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A Survey of Virtual Machine Migration Techniques in Cloud Computing

Sandeep Kaur, Prof. Vaibhav Pandey
Department of Computer Science and Engineering, *Punjab Institute of Technology, kapurthala*
Punjab, India

Abstract
Cloud computing is an emerging computing technology that maintains computational resources on large data centers and accessed through internet, rather than on local computers. VM migration provides the capability to balance the load, system maintenance, etc. Virtualization technology gives power to cloud computing. The virtual machine migration techniques can be divided into two categories that is pre-copy and post-copy approach. The process to move running applications or VMs from one physical machine to another, is known as VM migration. In migration process the processor state, storage, memory and network connection are moved from one host to another.. Two important performance metrics are downtime and total migration time that the users care about most, because these metrics deals with service degradation and the time during which the service is unavailable. This paper focus on the analysis of live VM migration Techniques in cloud computing.
Keywords: Cloud Computing, Virtualization, Virtual Machine, Live Virtual Machine Migration.

1. Introduction to Cloud Computing

Over the recent decades, propels in computing technology have revolutionized our lifestyle. Cloud computing engages IT holdings as an organization; suppliers are making a bestowed pool of configurable processing assets, which customers can alertly procurement and release on requests payable reason.

Rajkumar et. al. [2] "A Cloud is a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers." [3] .In cloud computing various cloud consumers demand variety of services as per their dynamically changing needs. So it is the job of cloud computing to avail all the demanded services to the cloud

Consumers But due to availability of finite resources it is very difficult for cloud providers to provide all the demanded services in time. From the cloud providers perspective cloud demanded services in time. From the cloud providers' perspective cloud resources must be allocated in a fair manner. So, it's a vital issue to meet cloud consumers' QoS requirements and satisfaction. The ultimate goal of efficient resource utilization in cloud computing is to maximize the profit for cloud providers and to minimize the cost for cloud consumers.

Cloud computing is not new to Information Technology. It has been for the most part considered as an unlimited scale dispersed registering perfect model dictated by economy of scale. The peculiarities that perceive distributed computing from different different models are administration driven,asset pooling, and information facilitating in outsourcing storage. Pooling asset the equipment execution be utilize by economy of scale. The peculiarities that perceive distributed computing from different models are administration driven, asset pooling, and information more effective and gives monetary profits to clients to lessen the capital expense and extra use. The greatest profit is that engineers no more oblige the vast capital expenses in hardware to deploy the inventive plans for new Internet administrations administration and subsequently slicing the human cost to work it [2] [3].

In this period where processing is offered as a utility, Datacenter is a key component encouraging endeavor applications. Each application is associated with a Service Level Agreement (SLA) organizing the application execution levels guaranteed to client and punishment installment structures in the occasion of the datacenter overseer's battlement to SLA.

The rest of the paper is organized as follows: Section 2 discusses Virtualization. Section 3 gives summary of virtual machine migration. Section 4 and 5 discusses various live virtual machine migration techniques proposed by researchers. In Section 6 the goals of VM migration are described. Conclusion of work is presented in Section 7.

2. Virtualization

Virtualization is a framework or methodology of dividing the resources of a computer into multiple execution environments, by applying one or more concepts or (VM) and technologies such as time-sharing, hardware and software partitioning, partial or complete machine simulation or emulation, quality of service, and many others [4]. The approach of virtualization which empowers to computing resources of a solitary physical machine (PM) among various virtual machines (VM) ensuring execution detachment, made ready for compelling and productive resource utilization and management.

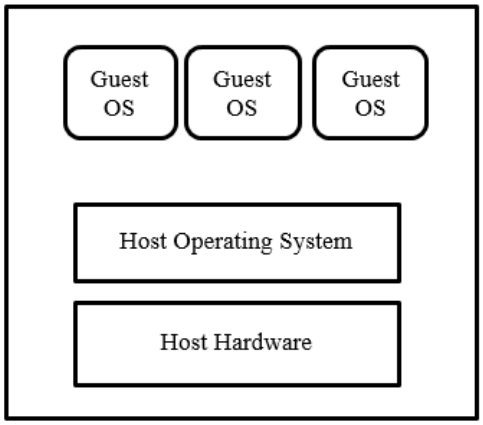

Fig 3: Virtual Machine Diagram [Ref. 1]

In a virtualized datacentre, every application segment (server) of an enterprise customer application is exemplified in a virtual machine (VM) and a solitary physical machine (PM) has different VMs. Virtualization gives an approach to change resources assigned to VMs dynamically (VM resizing) and moving VMs starting with one physical machine then onto the next. Furnished with an intelligent situation of virtual machines on physical machines, this permits us to take after the workload progressions of applications consequently empowering successful use of resources. Virtualization could be attained at the different type of levels. The Sorts of virtualizations are Server Virtualization, Storage Virtualization, Operating framework Virtualization and Network Virtualization, System Virtualization is the point at which a solitary physical host runs various VMs on it. This VM has it applications that run on its OS (guest OS). For the client, a VM carries on much the same as an autonomous physical machine.

