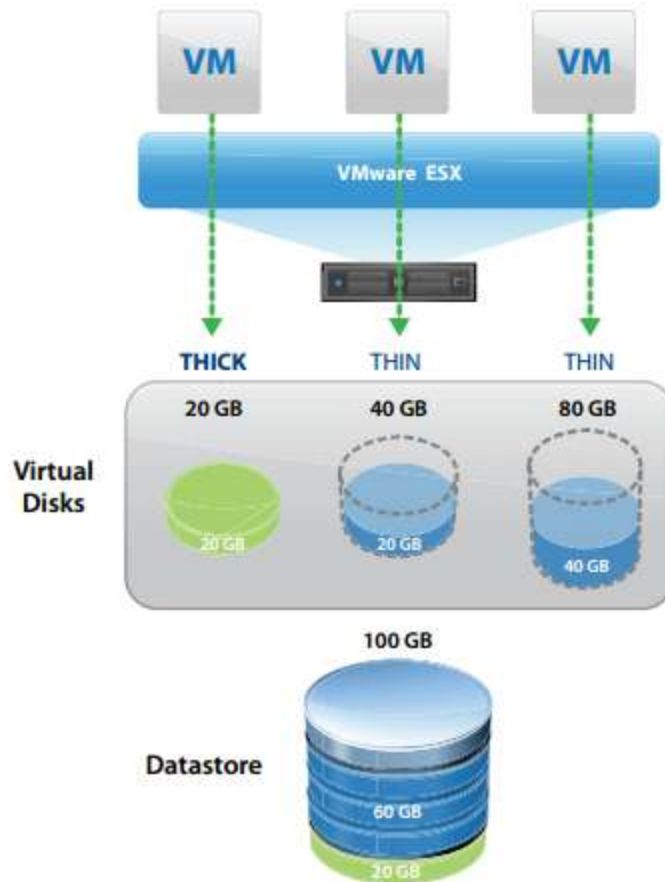
Figure 8: Thin Provisioning dramatically increases virtual machine storage utilization.
Image Source: VMware vStorage Thin Provisioning

In the case of VMs running Windows operating system, not selecting 'Quick format' while preparing the disks results in data being written on all sectors of the drive causing the thin disk to be fully consumed. Also, creating and deleting multiple files would cause the thin disk to inflate as it is possible for data to be written on a new sector rather than overwriting on a deleted sector. In these scenarios, the shrink feature available in VMware tools on certain operating systems and disk types can be used to free up space helping to deflate the thin disk.

The ultimate goal of storage capacity management is to improve storage efficiency. That involves every layer of abstraction (Figure 7). We could eliminate inefficiency in the storage infrastructure If we keep a close watch on the array and data stores and proper documentation is made of the way in which disks are carved to LUNs and then to data stores to vdisks.

Administrators must document every LUN that has been created and allocated in the array. There might have been LUNs that were created and not allocated to a host at all. There are

scenarios where LUNs were created and allocated to a host, but the host never formatted or used that LUN. Although the amount of capacity might be minimal, for efficiency of the cloud infrastructure, these are important aspects that need attention and help reduce resource waste.

Network Limitations

Network components do have limitations and must be tracked while planning capacity as it contributes to the topology-related aspects of the tenant's service.

Any physical switch would be logically divided into VLANs. Traditional network isolation techniques such as IEEE 802.1Q provide 4096 LAN segments that can be used in any Layer 2 domain. If you choose to implement a Vblock with Cisco Nexus 7000 acting as the aggregation layer, any Unified Compute System (UCS) that connects to that Nexus 7000 connects to the same Layer 2 domain and so must share this pool of 4096 VLANs.

The previous limits can be seen as a capacity limitation from a provisioning point of view; the provisioning systems can only create 4096 VLANs. The performance of the Nexus 7000—CPU and throughput, for example—is also a capacity limit. However, from a service assurance perspective, you can continue to add load to the Nexus until a certain threshold is reached, after which the performance of all resources will be impacted. The network itself also continues to be virtualized within the hypervisor with applications such as the Cisco Nexus1000v Distributed Virtual Switch (DVS) and VMware vShield. This illustrates that the traditional boundary between compute and network is disappearing from a capacity management perspective.

