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Review of Virtual Machine Migration in Datacenters

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***Abstract*— This paper takes a tour of Virtual Machine Migration systems across physical servers in datacenter which includes it's architecture, basic working, migration strategies, design issues and goals. Despite of various on-going research for more than two decade in this field, variations in migrations procedures, context, environment and needs is still a major challenge faced by it.**

***Keywords*— Virtualization, Virtual Machines, Migration, Hypervisor, Cloud Computing**

I. Introduction

In the field of networking the advancements in network infrastructures and the growing size of storage/data centers, the demand for Virtualization and Data Center flexible resource management has become significantly important. A need arises for approach that changes the economics of the data center by unifying compute, storage, networking, virtualization, and management.

II. Virtualization and Virtual Machines

Virtualization is an approach that allows developers to create a snapshot or replica of the existing system, to create customized environment without compromising and making changes to available physical resources. The purpose of Virtualization is to utilize the resource sharing, utilization and distribution to their maximum potential, reduce infrastructure costs in terms of physical resources, hardware, new network setups, system setups, and infrastructure maintenance.

Virtualization hides the characteristics of the physical system from the user and instead provides with another abstract computing platform. Virtualization often finds itself as an alternative to run the applications that are not currently supported by the existing systems, evaluate new systems, run multiple instances of same or other alternate systems on same machine. Virtualization in broad terms comes in various forms like Para-virtualization, Full virtualization, and container-based virtualization. Virtualization further can be in various forms like Operating Systems, Applications and Storage level virtualization. In this paper we explore OS level virtualization in servers residing in big datacenters and related issues with them.

A. Virtual Machine

Virtual Machines (VM) go with the context of Virtualization in physical machines like desktop, servers, etc wherein a copy of the existing system is made either in view to dynamically map new systems with existing ones, increase number of users and system usage, test the new systems on existing infrastructure, resource distribution and sharing. A typical VM comprise of a guest Operating System (OS), guest application(s), with shared CPU cores, shared memory, shared NIC and shared disk drives over a physical machine comprising its own layers of hardware and software.

A Virtual Machine though was originally defined by Popek and Goldberg as "an efficient, isolated duplicate of a real machine [1]". The purpose of designing Virtual Machines is to

- Allow existence of strongly isolated multiple OS on the same computer.
- Provide an instruction set architecture (ISA) that is somewhat different from that of real machines [1].
- Testing new developments, application provisioning, system maintenance, increased availability, storage transfers.

The major disadvantages that comes with any VM includes their low efficiency in comparison to physical machines due to indirect instruction execution and accesses, high dependence on physical resources like Memory, CPU processing speeds, current process execution speeds of processor, resource reservations, etc. But despite of these disadvantages Virtual Machines are still high in demands for deployment on existing systems and networks for workload distributions and accommodate fast growing business requirements and end-users.

B. Virtual Machine Migration

Term 'migration' in general states the movement or passage of a person from one locality to another. In terms of Computers and Networking, migration presents the movement of a system from one location or one network to another. VM Migration thus is a process performed between two or more physical servers deployed over a Local Area Network (LAN) or Wide Area Network (WAN) in which a Virtual Machine is moved from one machines to another often in context to server maintenance, load balancing, efficient resource sharing, network scalability, testing, storage back-ups, server management, disaster recoveries, etc.

With the growing data day by day and advancements in application processing and networking, Virtual Machines and their migrations are becoming major needs of any business today.

III. Virtual Machine Architecture

Since a Virtual Machine comprises of its own Operating System and shared hardware, it resides independently, in isolation on a physical machine and executes over a Virtual Machine Monitor (VMM) or hypervisor. VMM is a Virtualization software designed to make virtual machines which constantly monitors the VMs running over it. It acts as a bridge between these VMs and physical machines' hardware/software.

