Virtualization effects on Data Centers
& Cloud Technologies:
Getting your head out of the Cloud

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Abstraction is a fundamental key in computing. This one idea spans both hardware and software and continues to manifest itself in present day technologies. In the early days of computing, hardware was created with a predefined set of processes wired into its board. This was not flexible; because of this and the possibilities that machines promised, the Von Neuman model was ushered in. This separated hardware from software and in effect was the first level of abstraction that emerged. This allowed for unique instruction sets to be executed and finer control of the resources that a machine offered. Thus, more abstraction built into an architecture yields more flexible and agile architecture. Shortly thereafter, programming languages emerged and a whole slew of other abstracting techniques followed such as operating systems. Arguably, the most profound abstraction is virtualization. Virtualization is not a new technology. IBM was using virtualization techniques as early as the 1970's with mainframe systems allowing a process to use only a portion of the system's resources. However, virtualization really took off in the early 2000's. To understand virtualization, one must first understand what virtualization is not. A common definition of virtualization is : multiple virtual machines (VMs) being multiplexed into the same hardware separating hardware from software. While the previous definition of virtualization falls into the category of a type of virtualization a more encompassing definition is: turning physical (hardware) and/or digital (software) resources into logical or virtual resources. Virtualization has touched the fields of IT, operational technologies, personal technology, sensor/actuator technology, and much more. As technologies became more mature, uses of these technologies matured as well. Programmers used to program on a mainframe computer and have to develop files and applications for specific systems whether they be hardware (intel / AMD processors) or software (different operating systems). Then, came the client/server model where a central computing system sent data via networks to clients. Cloud computing and its use of virtualization offers the pooling of resources and many aspects of cloud computing can be referred to as serverless computing. There are several technical aspects that should be visited when dealing with cloud and data center technologies.The technical aspects discussed in this paper are virtualization techniques, operating systems, networks, data centers , data, and how virtualizing each lends itself to cloud computing .

Hypervisors or Virtual Machine Managers(VMMs) have allowed for the creation of virtual machines, virtual clusters, and virtual data centers. Most of the VMMs used are derivatives of Xen. The principal functions of a VMM are : execution and management of VMs and their resources, device emulation and access control, execution of privileged operations by hypervisor for guest VMs, and administration of VMM platform and VMM software. VMMs , including Xen, use a microkernel architecture instead of a monolithic kernel architecture. The microkernel architecture has only essential / non changing instructions of an operating system . There are three major types of VMMs: full virtualization, host-based virtualization, and para-virtualization. Full virtualization is a hypervisor that allows multiple VMs to sit on top of bare metal and does not modify the host operating system because there is no host operating system: the hypervisor sits on shared hardware. This is accomplished by allowing instructions of the VMs to execute at runtime on the actual hardware when the instructions are non-virtualizable. The virtualizable instructions are trapped and executed in an emulated environment through binary translation. The instructions that are virtualizable do not run directly on the hardware due to the fact that they are deemed critical instructions and thus compromise the security of the host system. Another type of virtualization is host based virtualization. Host based virtualization exploits the resources of a host operating system and runs as an application on the host operating system. Host based virtualization is used heavily in desktop emulation environments on personal devices. Host based virtualization partitions its system into several rings that have lesser privileges the further the rings are from the VMM. Thus, mapping instructions through all these rings slows down performance. Ultimately, full virtualization is the most prevalent virtualization technique used in data centers due to enhanced performance, no host operating system to compete with for resources, and security benefits. The main security benefit of a fully virtualized hypervisor is that requests for resources are made external to the guest operating system and the hypervisor in full virtualization making the VMs more isolated and not able to affect more than itself were something malicious to happen. Paravirtualization is another type of virtualization that is primarily used to reduce the overhead of virtualization. Overhead is reduced by modifying guest operating systems to run non-virtualizable instructions via hypercalls that help streamline these instruction's execution on the hardware. Paravirtualization uses layers known as Rings just like host based virtualization . Where paravirtualization differentiates itself is modifying the guest operating system to have modified drivers and executing instructions at compile time instead of runtime . In a paravirtualized environment, the hypervisor has a driver interface that helps map the calls to real drivers existing in the hypervisor reducing the mapping of calls and increasing the performance of non-virtualized instructions. This method is akin to having specialized APIs that hide the mapping complexities of non-virtualized instructions. Sadly, paravirtualization is not capable of taking advantage of hardware extensions, such as the virtualization hardware on new intel and AMD processors. A popular hypervisor is Xen. Xen uses paravirtualization in a similar fashion as KVM. KVM is the paravirtualization system that Unix systems use. Amazon Web Services has based its hypervisor, Amazon machine language (AMI), on citrix Xen. These virtualization techniques enable VMs to have a profound effect on data centers. The main advantage of having these technologies is server consolidation which is discussed in a later paragraph. VMs are often an integrable part of this server consolidation and have warranted the creation of their own set of tools such as templates and CAS to reduce the size of a VM. There are a number of benefits in having VMs prevalent in data centers including the improvement of : balancing of resources, fast provisioning, disaster recovery, and high availability. VMs leveraged by the ability to virtualize operating systems.