VXLAN: Cloud environments that need to scale and have more logical networks than traditional models could use VXLAN, a solution with a MAC in User Datagram Protocol (MAC-in-UDP) encapsulation technique and a 24-bit segment identifier in the form of a VXLAN ID. The larger VXLAN ID allows LAN segments to scale to 16 million in a cloud network. In addition, the UDP encapsulation enables each LAN segment to be extended across Layer 3 and helps ensure even distribution of traffic across Port Channel links.[7]

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[7] Further reading on VXLAN:
http://www.cisco.com/en/US/prod/collateral/switches/ps9441/ps9902/white_paper_c11-685115.pdf

Performance and Capacity Management

While there may not appear to be a link between availability and performance and capacity planning, there is a direct connection: If a resource is not available, performance is impacted; and if a resource has poor performance or limited supply, availability and accessibility are impacted.

We have discussed compute utilization as a key factor that defines the limit in the number of VDCs or VMs created.

In the previous section on storage capacity, we discussed defining the over-provisioning limit by predictive analysis. Storage array design must be carefully examined to satisfy:

- Performance

- Capacity

We successfully defined the limit for the capacity on that particular array. Similarly, disk performance should be considered while designing the array.

To design a cloud-enabled storage array, storage tiering should be implemented as the traditional approach is more of a hosting solution and not a true cloud infrastructure (resource pooling). We could derive the performance expected of each drive by referring to the specification sheet[8]. Further, we could calculate RAID Groups performance and finally, the pool[9]. Automated storage tiering helps automate the process of moving extents of data into the most appropriate disk-set based on performance and accessed time. Aggregating the whole storage array controlled by automated tiering helps maximize storage efficiency further.

Capacity Trending

Trending involves drawing capacity details against time. The time usually spans months. In IT, the technology can become obsolete in a matter of a few years and the reporting process would have to be restarted on the newly refreshed infrastructure. Trending is as important as measurement in capacity planning. To a certain extent, trending correlates to measurement of the data.

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[8] Page: 4, EMC VNX Specification: sheet http://www.emc.com/collateral/software/specification-sheet/h8514-vnx-series-ss.pdf

[9] In a VNX, the disks inside a Thin pool needs to be protected against failures. This is possible by applying traditional RAID protection. When disks are added to a pool, RAID gets applied to those disks and a private RAID group ID gets assigned to it and thereby protecting the disks against drive failures. The usable capacity available after applying RAID gets added to the Thin pool in which the drives were added.

Figure 9: Capacity statistics of memory, storage, and CPU over a period of 8 months for a cluster.

In a cloud infrastructure, resource utilization is the main area of interest. The utilization determines the breaking point of the infrastructure. Figure 9 shows the pattern in which the capacity has been utilized over a period of eight months. The three parameters of total capacity, allocated capacity, and utilized capacity has been gathered periodically, preferably in weeks and is marked on a line graph.

Figure 9 shows data of a cluster that were marginally used with adequate capacity available for growth. This data now could be used to accommodate future growth and hardware investment. In this case, no further capital investment is needed.

Similar to the data in Figure 9, cluster usage data (shown in Figure 10) must be analyzed:
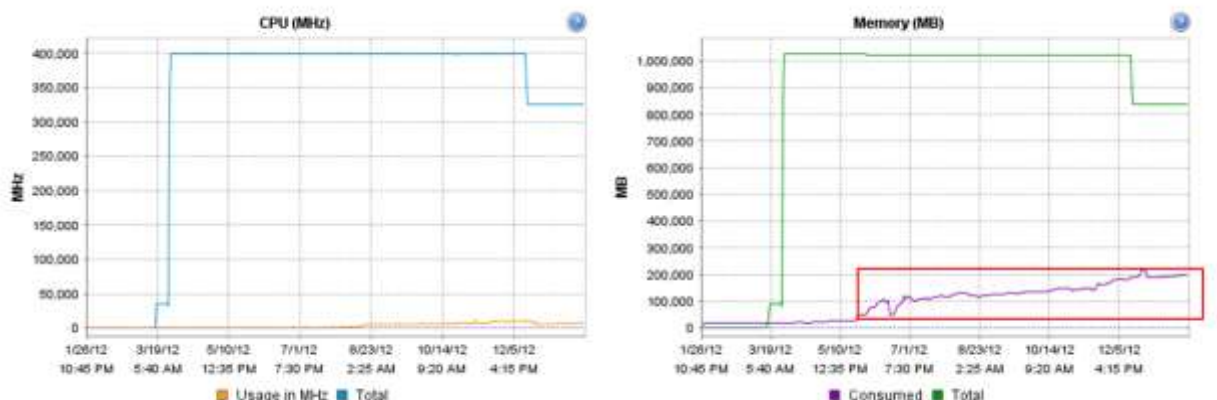
Figure 10: Resource utilization of a VMware Cluster over a period.