3. VM Migration

Migration is one of the most important features provided by modern VM technologies. It allows system administrators to move an OS instance to another physical node without interrupting any hosted services on the migrating OS. It is an extremely powerful cluster administration tool and serves as a basis for many modern administration frameworks which aim to provide efficient online system maintenance, load balancing, reconfiguration and proactive fault tolerance in clusters and data-centres.

VM migration consumes resources both on the machine from which it is being migrated and the machine to which it is being migrated. As a result, performance of the VM in migration and VMs residing on both source and destination machines will be affected. The technique to determine and carry out this dynamic (re)allocation of VMs in a virtualized datacentre is termed as dynamic server consolidation. In addition to monitoring the resource utilization of VMs, any such technique needs to be wary of the effect of VM migrations too, to figure out the new VM-to-PM allocation map from time to time. There is a lot of work done on this area trying to devise an effective dynamic server consolidation technique.

Most of existing techniques try to migrate VMs from lightly loaded and heavily PMs to moderately used PMs While keeping number migrations to a minimum (to curb migrations cost). This allow to power of least utilized machines while decreasing load on highly utilized machines to prevent possible SLA violation. Each of them formulates migration cost in their own way (e.g. number of migrations, migration efficiently). Though the original aim of server consolidation was to minimize server sprawl - i.e. minimize the number of PMs being used, this should not be exercised naively. The main motive of datacentre operator is to maximize its returns. Minimizing the number of active PMs obviously contributes to reduction in operational cost of datacentre. But this minimization carried out by migrating virtual machines is not free. Migration exhibits its own cost in terms of deteriorating application performance and reduction in amount of resources available while VM migrations are being done. If the deteriorated application performance meant a violation in service level agreement (SLA), penalty needs to be paid to client. Even then, migration may be a safe bet provided the aftermath reaps more revenue and this may not be possible unless previous migration activity is done.

3.1 Need to Migrate VM

Virtual Machine Migration can also migrate Virtual Machines in case of unscheduled server downtime (due to some fault in server), so that users experience high availability of applications at all times. Virtual Machine Migration can also be used for Disaster Recovery. This process involves setting up of similar resources in a DR site with high speed WAN links and specialized network connectivity equipment. The Virtual Machines and their memory states are frequently synchronized (replicated) between the primary servers and the servers, so that migration can happen quickly in case of a disaster. Its easier to migrate a Virtual Machine from one server to

another, than migrating the operating system and applications individually.

Every time it happens, its not possible to provision additional servers manually. So, Virtual Machine Migration accommodates for the changing workloads automatically (It can adapt to both additional workloads and reduced workloads). A Scheduled maintenance normally results in some downtime for the users of the server. But with Virtual Machine Migration, the VM can be migrated to some other server (for that period of scheduled maintenance) and brought back to the host server after the maintenance is completed. Using Virtual Machine Migration, its possible to migrate operating systems and applications from older servers to newer servers easily and without disrupting the services.

4. VM migration Techniques

Initially, pure stop-and-copy approach was used for VM migration. This involves halting the original VM and copying all pages to the destination, after then starting the new VM. This has the advantages in terms of simplicity but the service downtime is proportional to the amount of physical memory which is allocated to the VM. This can be lead to an unacceptable outage if the VM is running a live service.

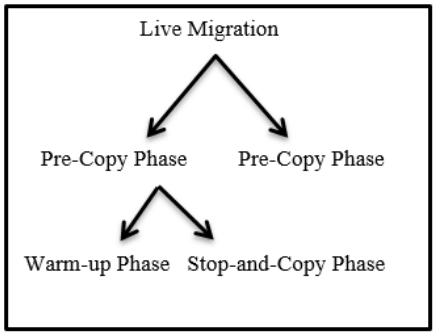

Fig 2: Phases of Virtual Machine Migration

4.1 Pre-Copy Memory Migration

In pre-copy memory migration, the Hypervisor typically copies all the memory pages from source to destination while the VM is still running on the source. If some memory pages change (become 'dirty') during this process, they will continue re-copied until the rate of re-copied pages is not less than page dirtying rate.

