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RESEARCH PAPER

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AN EXPERIMENT BASED EXAMINATION OF ENERGY OVERHEAD THROUGH VM MIGRATION

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Abstract: The use of cloud computing has increased in recent days with tremendous benefits to users and also provoked to rise in total ownership cost due to the swift increase in energy consumption of data centers. Out of various approaches, best of virtual machine (VM) placement policies can be exploited to reduce the energy consumption during migration in data centers. The virtual machine live migration during placement has enough potential to reduce energy overhead with a certain level of utilization. One of the mechanisms to achieve energy efficiency is to manage the migration time parameter of live migration with appropriate network bandwidth in communication aware connected data centers. In spite of this, virtual machine size and network bandwidth have a great impact on energy consumption of subsystems during virtual machine live migration. In this paper, critical examination has been done to analyze the impact of migration time on energy consumption of subsystems during guest virtual machine live migration. For experimentation, Kernel-based Virtual Machine (KVM) hypervisor and Virt-manager was used to perform the live migration on Ubuntu 14.04 Linux machines in various conditions. Afterwards, the noted observations are validated with Pearson's Correlation Coefficient statistical approach to study the strength of relationship of defined parameters.

Keywords: Data center; Virtualization; Live Migration; Energy Consumption; Virtual Machine (VM)

I. INTRODUCTION

The use of cloud computing has increased gradually with the demand of online resources. Various corporate firms and individuals are moving on cloud environment and accessing required computing resources. The number of servers is being installed throughout the world to fulfill the requirements of the consumers for various computing resources. The major giants of the industry like Amazon, IBM, Google and Microsoft are providing online services worldwide. Various significant concerns like fault tolerance, security and computing services are need to be resolved to provide quality and reliable services to customers worldwide [1]. Cloud computing technology is based on pay-as-you-go model that helps to drive economy. It becomes necessary for the service provider to ensure load balance and reliable computing services to its clients round the clock worldwide and keeping services ON means consuming power all the time [2]. Another major issue of concern comes into consideration is how to minimize energy consumption or going for Green computing [3, 4]. More than required energy consumption by deployed servers in host data centers and cooling systems is very expensive. In recent years, usage of cloud computing has increased and this makes the energy consumption problem more prevalent for research. According to [5], between 2000 and 2006 the amount of energy consumed by data centers around the world has doubled and today datacenter electricity consumption is almost 2% of world production. The energy consumed by cloud data centers not only influence electricity bill, but also CO2 emission and global warming [6]. Due to the energy consumption of components such as hard disk, memory, main board, a server at idle state still consumes about 70% of the energy it consumes at full CPU speed [7].

In addition, energy consumption during delivery of services increased with growth rate of 30 percent annually between 2012 to 2016 [8]. Therefore, problem of high energy consumption in cloud data centers becomes very significant and in these days researchers are striving for design of energy efficient policies. There are basically two components in data centers which are responsible for energy consumption.

One is ICT (Information and Communication Technology) systems i.e. host machines, storage, and communication channels and another is supporting infrastructure like air-conditioner, ventilation and heating. These components are potential candidates to be exploited and explored to decrease the extra energy consumption or overhead. In this paper emphasis has been put on virtual machine placement policies using migration on target machines.

A. Virtualization

The concept of virtualization technique separates the implementation detail and physical resources from installed operating system on the machine. This can be achieved with the help of hypervisors or Virtual Machine Monitors (VMM) which are installed in between the operating system (OS) and the hardware components [9].

The hypervisor helps to manage multiple operating systems (Virtual Machines) on single machine and implements the concept of virtualization (see Fig.1). These virtual machines provide different cloud computing services to customers based on requests while maintaining the Quality of Service (QoS). The Service Level Agreement (SLA) violation parameter defines the level of quality of service provided to the customers. The Live migration [10] feature of virtualization enables to move memory content from one physical machine to another machine with service delivery to customers as per SLA. There are various ways through which VMs' memory contents can be moved from one physical host to another.

The basic Pre-Copy [11] and Post-Copy [12] approaches are used for live migration of VM pages from source to destination machines with small variation in down time. Other techniques like Adaptive memory compression approach [13] and delta compression approach [14] are useful to reduce migration time and down time, but their compression operations introduced additional overhead to migration. So, when a VM is migrating with live services it is necessary that this migration balances the requirement of minimization of *downtime* and *total migration time* parameters of live migration.