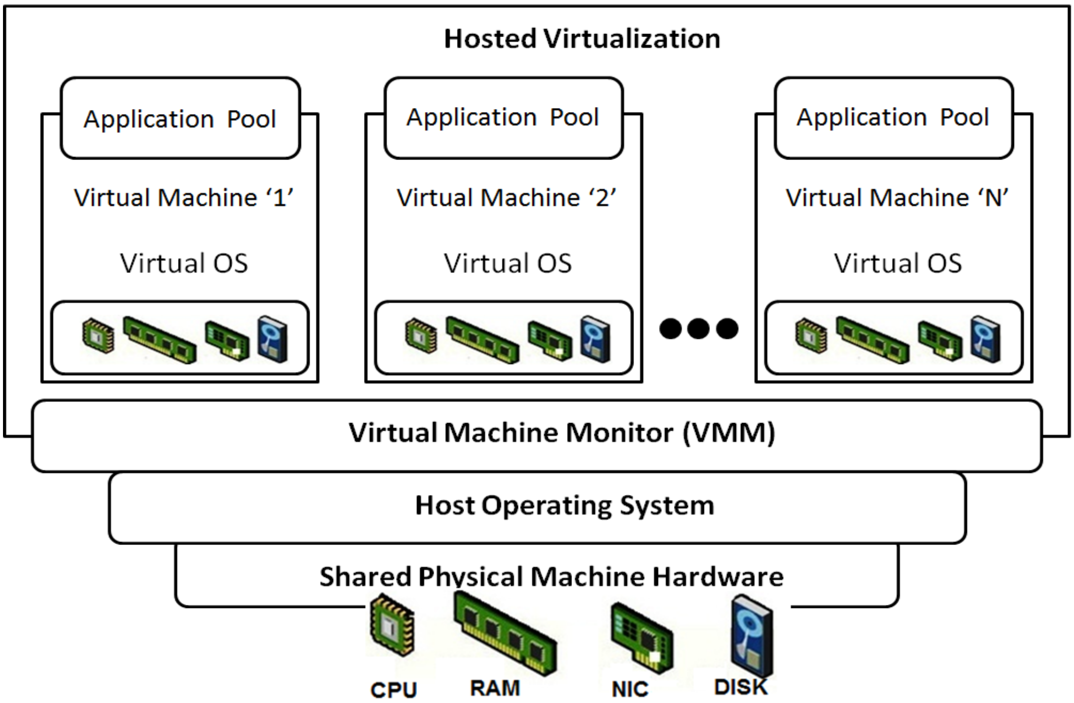

Fig. 1 Virtual Machine architecture for a server

Figure 1 above demonstrates a simple VM architecture for a Datacenter Server machine. Starting from the bottom of the logical stack, the host operating system (any server OS like Windows Server 2008) manages the physical computer. The Virtual Machine Monitor (VMM, also known as Hypervisor) acting as a virtualization layer that manages virtual machines, providing the software infrastructure for VMs hardware emulation by sharing server resources. Each virtual machine consists of a set of virtualized devices.

When a guest operating system is running, the special-purpose VMM kernel manages the CPU and hardware during virtual machine operations, creating an isolated environment in which the guest operating system and applications run close to the hardware at the highest possible performance rate.

IV. Virtual Machine monitor types

VMMs (also "hypervisors") as discussed, are special type of software which is designed with a motive to act as a gateway or act as a layer between VMs and server hardware/software. Therefore, VMMs are of three basic types:

- *Type1 VMM that* are deployed between server hardware and VMs (as in Fig.2 below). In this type there is no Server OS installed on server, hence each VM is pre-allocated with one shared resource on server hardware.

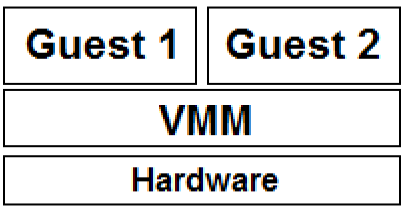

Fig. 2 Type 1 hypervisor

- *Type2 VMM,* that are deployed between server OS and VMs (as in Fig.3 belo). This type of hypervisor will be considered for our approach of load balancing, since in this approach the resources are shared by both VM and server OS for other side process executions. It also provides with an added advantage of resource scheduling and optimization for server hardware/software/I/O by server OS so the resources are assigned and utilized by VMs and processes efficiently.

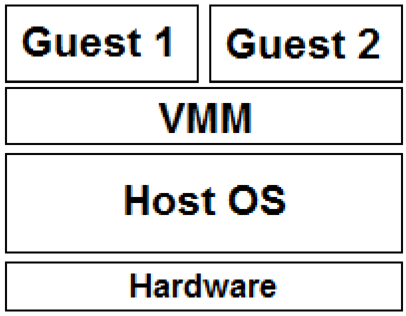

Fig. 3 Type 2 hypervisor

- Type 3 VMM, also known as Hybrid VM (as in Fig.4 below). These VMMs are combination of Type 1 and Type 2 in which server OS works individually for its process execution and resource management while certain server hardware resources are allocated to VMM for their execution.

