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COMPARATIVE ANALYSIS OF VIRTUAL MACHINE MIGRATION SYSTEMS FOR CLOUD ENVIRONMENTS

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Abstract: Virtualization techniques are successfully used in large-scale Cloud Data Centers (CDC) to address the increasing demand for compute, storage, and communication resources. Many resource management objectives, such as load balancing, online system maintenance, proactive fault tolerance, power management, and resource sharing, can be achieved by virtual machine (VM) migration. Since virtual machines require constant access to CPU cycles, cache memory, memory space, and communication bandwidth, the process of migrating virtual machines is resource-intensive. We discuss many performance metrics, including data movement volume, total migration time, and downtime of application services. The transfer of CPU, memory, and storage data is a part of virtual machine migration, and we outline the specific kinds of data that need to be moved in each scenario. We offer a brief overview of security vulnerabilities associated with live virtual machine migration, classifying them into three categories (control plane, migration module, and data plane). We also discuss the requirements for security and the available countermeasures against possible attacks. Particular gaps are identified and research issues related to improving the performance of live virtual machine migration are tackled.

Keywords: virtualization, cloud computing, virtual machine migration, pre- and post-copy techniques, security

1. Introduction

In cloud computing [1] environment services are delivered in the form of hardware, software, storage, platform, infrastructure, database and much more using Google’s App Engine [2], Microsoft Azure [3], Amazon’s EC2 [4], IBM SmartCloud [5], etc. Cloud Computing delivers hardware and software capabilities in the form of services over the internet and allows consumers to be provisioned resources on-demand, on a pay-per-use [6] model. Due to the increased demand for cloud resources, cloud providers handle warehouse size data center, this large scale Cloud Data Centers (CDCs) carry more than thousands of computing servers which are connected by high-speed communication links and consume a large amount of

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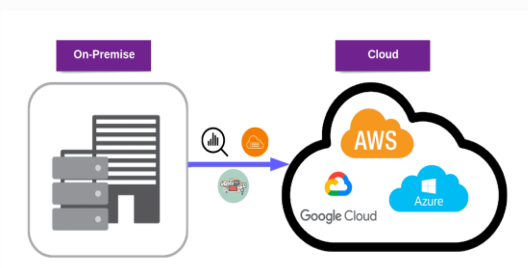
electricity. Further to provide guaranteed services, on an average 30% of servers remains in idle mode and approximately 10–15% of server capacity is used for fulfillment of resource demands [7]. The under utilization or over provisioning of resources result in a phenomenal increase in operational cost and power consumption [8, 9]. In 2013, it was estimated that Google data centers consume approximately 260 million Watts of electricity, which is enough power to give continuous electricity to more than 200,000 houses [10, 11]. In 2014, it has been estimated that IT would contribute only 25% to the overall cost of operating a CDCs whereas about 75% of the total cost would contribute to infrastructure and power consumption [12]. One of the basic solutions of such problem is to switch the idle mode server to either sleep mode or off mode based on resource demands, that leads to great energy saving because idle mode server consumes 70% of their peak power.



Virtualization technology was developed by IBM in 1960 to maximize the utilization of hardware resources because powerful and expensive mainframe computers were underutilized. It is a thin software layer running between Operating System (OS) and system hardware, termed as a Virtual Machine Monitor (VMM) or hypervisor, that control, manage, and mapped multifarious VM's (applications running on guest OS) on a single platform [14–16]. Also, it is a complete software and hardware stack to fulfill the incoming request or provide a service to users [17]. Examples of popular virtualization software are VMware ESX and ESXi [7], Kernel-based Virtual Machine (KVM) [uick Emulator (QEMU), Citrix XenServer [11], Microsoft Virtual PC Microsoft Hyper-V , Oracle VM VirtualBox [4], and Parallels Desktop for Mac The main advantage of virtualization is to provide better resource utilization by running multiple VM's parallels on a single server. Hypervisor supports the legacy OS to combine numerous under-utilized servers load onto a single server and also support fault tolerance and performance isolation to achieve better cloud data centers performance. Due to VM's isolation, failure of one VM does not have an effect on execution/functioning of other VM's and on the entire physical machine [6]. To improve CDC efficiency, different types of resource management strategies like server consolidation, load balancing, server up-gradation, power management etc. are applied through migration of single/multiple VM's. Also to achieve energy efficient environment, it combines numerous servers' loads onto a few physical servers and switch off the idle servers. For improving application performance, hypervisor also helps to migrate the running VM's from a low-performing to another better performing

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physical server [7]. Consequentially, co-hosting several different types of VM's onto a few servers is a challenging issue for researchers because resource contention among co-hosted applications that leads to servers over-utilization which results in application performance degradation Also a large number of cloud applications like interactive applications experience frequently changeable workload requests that generate dynamic resource demand which results in Service Level Agreement (SLA's) violation and performance degradation if dynamic server consolidation is used.