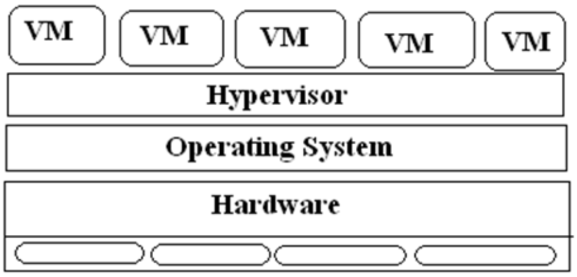

Figure 1. Layered view of Virtualization

Downtime is that time during which the VM service is interrupted and unavailable to clients because there is no currently executing the instance of the VM. The latter is the time duration between the start of migration and when the original VM discarded on the destination machine. With this source, machine can be used for maintenance and up gradation. Virtual machine live migration has attracted considerable interest to minimize extra energy consumption in cloud data centers in recent years. In order to save energy, we are focusing on live migration of VMs from one server to another with quality constraints. But energy overhead cannot be considered negligible during VM live migration [15]; it can be reduced up to some extent. The contribution of this paper is summarized as follows:

1) Examined the impact of VM size and network bandwidth on migration time of Virtual Machine and energy consumption of source machine during VM migration.
2) Performed validation on the defined relationship of parameters by implementing experiments on real environment and used Pearson's Correlation Coefficient approach. The results have shown significant affect on migration time and energy consumption of source machine.

The rest of the paper is organized as follows: Section II describes related work of analysis. Section III represents migration energy relationship parameters to study the effect. Section IV explains machine specification, tools used and implementation details of experiment. Section V presents the result evaluation with graphs and statistical validation using defined parameter values. Finally, Section VI concludes all of analysis work with future directions.

II. RELATED WORK

The energy consumption during VM Live Migration has been investigated in various research studies [15, 16, 17]. Most of the existing or proposed studies focus on energy overhead during VM Live migration in terms of its migration time and down time under various conditions. Work that analyses the energy consumption of VM live migration in specific constraints of subsystems is very rare.

Jianxin et al.[18] proposed an adaptive approach in which they specify some key metrics of live migration performance and conducted some experiments to see the affect of parameters i.e. *speed limit, TCP buffer size ,max downtime, workload* , VM size and network bandwidth on VM live Migration on KVM and energy consumption of the source and remote systems. Aggressive setting of these parameters may incur excess energy consumption during VM Live Migration. Authors designed self adaptive approach to optimize migration time and reduced energy consumption by 45% compared to default migration approach.

Yichao Jin et al. [19] investigated the affect of server virtualization on energy consumption of physical server with some experiments. Idle server consumed approximately two thirds energy when its computing resources are fully occupied during virtualization. KVM consumed more energy than Xen server in virtualization state. The increase in number of virtual machines caused more energy consumption than optimum use of VMs.

Anja Strunk and Waltenegus Dargie [16] experimentally investigated the live migration of virtual machines that caused energy overhead due to size of virtual machine and network bandwidth. Current approaches are focused on migration time of virtual machines and down time of services under various conditions. The investigation of energy consumption during migration process is very rare. In migration techniques, processes like pre-copy and stop-and-copy requires extra network bandwidth and CPU cycles for migration. Unlimited and aggressive usage of resources during live migration became the major reason for extra energy consumption. This experiment proved that power consumption due to migrating virtual machines cannot be considered negligible and increased by 63 percent as compare to power consumption of the idle systems. The live migration cost with respect to energy consumption is not insignificant and it varied with the size of virtual machine and bandwidth of the communication link. The higher energy consumption problem increased with increase in size of virtual machines in migration stage and reduced with an increase in the bandwidth of communication link. The impact of variation in network bandwidth is more on energy consumption as compare to change in size of migrating virtual machine.

Pinheiro et al. [20] designed an algorithm to reduce power consumption in a heterogeneous cluster of computing nodes serving multiple web-applications. The designed approach is to switch on or off various cluster systems based on application load generated dynamically. The algorithm was implemented on application level and operating system level to take decision for cluster load. The proposed algorithm continuously observed the load of resources and made decisions on switching nodes on / off to minimize the overall power and energy consumption, while providing the expected performance. The experimental results showed that proposed technique can minimize total power and energy consumption by 83 percent and 43 percent respectively as compare to traditional systems with 20 percent degradation in the performance. This algorithm can be used for organizations that are based on large clusters and servers.