As previously explained, cluster usage should be closely monitored as it determines the limit of allocation of new resources (VDCs) in the environment. If utilization is very low, the existing hosts could be removed from the cluster and used for other workloads that demand capacity.

Decreasing trends in capacity

There are instances where resource capacity could be reduced. This might sound good for capacity planning and performance but a reduction in capacity impacts company revenue and reduces hardware utilization. The various causes of reducing trends are:

- Termination of contracts.
- Retired projects.
- Removal of non-revenue assets.
- Periodic clean-up of the infrastructure.
- Removal of Proof-of-concept resources.

Increasing trends in capacity

Positive resource growth contributes to revenue for the cloud business and should be welcomed. Existing data must be analyzed and reviewed to ensure that the new projects or the customer can be comfortably accommodated within the existing cloud infrastructure.

In scenarios where required capacity could exceed available capacity, a decision would have to be made about procuring hardware. Factors contributing to increasing trends in capacity include:

- New contracts/deals.

- Expansion of existing client infrastructure.

Capacity Forecasting

Weather forecasts predict the state of the atmosphere for a given day in the near future. The prediction is made using existing and historical data with the forecast reaching closest approximation only as the day approaches.

Predicting IT resource growth uses a similar approach. As with the weather, the amount of capacity that could potentially consume capacity is only clear after the requirements are made. This might take several weeks after the contract (or project) has been signed.

The Sales team plays the role of forecasting capacity by notifying the cloud capacity planners well in advance about possible contract wins. A public cloud provider tracks its customer's pattern. In most cases, they are SMEs requesting small increments of capacity. Public CSPs would invest as little as possible on hardware. Public CSPs don't really expect an Enterprise-class request such as the following being requested online:

- 300 vCPUs

- 400 GB of Memory

- 500TB of Storage

Theoretically, there is no reason why a CSP will not be able to satisfy this request. However, for large requests such as this, a CSP would usually contact the potential customer and work on possibilities. The important point to note here is that service level agreements might not be the same for all customers. A large customer like the one seen above would have to be dealt with carefully as such a large deal would benefit the revenue of the CSP. At the same time, the CSP should check its capacity availability to satisfy this unusual request.

Such inorganic capacity requests are not uncommon. CSPs must be capable of satisfying these requests; failing to do so could have negative impact on the CSP. Nonetheless, there can be various reasons such as domain expertise and legal why a CSP might not agree or accept the inclusion of certain customer requirements.

The following worst cases can be anticipated with these requests:

1. Capacity might be unavailable at the given time.

2. Capacity might require the CSP to invest in CapEx – purchase hardware.

3. Time required to satisfy the request might exceed the service agreement due to delays in the above two points.

From a business perspective, these are opportunities for expanding the portfolio of the CSP and must be taken positively. CSP's must have a high-level business plan to deal with such situations.

The Sales team should predict the probable customers and provide the technical details such as vCPU, memory, and storage that the potential customers might occupy in the cloud. This information must be periodically collated and discussed.

Potential customers conflicting for capacity

Let's take an example of three potential customers to a cloud environment.

Potential Customer Name	Capacity Requirement			Deal Probability (%)
	vCPU	Memory (GB)	Storage(GB)	
Fictional Corp.	100	200	2000	90%
Small Business Inc	5	20	300	100%
Largest Corp.	100	200	3000	90%

Table 7: Weekly sales report with the deals that are in pipeline.

Table 7 is an excerpt of a sample report that shows the capacity requirements of potential customers for a CSP. It outlines a scenario where storage capacity is extremely limited and a decision needs to be made to accommodate all or just a few of the customers in a particular cloud infrastructure.

Undoubtedly, 'Small Business Inc' should be the first customer chosen to occupy the capacity of the array because of the probability factor (100%) that confirms that the customer would use the resources in the cloud. Secondly, the resources requested by Small Business Inc are much less than any of the other potential customers and could be easily satisfied with the current capacity.

However, careful consideration must be made while reserving capacity for the other two clients with 90% probability and if the Cloud infrastructure has very limited capacity, e.g. if the storage

array could satisfy only 2000GB at the moment, two things have to be considered while planning for this situation.