Operating Systems manage processes, memory, scheduling, I/O, and file management. Guest operating systems in VMs are not the fully decked operating systems that appear in a personal computer. Instead, these operating systems are modified in order to streamline performance in an environment where they will be competing with other operating systems for resources. These operating systems vary depending on the architecture that is being used; for

instance, fully virtualized hypervisors emulate drivers and have a large amount of binary translation, thus overhead, to translate the VM's instructions to run on the hardware and have no host operating system. Whereas , paravirtualized machines have modified drivers in the guest operating system that perform hypercalls to a hypervisor driver interface via hypercalls speeding up binary translation and reducing virtualization overhead. A typical hypervisor will take on responsibilities such as scheduling, memory management, and I/O operations. Resource allocation and the provisioning of VMs is typically done by a cloud operating system / virtual infrastructure manager. This cloud operating system is usually responsible for a network or networks. Common cloud operating systems include: Nimbus, Eucalyptus, OpenNebula, and vSphere 4. The cloud operating system's responsibilities include: network management, dynamic provisioning, data protection, and monitoring capabilities. These cloud operating systems provide a one-stop shop for personnel to monitor the state of the data center. There is one more major player that must be considered: containers. Containers differ from VMs in that VMs function at the border of hardware and the guest operating system. In contrast, containers have a host operating system and function in between the host operating system and applications. Containerization can be described as running on top of the host operating system kernel and sharing a common operating system kernel. Containers provide a runtime environment for applications by providing necessary libraries. Containers are feasible due to resource control and process isolation. VMs and containers have a different lifecycle but both are widely used in a vast array of data center technologies. These virtualized technologies that relate to operating systems have produced a new way of managing resources. One sector of technology that has had to conform to these new operating system virtualization techniques is networks.

Along with the technologies used to manage VM's , containers, and other virtualized technologies, networks have undergone major virtualization. This virtualization affects infrastructure addressing schemes, bandwidth allocation techniques, routing processes, and other network tools such as vSwitches, vLans and link layer virtualization. Network topologies and hierarchies have been created to accommodate ever changing demands of data centers and clouds. Data center networks are mostly IP based commodity networks, using 10 Gbps ethernet cables that are optimized for internet traffic. These networks require low latency , high bandwidth, low cost, mpi communication support, and high fault tolerance. Common networks that are in data centers are fat trees and crossbar networks that provide expandability and modular network growth . Modular network growth is important because networks in data centers are growing in a peculiar way. Container-based modular data centers are networks that are packaged in a container usually a 12 meter shipping container. These pre fabricated containers are added to a network and are used until the mini-data center degrades to a point where it has depreciated beyond use. The addition of these MDCs to an already functioning network is usually done with smart network technologies that automatically handle routing and other configuration techniques. CIDR, subnet, and masking techniques are heavily used in order to manage load balancing and a modular topology of data center networks. Virtualization techniques such as vLans, vSwitches, virtualized link layers, and the virtualization of networks is handled primarily by layers 2 and 3 of the OSI model. These 2 layers connect physical and virtual networks with routers, NICs, network adapters, and vSwitches. Several technologies have

been created to help manage these networks like Host-based Intrusion Detection software which runs on VMs and monitors the data center. The evolution of networks has improved the key driving forces behind cloud computing : ubiquity of broadband and wireless networking, multi tenant techniques, and web scale communication. These network improvements help create dynamic data centers that meet ever demanding requirements.

Each data center has its own data center network(s). Networking in data centers is not the largest cost but it is the key to reducing overall costs and maximizing performance. The largest effect of virtualization on data centers is server consolidation. Server consolidation is the process whereby several virtual machines run on a set of shared hardware resources. These VMs do not have to have the same runtime environment and can reduce a server room's physical footprint by upwards of 75%. The number of guests that can exist on a single host is measured by a consolidation ratio. 2020's technologies are at a 15:1 consolidation ratio. Some benefits of server consolidation are: enhancements of hardware utilization, enables more agile provisioning and deployment, total cost of ownership is reduced, improves availability and business continuity. Server consolidation also makes building redundancy into a network more cost effective since data can be mirrored among virtual resources as well as physical resources. Hosts in virtualized data centers are physical blades in a server rack which have their own IP address(es). Each host runs an accompanying application. This used with server consolidation reduces transmission rates because traffic doesn't have to cross several server racks. The virtualization of operating systems, networks, and data centers has happened so that data can be virtualized.

Nothing influences decisions more than data including but not limited: to physical characteristics, performance requirements,volatility, volume, regulatory requirements, transaction boundaries, and retention period. Things like the speed of access will affect the architecture. For instance, if a faster response time is needed more cache will have to be leveraged over disk and more cache will probably be built into the architecture. Several data storage techniques utilize network technologies such as SAN, NAS, and DAS. The SAN technique is the primarily used storage technology in data centers. It is a file storage scheme using hard disks to create storage. SAN is good for mirroring servers. NAS technologies are good for replication using RAIDs and Network File System softwares. NAS devices can be used to create drives on the network by appending files. DASs are internal hard drives that are used to capture the server hierarchy and often exist in the VMM. All of these storage devices are important in data centers and are used in techniques like live migration. Depending on the size of the data being requested, data may come from storage or data may arrive from CDNs. If data is large like video, the data is more likely to be streamed from a CDN instead of a data center. Data centers handle virtual memory in much of the same way that a typical operating system would handle virtual memory. Software solutions, such as Parallax, have arisen to handle cases of distributed storage of data. These data techniques in virtual storage provide data services for data center infrastructure, working space to apps and workloads, and storage related mechanisms: workload migration, automated backups, integrated version control and block storage.

In conclusion, virtualization has affected many aspects of technology. In operating systems, networks, and data centers, virtualization has and is continuing to enable broadband access, rapid elasticity, and a customizable platform that utilizes resources making its use both economically and technically desirable.

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