Takahiro et al. [21] presented a proposed energy aware virtual machine consolidation approach using the concept of post-copy live migration. Due to lengthy migration time of pre-copy live migration, authors had chosen post-copy live migration having shorter and determinable migration process to perform VM consolidation. The proposed system attained more regular live migrations and adaptations in server power states. This optimized policy enabled the server to minimize extra energy consumption as compared to using pre-copy live migration. The designed algorithm is based on CPU statistics excluding network and disk components from this. Authors designed a consolidation approach with ACPI S3 mode and conducted several experiments to assess the efficiency of post-copy live migration. Watt meter was used to measure the power consumption of underlying systems. Our experiments revealed that proposed consolidation system with post-copy live migration reduced excessive power consumption as compared to pre-copy live migrations. This consolidation approach removed 11.8 percent energy overhead of executing virtual machines and improved with 50 percent as compared to pre-copy live migrations.

Rybina et al. [15] experimentally investigated the magnitude of VM migration overhead in terms of energy consumption and service execution latency. Authors performed various tests with pre-copy live migration algorithm on two homogeneous servers attached with Network Attached Storage (NAS). The power analyzers were used to measure the power consumption of source and destination server. During each migration, they recorded the power consumption and the resource utilization of both servers. The power consumption of the source server was higher than the power consumption of the destination server and the energy overhead of a live VM migration significantly reduced with higher network bandwidth.

Bing [22] designed advanced live migration performance models with respect to energy consumption and flexible workloads of underlying servers. The energy guided migration model and workload adaptive model were established for minimization of energy consumption and to consider the changeable workload, respectively. The first mentioned model helps to select the feasible virtual machine for migration having minimum energy consumption whereas the subsequent model ensures minimum energy consumption of selected destination physical machine with composite workload characteristics and efficient service performance. The former model chose virtual machine with least memory size and efficient CPU utilization. The workload adaptive model chose the best migrating destination server with minimum energy consumption. The physical machine with smallest distance on a network had been chosen as destination to conserve energy with optimum workload. The experiments were carried out to verify the energy saving nature of two algorithms. The results showed that models are achieving better energy efficiency with optimum workload and lesser migration time. In this approach, several notable unnecessary live migrations have been avoided to control the energy consumption with changeable workload environment.

With this we have reviewed various Research papers [23] and highlighted the various research issues to minimize energy consumption in data centers exploiting virtualization technology. In this paper specifically we are discussing some experiments to analyze the impact of variation in VM Size with network bandwidth on migration time and energy consumption during VM Live migration.

III. MIGRATION ENERGY OVERHEAD

In huge data centers, number of overloaded and underutilized servers is more than proper utilized servers. Most of energy is being wasted by these data centers. These servers can be utilized by migrating VMs from overloaded systems to underutilized servers after knowing the cause of power wastage [24]. So, it is necessary to analyze migration parameters i.e. VM size, network bandwidth and migration time.VM migration cost power model can be given as follows:

$$\text{Power dissipation} = Pidle + Pcpu\ (Pbusy - Pidle) \quad (1)$$

Where P_{idle} is the power consumed by idle server, P_{cpu} is the power consumed by CPU, P_{busy} is power consumed by busy server.

Therefore, energy consumption E, of Live migration is defined as the average power dissipated P, multiplied by the migration duration t:

$$E = p * t \quad (2)$$

If $$t = VMsize\ /\ (\ bandwidth) \quad (3)$$

then,

$$E = P * \{VMsize\ /\ bandwidth\} \quad (4)$$

To calculate the energy consumption of Live Migration, We measure the power consumption of source and destination servers, before and during live migration and analyze the migration time. Then consumed energy is being calculated as follows:

$$E_{consumed} = \int_0^t (P_t - P_0)\, dt \quad (5)$$

To measure the cost of live migration from all results due to uncontrolled activities, we carry our live migration when both systems are idle with zero percent CPU utilization. As previous work [15, 16] shows the energy overhead of live migration of virtual machines varies with the RAM size of the virtual machine and the available network bandwidth. We chose migration time, VM size and network bandwidth as model parameters to validate equation 3 and 4 in our experiment. This paper presents the analysis work of the impact of VM size and network bandwidth on migration time and energy consumption of source system during virtual machine placement.

