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Research Article

Selection Strategy for VM Migration Method

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ABSTRACT

Virtual machine (VM) live migration occurs frequently in cloud environments. When it is necessary to migrate many VMs, minimizing the migration time is an important concern. Thus, choosing an appropriate strategy to perform VM migration is essential. Accordingly, this paper discusses the advantages and disadvantages of four different migration methods and evaluates their respective migration times and throughputs.

1. INTRODUCTION

Virtual machine (VM) migration plays a critical role in cloud computing in satisfying user demand for computing resources while simultaneously meeting the needs of the operator for energy savings, load balancing, periodic maintenance, and so on. VM migration can be performed using four different methods, namely sequential, delay, parallel, or simultaneous. In sequential migration, migration of a VM is performed only once the migration of the previous VM on the same server has been completed. In delay migration, the VMs are located on different servers and a small delay is introduced between their migration. In parallel migration, multiple VMs located on the same physical server are migrated at the same time. Finally, in simultaneous migration, VMs located on different physical servers are migrated at the same time. In practice, the migration times of the four methods may vary widely. Thus, the choice of an appropriate migration method is essential to minimize the total migration time under different VM memory loads, migration link bandwidths, page dirtying rates, and so on.

The main contributions are as follows:

(1) The study has analyzed the migration time and throughput performance of four different VM migration methods (sequential, delay, parallel, and simultaneous).

(2) The study has proposed a selection strategy for VM migration method under different link bandwidth.

(3) The study has experimented the variation of the total migration time with the VM memory load under each of the considered migration methods.

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2. BACKGROUND AND RELATED WORK

2.1. VM Migration Techniques

Virtualization platforms generally utilize either a pre-copy live migration approach [1,2] or a post-copy live migration approach [3,4]. Of the two methods, the pre-copy method results in a shorter downtime, while the post-copy method results in a shorter total migration time. In Akoush et al. [5] and Elsaid et al. [6], the authors showed that the overall migration time for Stages 0–5 of the pre-copy method comprises four components, namely the Pre-Migration Overhead (Stages 0 and 1), the Stage 2 Overhead, the Stage 3 Overhead, and the Post-Migration Overhead (Stages 4 and 5). Among these components, the Stages 0/1/4/5 overhead time is static but not constant. Consequently, under the same VM migration conditions, the overhead times of the pre- and post-copy migration methods are slightly different.

2.2. Migration Performance Indicators

Common migration performance indicators include the total migration time, the migration down time, and the total number of VM migrations. The total migration time measures the elapsed time between the start of the first VM migration process and the end of the final VM migration process. Akoush et al. [5], Elsaid et al. [6], and Salfner et al. [7] investigated the effects of various factors on the total migration time, including the migration link bandwidth, the frequency of dirty memory pages, the VM memory size, and so on. The migration down time measures the time for which service is interrupted during the migration process, and should be minimized in order to maintain user satisfaction. Finally, the number of VM migrations indicates the total number of VMs migrated, and should be reduced to the minimum number possible to minimize the impact of the migration process.

2.3. TCP Window Size

Virtual machineware [8] prescribes the use of the transmission control protocol (TCP) to establish a connection for VM migration and transmit the corresponding migration traffic. TCP is a synchronous transmission protocol with good reliability and completeness. The TCP window size used to transmit the migration packets is assigned a minimum value of Congestion Window (CWND), receiver window (RWND), i.e., sendwin = min(cwnd, rwnd). Phanishayee et al. [9] presented a scheme for lowering the value of slow start threshold (ssthresh) in order to enter the congestion avoidance stage early. However, the system suffered an insufficient startup problem accordingly. Osada et al. [10] considered a serial transfer process rather than parallel server request units (SRU) transmissions. However, the method resulted in a low bandwidth utilization rate during the slow start cycle.

3. VM MIGRATION METHODS AND WINDOW SIZE

3.1. Sequential Method

Figure 1a shows a typical example of the sequential VM migration process. Let bandwidth delay product (BDP) be the product of the link bandwidth and the round-trip time. Assume that VM1 and VM2 have the same memory size and page dirtying rates (i.e., $t_{ss} + t_1$ is constant). Furthermore, assume that TCP ssthresh is larger than BDP. Thus, sendwin is equal to BDP in the slow start phase. The sum of sendwin for the two VMs is then obtained as shown in Figure 1b.

In the sequential migration method, there is no overlap between the migrations of VM1 and VM2, respectively. Consequently, the sum of sendwin in Figure 1b does not exceed BDP. As a result, the throughput is not degraded by overflows at the switch buffer. However, the bandwidth cannot be fully utilized during the slow start phase and the migration overheads of the two VMs cannot be processed at the same time. Consequently, the total migration time is increased. Furthermore, the operator cannot explicitly configure the time at which each VM migration task is to be performed. In other words, the sequential migration method lacks versatility.