1. **Service level agreement** detailing the lead time to implement the cloud infrastructure.

2. **Business plan** to accommodate physical growth of the cloud infrastructure (storage array in this case).

Scenario 1: The deal with 'Fictional Corp' has been signed.

a. Satisfy the request as capacity is adequate. No further capacity can be accommodated in the cloud.

Scenario 2: The deal has been signed with the 'Largest Corp' which has a requirement of 3000GB and cannot be satisfied at the moment in the cloud.

a. Option 1: Release capacity by decommissioning or cleaning up resources.

b. Option 2: Consolidate storage capacity to accommodate this request.

c. Option 3: Proceed with procurement of hardware if option 1 or 2 does not release any capacity.

Scenario 3: Both the deals have been signed.

a. Option 1: Satisfy the request for 'Fictional Corp' and await release of capacity by decommissioning and/or consolidating capacity well before the breach of SLA.

b. Option 2: Proceed with procurement of hardware if decommissioning and/or consolidating does not release any resources required.

Vendor management

Hardware procurement cannot be done overnight. The formality of the whole process by the CSP and its execution by the hardware vendor is time consuming, usually taking several weeks. This is not favorable for the CSP as this causes delays in delivering resources to the CSP's clients.

An agreement should be made with the vendor for better hardware procurement and installation to stay in-line with the expectation of the cloud. Various vendors allow hardware to be purchased in a utility model where the hardware, although installed, will be charged by the CSP

only when it is actually used. This reduces the time to procure. Further challenges that arise while balancing the cost surrounding procurement is discussed next.

Cost and Capacity

Storing unused IT hardware is not a good approach to capacity planning. Purchasing an IT resource must be the last resort to a capacity problem. Hardware becomes outdated very quickly; a new, improved, and cheap version might arrive very soon (Moore's law[10]).

All possible steps such as over-subscribing, consolidation, storage aggregation, migration, decommissioning unused data, and reducing internal workloads must be performed well before deciding to procure hardware. This does not mean that purchasing hardware is the worst idea of capacity planning. Any genuine reason like the one seen in the previous section (potential customers conflicting for capacity) must be honored with priority.

Data Center Facilities

Compute and storage hardware consume data center floor space. Also, they add to the power, cooling, and connectivity costs within the data center.

While considering hardware procurement, rack space, floor space, connectivity, power, and cooling factors must be checked. For data centers with little floor space, high density servers and disk array enclosures must be considered.

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[10] Moore's Law is the observation that over the history of computing hardware, the number of transistors on integrated circuits doubles approximately every two years. The period often quoted as "18 months" is due to Intel executive David House, who predicted that period for a doubling in chip performance (being a combination of the effect of more transistors and their being faster).

Conclusion

Managing capacity for cloud infrastructure needs to be at the *Optimized level* on the capacity management maturity scale. Cloud infrastructure cannot tolerate 'wastage' of resources. The whole infrastructure must be carefully examined from the ground level up.

Focus must be on granularity of each component in the infrastructure. Various technologies such as thin provisioning, FCoE, virtualization, and VXLAN are the key ingredients of a cloud infrastructure. These technologies must be leveraged to the fullest extent to maximize hardware utilization and management of the cloud infrastructure.

Problems related to security in the cloud are logical problems that are addressed by applying various software tools and aligning the systems to various compliance standards and regulations. Capacity on the other hand is a realistic problem that if it is not tracked, monitored, trended, and finally optimized, could defeat the whole definition of cloud computing.

Appendix A

Automation of resource gathering is important to ensure that the latest data are available to measure the resources. A few of the methods possible are:

<u>Storage</u>

In VNX arrays, the arrayconfig command could be used to gather all the information about the array. The command generates a XML file which could be transformed into a detailed spreadsheet using Unisphere® Service Manager.

For VMAX arrays, SYMCLI scripts could be customized to obtain data related to pool utilization, FAST policies, etc.

ProSphere® could be used to monitor storage capacity and trending.

<u>Compute</u>

PowerCLI scripts can be used to customize the data required for ESX Clusters and VM.

<u>Third-party Monitoring tools</u>

The following is a partial list of tools available for monitoring cloud infrastructures:

- Zenoss Cloud Monitoring

- RevealCloud

- RevealUptime

- Gomez APM

- Nimsoft

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