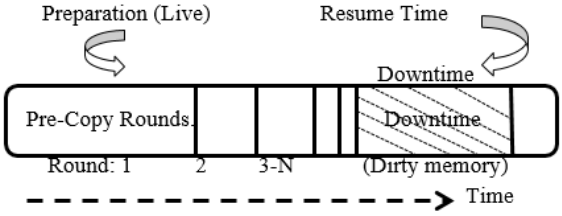

Fig 2: Pre-copy Timeline [9]

4.1.1 Warm-Up Phase

In warm up VM memory migration phase, the hypervisor copies all the memory pages from source to destination while the VM is still running on the source. If some memory pages change during memory copy process dirty pages, they will be re-copied until the rate of recopied pages is not less than page dirtying rate.

4.1.2 Stop-and-Copy Phase

After the warm-up phase, the VM will be stopped on the original host and the remaining dirty pages will be copied to the destination, and then the VM will be resumed on the destination host. The time gap between stopping the VM on the original host and resuming it on destination is called "down-time", and ranges from a few milliseconds to seconds according to the size of memory and applications running on the VM. There are some techniques to reduce the migration down-time, such as by using probability density function of memory change.

4.2 Post-copy memory migration

Post-copy VM migration is initiated by suspending the VM at the source, by suspending the VM a minimal subset of the execution state of the VM (CPU registers and non-pageable memory) is transferred to the target. The VM is then resumed at the target, even though most of the memory state of the VM still resides at the source. At the target, when the VM tries to access pages that have not yet been transferred, it generates page-faults. These two faults are trapped at the target and redirected towards the source over the network. Such faults

are referred to as network faults. The source host responds to the network-fault by sending the faulted page. Since each page fault of the running VM is redirected towards the source, this technique can degrade performance of applications running inside the VM. However, pure demand-paging accompanied with techniques such as pre-paging can reduce this impact by a great extent.

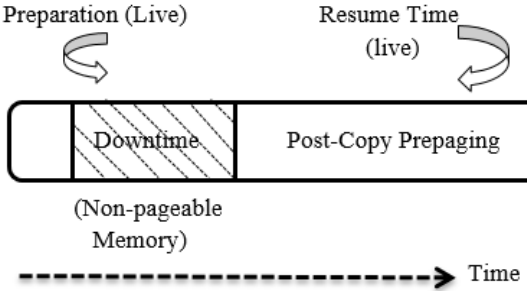

Fig 4: Post-Copy Timeline [9]

5. Literature Review

The basic pre-copy approach is suggested by **Michael Nelson et al. [6]**. They proposed first system that provided transparent virtual machine migration of existing applications and operating systems, where neither the applications nor the operating systems need to be modified. It is the first research to provide performance measurements of hundreds of virtual machine migrations of concurrently running virtual machines with standard industry benchmarks. It characterizes the overheads and resources required during virtual machine migration. They described a migration system, named VMotion that has an integral part of the VMware Virtual Centre product. In data centers and clusters environment migrating operating systems (OSes) instances across different physical hosts is a useful tool for administrators.

Clark et.al.[7] deliberated the design options for migrating OSes running services with liveness constraints, focusing on datacentre and cluster environments. They introduced and analyzed the concept of writable working set, and presented the design, implementation and evaluation of high performance OS migration built on top of the Xen VMM.

In order to minimize the downtime of migration of virtual machine several authors have proposed improvement over the basic pre-copy approach. Live migration of virtual machine's downtime directly depends on the size of memory state of the VM that is going to migrate from one host to another host. To minimize the size of memory state of the VM different memory compression techniques are proposed.

Hai Jin et al. [8], presented the design and implementation of a novel memory compression based VM migration approach (MECOM) that first uses memory compression to provide fast, stable virtual machine migration, while guaranteeing the virtual machine services to be slightly affected. They design an adaptive zero aware compression algorithm for balancing the performance and the cost of virtual machine migration. Pages are quickly compressed in batches on the source and exactly recovered on the target. Another memory compression technique is proposed by

Svard et al.[9]. implemented the application of delta compression during the transfer of memory pages in order to increase migration throughput and thus reduce downtime. The delta compression live migration algorithm is implemented as a modification to the KVM hypervisor. Its performance is evaluated by migrating VMs running different type of workloads and the evaluation demonstrates a significant decrease in migration downtime in test cases. An enterprise application scenario, the delta compression algorithm successfully live migrates a very large system that fails after migration using the standard algorithm. Finally, they discussed some general effects of delta compression on live migration and analysed when it is beneficial to use this technique.