For VM migration, hypervisor exploits live VM migration for moving VM's between respective servers using shared or dedicated resources. Live VM migration continuously provides the service without interrupting the connectivity of running application during migration time to obtain seamless connectivity, avoiding SLA violation and to get optimal resource utilization. It is also used in adaptive application resource remapping It is a very useful technique in cluster and cloud environment. It has many benefits like load balancing, energy saving, preserving service availability. It also avoids process level problem such as residual dependencies [3], process dependency on its original (source) node. VM migration controller migrates a single VM [3] or multiple VM's (cluster VM set) [4] on Local-Area Network (LAN) or Wide-Area Networks (WAN) network for efficient management of the resources. If VM migration is performed within LAN [4] servers then it is easy to handle because storage migration is no longer required in Network Attached Storage (NAS) integrated data center architecture. Also, the network management within LAN requires minimal effort because IP address of the corresponding server remains unchanged. VM migration over a WAN network [takes a considerable amount of migration time because the transfer of storage migration, limited availability of network bandwidth, IP address management, packet routing, network congestion, and the faulty behavior of WAN links having considerable overheads.

Now a days, most of the hypervisors support live migration but the implementation of live migration with a little or no consideration towards its security. Hence live migration might be susceptible to range of attacks from Denial-of-Service (DoS) attacks to Man-In-The-Middle (MITM) attacks. During the migration, data can be tampered or sniffed easily as it is not encrypted. Thus compromising confidentiality and integrity of migrating data. These security threats in live VM migration discourages many sectors, such as financial, medical, and government, from taking advantage of VM live migration. Hence, security is the critical challenge that needs examination to provide secure live VM migration.

2. LITERATURE SURVEY

In the literature, few surveys highlight the importance of VM migration in a cloud

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environment. Soni and Kalra [38] reviewed different existing techniques which concentrate on minimization of total migration time and downtime to avoid service degradation. Kapil et al. [9] performed a summarized review of existing livemigration techniques based on pre-copy and post-copy migration. They considered total migration time, service downtime, nd amount of data transferred as a key performance metrics for comparison. They mention some research challenges like the type of network (LAN/WAN), link speed, page dirty rate, type of workload, address wrapping and available resources. Further different aspects of memory migration, process migration, and suspend/resume based VM migration techniques have been surveyed by
Medina and Garcia. In this, few VM migration techniques are included and no comparison is performed.

The authors have not considered performance parameters of currently running applications under VM migration, network bandwidth optimization, and hybrid VM migration
technique for improving migration process. Xu et al. [3] present a survey on performance overheads of VM migration within inter-CDC, intra-CDC, and servers. Their proposed classification does not consider different aspects of VM migration, timing metrics, migration pattern, and granularity of VM migration for highlighting the application performance and resource consumptiontrade-off. A comprehensive survey has performed by Ahmad et al. [4] covering different VM migration points like VM migration patterns, objective functions, application performance parameters, network links, bandwidth optimization, and migration granularity. They reviewed state-of-the-art live VM migration and non-live VM migration techniques. But the authors did not show any analysis based on performance parameters of VM
migration. Moreover, they did not describe the weakness of reviewed techniques. In their extended survey work, Ahmad et al. [11] presented a review on state-of-the-art network bandwidth optimization approaches, server consolidation frameworks, Dynamic Voltage Frequency Scaling (DVFS)-enabled storage and power optimization methods over WAN connectivity.

They proposed a thematic taxonomy to categorize the Live VM migration approaches. The critical aspects of VM migration is also explored by comprehensive analysis of existing approaches. A survey on mechanisms for live VM migration is presented by Yamada [12], covering existing software mechanisms that help and support in live migration. They reveal research issues that not covered by existing works like migration over high speed LAN, migration of nested VMM, and migration of VM attachedto pass-through accelerator. The techniques are classified into two categories: performance and applicability. In a long-distance network, how the live