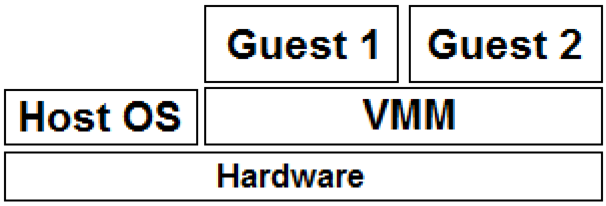

Fig. 4 Type 3 hypervisor

VMMs through its dedicated software components, keeps the records of all loads – memory usage, storage usage of individual VMs; helps in server's resource management – CPU, memory, I/O device sharing by VMs; maintain a log for server's CPU load and memory usage; provides an interface to configure hardware/software based load balancing strategies to manage VMs loads on server resources etc.

V. VM MIGRATION STRATEGIES

Virtual machine migration includes two modes: non-live VM migration and live VM migration. In non-live VM migration, the execution of the VM is suspended during whole migration process [3]. During live migration process for VMs, the VM on source server which is to be migrated keeps running during most of migration time. The two categories of live migration algorithms include: Pre-Copy (with stop-copy-resume) and Post-Copy of VM storage.

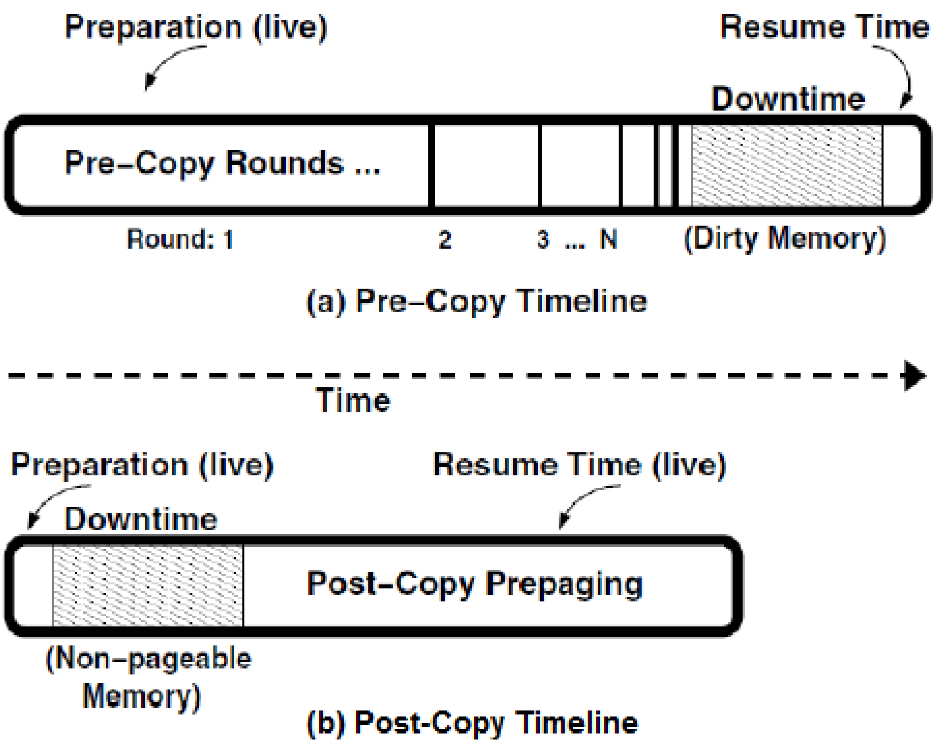

Fig.5. (a) Pre-copy and (b) Post-copy migration strategies

Pre-Copy is the more frequent and common live migration technique to perform live migration of VMs. Using Pre-copy, the storage memory of the migrated VM is copied to destination host first while the VM is still running on the source host. The source host maintains the newest memory image until migration is finished as can be seen in Fig.5(a) below where vRAM, vCPU and vDISK are the virtual RAM, virtual CPU and virtual Disk respectively, allocated to a Virtual Machine on a physical machine for its operation and execution.

At the end of Pre-copy migration phase, the VM is suspended and the remained memory image is copied to destination host. The remaining new memory images are called Dirty Memory. This technique of migration usually results in redundant dirty pages at destination host which are generated till the time VM is suspended at the source. As a result, the migration time for extra page delivery increases. This phase is known as Stop & Copy migration phase.

The migration itself encompasses transfer of the persistent state of the VM (i.e. its file system), transfer of the volatile state of the VM i.e. RAM contents and CPU state, and the redirection of network traffic. Once the state transfer is complete, the VM continues to run in the new physical machine, known as VM resume phase.