There are some other techniques which are useful in minimizing the downtime of live migration of virtual machines. While transfer of memory state of the VM marked the frequently updated pages and transfer these dirty pages at last iteration of memory transfer.

Fei Ma et al. [10], added a bitmap page in his improved pre-copy approach, which marks those frequently updated pages. By the judge in the iteration process, it put those frequently updated pages into the page bitmap, and those pages can only be transmitted in the last round of the iteration process. This can ensure that those frequently updated pages are transmitted just once in the iteration process.

Bolin Hu et al. [11] also proposed an improved time-series based pre-copy approach for virtual machine migration. With the time-series prediction technique, they identified frequently updated dirty pages (high dirty pages) in the past and future period more precisely, and transmit them in the last round of iteration, in order to reduce unnecessary, repeated transmission of dirty pages.

Ibrahim et al. [12] presented a novel algorithm that achieves both low downtime and low application performance impact. At the core of the algorithm is detecting memory update patterns and terminating migration

when improvements in downtime are unlikely to occur. They implemented this approach in KVM and demonstrated its benefits for both Ethernet and RDMA (InfiniBand) migration.

The Post-copy approach is proposed by Michael et al [13]. The Post-Copy approach is opposite to pre-copy approach for live migration of VMs. In the post-copy approach, first it migrates the VM's execution states such as CPU states etc. and after migration of CPU state, it transfers VM's memory pages. The main benefit of this approach is that each memory page is transferred at most once, thus avoiding the duplicate transmission overhead of pre-copy. Michael et al [13], presented the design, implementation, and evaluation of post-copy based live migration for virtual machines (VMs) across a Gigabit LAN. The post-copy strategy can provide a "win-win" by reducing total migration time while maintaining the liveness of the VM during migration. They facilitated the use of post-copy with adaptive pre paging techniques to minimize the number of page faults across the network. Finally, they eliminate the transfer of free memory pages in both pre-copy and post-copy through a dynamic selfballooning (DSB) mechanism. DSB periodically reclaims free pages from a VM and significantly speeds up migration with negligible performance impact on VM workload

Many previous approaches focused on transferring memory but there are some techniques which used different approaches to provide fast transparent live migration of virtual machines.

Weining Lie [14], described a novel approach based on recovering system and CPU scheduling to provide fast, transparent live migration. Target host executes log files generated on source host to synchronize the states of source and target hosts, during which a CPU scheduling mechanism is used to adjust the log generation rate.

Hai kum liu [15], described the design and implementation of a novel approach CR/TR-Motion that adopts Check pointing/recovery and trace/replay technology to provide fast, transparent VM migration. With execution trace logged on the source host, a synchronization algorithm is performed to orchestrate the running source and target VM until they get a consistent state. This scheme can greatly reduce the migration downtime and network bandwidth consumption.

Soramichi et al. [16] discuss the placement of Virtual Machines (VMs) on physical hosts are dynamically optimized in response to resource utilization of the physical hosts. However, the existing live migration techniques are used to move VMs from one host to another, and need to involve large data transfer and also prevents dynamic consolidation systems from optimizing VM placements efficiently. The proposed technique called "memory reusing "that reduces the amount of transferred memory of live migration. When a VM migrates between hosts, the memory image of the VM is kept on the original host (from where VM migrates). When the VM migration go back to the original host later, the kept memory mage will be "reused",i.e.memory pages which are identical to the kept pages will not be transferred. Implemented a system named MiyakoDori that uses memory reusing in live migrations.

Arun et al. [17] promoted a proactive technique where processes automatically migrate from "unhealthy" nodes to healthy ones. This approach relies on operating system virtualization techniques exemplified by but not limited to Xen. This paper contributes an automatic and transparent mechanism for proactive FT for arbitrary MPI applications.

Troger et al. [18] proposed an architectural blueprint for managing server system dependability in a pro-active fashion, in order to keep service-level promises for response times and availability even with increasing hardware failure rates. They introduced the concept of anticipatory virtual machine migration that proactively moves computation away from faulty or suspicious machines. The migration decision is based on health indicators at various system levels that are combined into a global probabilistic reliability measure.