IV. TESTBED AND EXPERIMENT

Testbed was created for live migration of virtual machines using *virt-manager* and KVM/QEMU supported hypervisor. For the analysis of the various energy consumption metrics, live migration of VMs was carried out using the open source operating system Ubuntu 14.04 LTS. Two physical machines each having Intel Core2 Quad CPU Q9400 2.66GHz x4 processor, with 4GB RAM and 200GB hard disk with enabled Virtualization Technology (VT), were used for virtualization to handle VMs in each of them. KVM/QEMU hypervisor was used for this experiment and *Virt-Manager* VM manger was used to manage VMs for live migration in two given hosts. The systems were connected using Ethernet cable in LAN and application protocol SSH was used for remote host secured connection to perform tunneled migration as shown in Fig. 2.

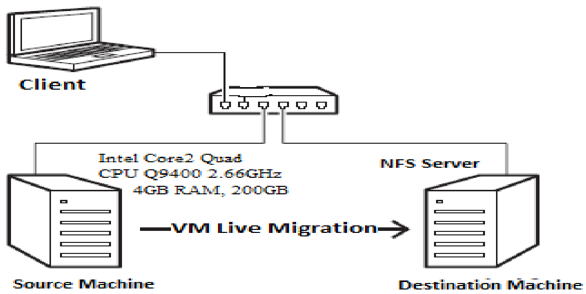

Figure 2. VM migration system setup

The Network File Storage (NFS) was used in a server and mounted on both the host machines to share storage of host machines. First, source host machine was observed for power consumption at idle state, before the start of live migrations and then we multiplied power consumption with migration time to calculate average energy consumption. We used WattsUp Pro [25] electric meter to measure power consumption with 1% accuracy. Power consumption measurements represent the entire system with their components, not only CPU or memory. For workload, we selected guest image Window XP operating system configured with one CPU and 1GB RAM initially. In each experiment VM was migrated six times between two machine hosts for the fixed value of bandwidth. Results calculated are the average of these six migrations. Then we increased the VM size to 2GB and applied same steps to measure the power consumption and migration time for different bandwidth values. Then, we calculated average energy consumed (AEC) and average migration time (AMT) of iterations performed for VM live migration as per equation No. 5. *Virt-manager* Virtual Machine Manager was used on both machines to support migrations. Once VM started on source machine, we applied migrate command in *Virt-Manager* by providing SSH and destination host name with specific IP address and port number as shown below:

```
Connection: qemu+ssh://mca@192.168.10.209/system
```

Virt-manager uses pre-copy [11] live migration approach to copy memory state pages in multiple iterations and in last iteration migrates VM CPU status. When the entire VM is transferred to the destination with dirtied pages, it continued to provide services there until stopped explicitly.

V. PERFORMANCE EVALUATION

This section composed of graphical analysis of the experiments conducted on testbed and statistical analysis based on *Pearson Correlation Coefficient*. This entails the extension of preliminary study based on virtual machine live migration [26].

Based on experimental setup, these observations clearly validate migration energy cost equation 3 and 4 i.e. the affect of VM size and Network bandwidth on migration time and energy consumption of source machine. Parameter VM size has linear relationship with energy consumption and migration time. As shown in Figure 3 VM migration time increased with increase in size of VM and reduced with high network bandwidth.

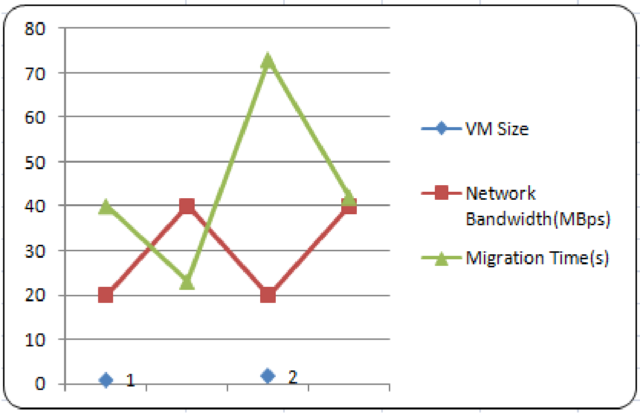

Figure 3. Impact of VM Size and Network bandwidth on Migration time

In Figure 4 Average Energy consumption (AEC) increased with increase in VM size with 50 MBps and 100MBps network bandwidth. As the network bandwidth increases from 50 to 100 MBps, Average energy consumption decreased with same VM size. Network bandwidth results are depending on network traffic during VM Live migration.