In Post-Copy, it works in two phases: [4,5] (Fig.5(b)) In the first phase, VM is suspended on the source host, and its VCPU context and minimal memory work-set is copied to destination host. In the second phase, VM is started on the destination host, and the remained memory image is continued transfer to destination host. Though it saves the migration time initially but then the frequent requests for disk dirty pages for old data to the source increases the load on the server as well as to the communication further. Under Post-copy migration the page fetching handling is done in various schemes: Post-copy via Demand Paging, Post-copy via Active Paging, Post-copy via Pre-paging.

VI. MAJOR HYPERVISORS

With large popularity of VM and migrations worldwide, many big IT business leaders came out with their solutions to implement the powerful technologies to support integrated system creations. Virtualization support companies like VMware, Microsoft brought down into market their own hypervisor solution systems in order to create a abstraction layer between physical machines and virtual machines in their datacenters. Different companies made different hypervisors with varied functionalities but with a common functionality of VM migrations. Following companies brought the following Open-source and licensed software:

- *VMware:* VMware Inc., the leader in virtualization market designed a complete infrastructure solution for Virtualization in datacenters. That includes ESXi server hypervisor on which virtual machines are created, vMotion with vCenter for VM migration process initiation and completion and central storage communication in the form of iSCSI/NAS.
- *Microsoft:* Microsoft corporation for its datacenter designed hypervisor named MS Hyper-v with NAS for multiple VM migrations at the same time.
- *XEN:* the oldest Virtualization technology developer designed XEN-Motion to support para-virtualization technology for the systems to keep the VMs highly isolated from each other when deployed on a host with low penalties for performance. Additionally, in XEN-based systems guest VMs know the hypervisors and run efficiently without virtual emulated hardware.
- *KVM:* Kernel based Virtual Machine, works on full virtualization of hardware technology that add virtualization capabilities to a standard Linux kernel and along with dedicated QEMU process, the emulation of the VMs on host machines is carried out considering them as Linux process running in guest mode. Therefore no guest VM modifications for its execution are required on new physical machine to which it is migrated.
- *OpenVZ:* OpenVZ along with Parallels Computer Servers offers a solution for VM migration. It works on container-based virtualization for Linux systems and creates secured containers which act as independent server on physical machine to get better server utilization and resource availability.

VII. ISSUES RELATING VIRTUAL MACHINE MIGRATIONS

- *Isolation of VMs:* In order to operate multiple VMs parallel to each other on the same physical server, it has to be guaranteed that these VMs are isolated, i.e., different VMs cannot interfere with each other's execution.
- *Scalability of VMs:* Careful planning and dimensioning can decrease the effects of "weak isolation" of VMs on a single server. Servers should have enough resources that the creation, update and deletion of VMs should be scaled with the needs of the datacenter and the services.
- *Execution:* The virtual machine must be executable on the target processor architecture. Emulation functionality and the required I/O devices must be available.
- *Resource Utilization:* The resource utilization of the target processor must be low enough to permit the addition of the virtual machine (CPU, memory, I/O).
- *VM Downtime:* The downtime imposed by the migration process should be short so that the service delay of migrated VM is as less as possible.

VIII. APPLICATION AREAS

Virtual Machines together with VM migration facility are finding their existence in many area of business today. Be it Information Technology, finance, health-care, daily lives, or else, businesses' are more and more inclining towards virtualization to meet ever changing requirements. Following are some application area of VMs with migration:

- *Cloud Computing*
- *IP-TV and DTH networks*
- *Storage Area Networks (SAN)*

- *Data warehousing and Big Data*
- *Social Networking and e-Mails systems, etc.*

IX. FUTURE SCOPE

In accordance to the review of the existing VM migration technologies future datacenter systems should be capable enough in a manner that they can withstand the robust and dynamic computing environments of a Datacenter. Moreover, the migrations should be performed in such a way that the resources of the physical machines Datacenters are best utilized in a manner that scalability of VMs does not hinder their overall performances. VM migration infrastructure and Hypervisors should be designed in view of automation of migration process so that performance of physical and virtual machines are not dependent on manual interventions to initiate migration process at high-in-demand and peak hour situations and the end user receives the best of service and businesses carried out in a more efficient manner.

X. CONCLUSIONS

Research in the field of Virtualization has been in existence for more than a decade now as not only the technology is best suited for scaling demands for the IT infrastructure, it reduces the overall expenditure on infrastructure developments and the maintenance thereafter. With developments in Virtual Machines design technology for both hardware and software, it now became easy to deploy new systems on existing ones without any hefty additional costs, maintain them, test new developments and provide best of the class service in potential application areas of Virtual Machines with migration process.

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