Load balancing is the process of sharing the load among computers in order to optimize the utilization of available CPU resources. A number of techniques proposed for load balancing are based on live virtual machine migration.

Ma et al. [19] proposed a new model for distributed load balancing allocation of virtual machine in cloud data center using the TOPSIS method which is one of the most efficient Multi Criteria Decision Making (MCDM) technique. This method can find the most suitable physical machine in the datacentre for the migrated VMs. MCDM technique try to avoid the live virtual machine migration.

Zhao et al. [20] proposed a distributed load balancing algorithm COMPARE_AND_BALANCE based on sampling to reach an equilibrium solution. They designed and implemented a simple model which decreases the migration time of virtual machines by shared storage and fulfils the zero downtime relocation.

6. VM Migration Goals

As explained by Anju Mohan et.al [21], its main goals are as follows:

a) **Server Consolidation:** Server consolidation algorithms are required to decrease server sprawl in data canters. Such algorithms are in actual the VM packing heuristics attempt to pack whatever number VMs as would be prudent on a PM so that asset utilization is enhanced and unused or under-used machines could be turned off. This brings about reduced power consumption and in this way decreasing general operational expenses for data

center administrators.

b) **Load balancing:** This decreases the imbalance of resource use levels over all the PMs in the group. This keeps a few machines from getting over-burden in the vicinity of lightly loaded machines with sufficient extra limit. Movement could be utilized to adjust the framework. The general system load could be adjusted by moving VMs from over-burden PMs to under-loaded PMs.

c) **Hotspot & Cold spot Mitigation:** Typically, a higher resource utilization esteem near greatest is situated as the upper limit and a low resource use worth is situated as the lower edge. PMs having resource utilization values past the upper limit are said to have shaped hotspots, and whose use values underneath the lower edge are said to have structured cool spots **[21].**

7. Comparative Study of Different VM Migration Techniques

In this section will describe compare various techniques used for live migration of VMs with their basic concept and their pros and cons. This paper discussed about different approaches that are used for live migration of virtual machines. Each approach consists of some advantages and disadvantages. The two main techniques that are used for live migration of virtual machines are pre-copy and post-copy techniques. The basic concept of pre-copy is very simple that is if one VM want to migrate form one physical host to another physical host than first transfer their device states, network connections and physical memory to remote location and finally transfer the processors states to that location. During the migration, the client connection is maintained and client feel little service downtime .The post-copy techniques are just opposite of precopy techniques. In post copy technique, firstly the processor states are transferred than the physical memory etc. transfer. A lot of techniques for the improvement of pre-copy approach have been proposed. The improvement over pre-copy is based on how can reduce the amount of physical memory transfer from one physical machine to other physical machines. Many memory compression techniques and frequently updated pages of memory techniques are used to reduce the size of physical memory of virtual machine.

Table 1. Comparison of different migration of virtual machines techniques

Virtual Machine Migration Techniques	Less Downtime	Less Data To Be Transferred	Less migration Time	Pre-Copy Migration Technique	Pre-Copy Migration Technique
Pre-Copy approach [6]	Yes	Yes	No	Yes	No
Adaptive Rate Limiting approach[7]	Yes	No	No	Yes	No
adaptive memory compression approach [8]	No	Yes	Yes	Yes	No
delta compression [9]	Yes	Yes	No	Yes	No
page bitmap [10]	No	Yes	Yes	Yes	No
timeseries prediction technique [11]	Yes	Yes	Yes	Yes	No
detecting memory update patterns [12]	Yes	Yes	Yes	Yes	No
Post-Copy approach [13]	No	No	No	No	Yes
Recovering system and CPU scheduling [14]	Yes	No	Yes	No	Yes
Check pointing/recovery and trace/replay approach (CR/TR-Motion) [15]	Yes	Yes	Yes	No	Yes
Memory reusing mechanism for VM Consolidation[16]	Yes	No	Yes	No	Yes

8. Conclusion

This paper presents a review of various live virtual machine migration techniques in cloud computing. The live virtual machine migration techniques can be broadly divided into two categories that is pre-copy and post-copy approach. Few techniques proposed by researchers other than these two approaches are also discussed. The paper also discussed VM migration techniques for cloud federation. All the techniques discussed above try to minimize the total downtime of migration and provide better performance in low bandwidth and the memory reusing mechanism for VM consolidation [16] reduces the amount of transferred memory and also reduce total migration time.

We present that the migration approach which is used by the previous researchers is based on the past performance of the datacentres.

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