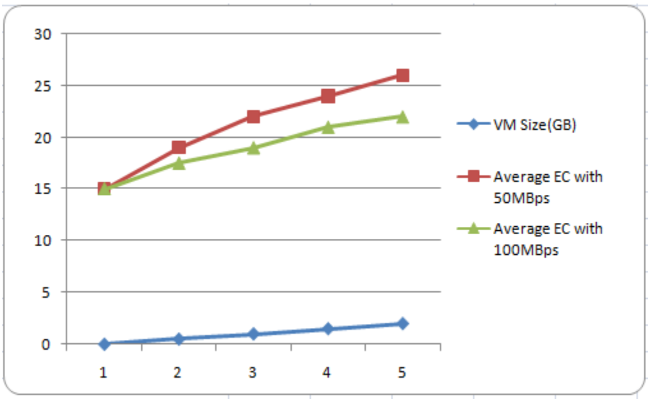

Figure 4. Energy consumption with Network bandwidth and VM Size

Our results have shown that VM size and network bandwidth have significant impact on migration time and average energy consumption of source system during VM migration within subsystems.

These values are specific for the cluster setup that we used in our experiment and cannot be generalized. The entire system is being considered for observation of energy consumption and migration time parameters instead of components i.e. CPU or memory utilization.

A. *Pearson's Correlation Coefficient of Data Sets*

The correlation co-efficient of data sets is statistics that quantify the relationship between various variables with correlation strength. The graphs (in figure 3 and figure 4) represent that there is strong positive correlation between variables plotted. To validate the correlation factor, correlation coefficient r for given sets of data was determined as follows in eq. 6 and eq. 7:

$$r(\text{VM size, Migration Time}) = 0.987218 \quad (6)$$
$$r(\text{VM size, Energy Consumption}) = 0.93345 \quad (7)$$

It has been predicted from r values and shown in the graphs that, the correlation coefficient with the large number of parameter values is likely to be negative. To validate the correlation coefficient (ρ) of population, the following Null hypothesis was created:

Null Hypothesis $H_o : \rho = 0$ (8)

Alternate Hypothesis $H_A : \rho \neq 0$ (9)

The fixed level testing was conducted and $\propto = 0.05$ was selected. Then hypothesis can be tested with t statistics:

$$t_{stat} = {}^{r}/_{se_r} \quad (10)$$

Where se_r represents the standard error of correlation coefficient:

$$se_r = \sqrt{\frac{1-r^2}{n-2}} \quad (11)$$

Table I. Correlation between different parameters

Pearson's Correlation Coefficient	*P Value*	t_{stat}	t_{crit}
r(VM size, Energy Consumption)	0.000180641	4.50	2.7
r(VM size, Migration Time)	0.000340695	15.16	2.36

In both the data sets, $t_{stat} > t_{crit}$ and P value < 0.05(see Table I). This provides the evidence in support of rejection of Null hypothesis. The acceptance of alternate hypothesis (eq.9) confirms the impact of VM size and network bandwidth on VM migration time and energy consumption of the source machine. These facts conclude that there is positive correlation between Migration Time, Energy Consumption and VM Size during VM live migrations. These dependent parameters can be controlled to reduce energy overhead with required quality of service.

VI. CONCLUSION

In this paper, experiment was conducted on real environment to analyze the variance of energy consumption with respect to various parameters like VM migration time, network bandwidth of link and VM size. This experiment revealed that VM size and network bandwidth has significant impact on migration time and average energy consumption of source system during VM migration within subsystems. The energy consumption grew with rise in size of VM and migration time. But energy overhead reduced with increase in network bandwidth of communication link. The Pearson's correlation coefficient of data sets provided evidence in support of rejection of null hypothesis. Then, these facts conclude that there is positive correlation between migration time, energy consumption and VM size during VM live migrations.

In future work, it would be interesting to optimize some performance parameters during VM Live migrations with different scenario and within defined Quality of service constraints.

VII. ACKNOWLEDGMENT

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