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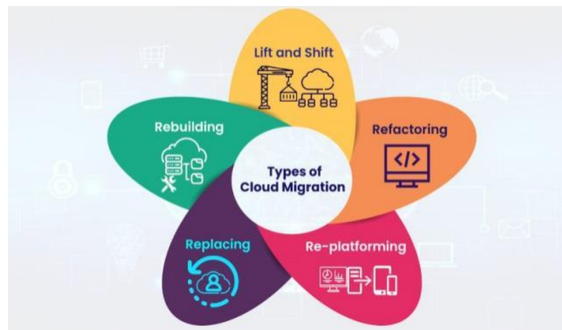
migration and disaster recovery are performed with necessary operations is addressed by Kokkinos et al. [4]. They focus on new technologies and protocols used for live migration and disaster recovery in different evolving networks. In our work, we address the limitations of existing surveys [16] and present comprehensive survey on state-of-the-art live VM migration techniques. We consider different important aspects of VM migration
while incorporating the trade-off among application performance, total migration time, network bandwidth optimization for meeting the resource management objectives. Our major contributions in this paper can be summarized as follows:

1. Comprehensive literature review of state-of-the-art live VM migration techniques and description of strengths, weaknesses, and critical issues that require further research.
2. Definition of key aspects of migration process like CPU state, memory content and disk storage that affect total migration time and understanding of type of memory and storage content that need to be igrated.
3. Discussion on the various the performance metrics that affect VM migration process.
4. Discussion of various security threats and their categories in live VM migration and explanation of security requirements and existing solutions to mitigate possible attacks.
5. Classification of the existing migration mechanisms into three basic categories: type of live VM migration, duplication based VM migration and context aware migration based on the objectives and techniques used.
6. Identification of specific gaps and research challenges to improve the performance of live VM migration.



Migrationmodule

Migration module is a software component in the VMM that allows live migration of VM's.A guest OS can communicate with the host system and vice versa. Moreover,the host system has full control over all VM's running over its VMM. If the attacker is able to compromise the VMM via its migration module, then the integrity of all guest VM's that are running above this VMM will be affected.Any VM in the future that will migrate to the affected VMM will also be compromised. VM with a low security level is exploited using the attack techniques in the migration module. When an attacker discovers a VM with a low security level during the migration process,they will attempt to compromise it and can do it easily. They can use it as a gate to compromise other VM's on the same host with higher levels of security [15]. Moreover, the attacker will be able to attack

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the VMM itself, after identifying a way to enter the system.

Security requirement in VMmigration

There are security requirements that must be implemented in the live VM migration, which will enhance the security level in the previous classes to protect both VMs and host servers from any attack - before,during, and after the live migration process. Aiash et al and John et al

[16] discussed security requirements in live VM migration. Following are the security requirements that should be implemented in VM live migration: (1)defining access control policies, (2) authentication between sender source server and the destination server, (3) non-repudiation by source and destination server, (4)data confidentiality while migrating a VM, (5) data confidentiality before and after migration, and (6) data integrity and availability.

Migration overWAN network

The existing VM migration techniques cannot deal efficiently with VM migration over aWAN where the source and the destination servers are part of different networks [14]. Live VM migration across WAN network is big challenge as:

1. **Migrating network and storage connections:** TCP connection survivesVMmigration and its application without disruption in network connections if the source and destination servers are on the same sub-net. Otherwise, migration process also deals with breaks when migration occurs across sub-nets.
2. **Migrating storage content:** migration of large size virtual disk over WAN takes a long time. Hence the volume of data transferred over the WAN is also critical.
3. **Persistent state remains at the source side:** The re-located VM accesses the earlier centralized storage repository, over the WAN. Nevertheless, network latencies and considerable bandwidth usage result in poor I/O performance.

3. Conclusion

Moving a running virtual machine (VM) or several operating VMs from one server to another is known as live VM migration. The virtual machine (VM) services need to be migrated while they are still operational because users need to be able to access them at all times. Only if virtual machines are moved with no downtime would this be feasible. Load balancing, proactive fault tolerance, power management, resource sharing, and online system maintenance are the driving forces behind live virtual machine migration. We determine which content types—CPU state, RAM content, and storage content—need to be moved throughout the migration process. We outline the fundamental procedures involved in the migration process and talk about pre-copy, post-copy, and hybrid VM migration strategies. We discuss the key performance indicators that have an impact on migration overheads. The thorough analysis of cutting-edge Approaches to live virtual machine

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migration fall into two main kinds. First, we talk about the models, which are stages of theory. Next, we talk about the frameworks, which are actual applications. Performance measurements are used to compare the current methods used in each of the aforementioned subcategories. Threats associated with live virtual machine migration are examined, and potential assaults are divided into three groups according to their nature: control plane, data plane, and migration module. Lastly, we discuss a few of the major research issues that still need to be resolved in order to enhance the effectiveness of the CDC's migration process.

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