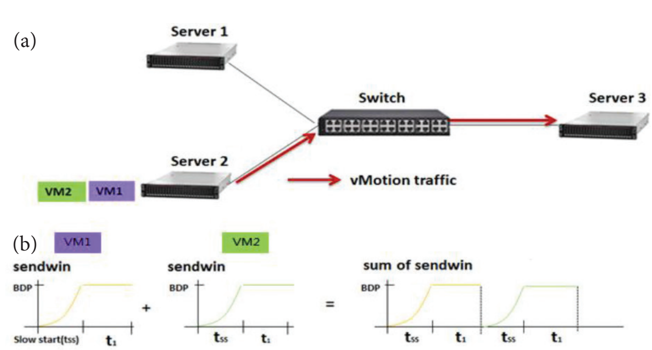

Figure 1 | (a) Sequential method. (b) Sum of sendwin.

3.2. Parallel Method

As shown in Figure 2a, in the parallel migration method, VM1 and VM2 are located on the same server and are transmitted at the same time over a single connection. The sendwin size of each VM is thus reduced to (1/2)BDP. Consequently, the sum of sendwin is equal to BDP, as shown in Figure 2b. It is seen in Figure 2b that t'_{ss} is less than t_{ss}. In other words, the parallel migration method improves the bandwidth usage during the slow start phase. In addition, the migration overheads of the two VMs can be processed at the same time. Hence, the total migration time is reduced.

3.3. Simultaneous Method

Figure 3a illustrates the simultaneous migration method, in which the migrations of VM1 and VM2, which are located on different servers, are executed in a many-to-one communication mode. Assuming that the links between the source servers and the switch have the same bandwidth, the sum of sendwin reaches BDP after just t', as shown in Figure 3b. Notably, t' is less than t_{ss}. In other words, the migration process results in a long overlap time between the transmissions of the two VMs. Consequently, the switch buffer easily overflows; resulting in packet drops and a significant reduction in the throughput. Thus, the total migration time of the simultaneous migration process is longer than that of the parallel migration process.

3.4. Delay Method

As shown in Figure 4a, the delay migration method is similar to the simultaneous migration method other than for the fact that a short

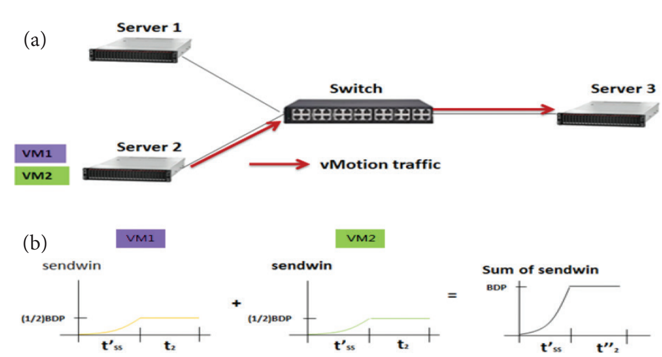

Figure 2 | (a) Parallel method. (b) Sum of sendwin.

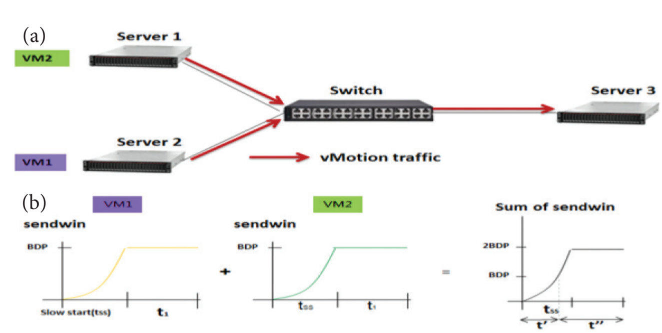

Figure 3 | (a) Simultaneous method. (b) Sum of sendwin.

delay is introduced between the migrations of the two VMs. The delay method reduces the overlap time of the multiple TCP connections (see Figure 4b), and therefore smooths the traffic volume and improves the throughput. However, the total migration time is usually much longer than that of the simultaneous migration method.

Table 1 lists the difference of the performance and total migration time in the four approaches.

4. PERFORMANCE EXPERIMENTS AND ANALYSIS

4.1. Experiment Environment

Migration experiments were performed using three HP ProLiant DL380 G6 (Palo Alto, California, USA) physical servers (two sources and a destination) and hypervisor VMware vSphere 5.5 software (Palo Alto, California, USA). The experiments replicated the network architectures and migration methods shown in Figures 1a–4a. Each VM was configured to have eight virtual CPUs and 14 GB of virtual RAM. Memory testing tool was used to increase the memory loads of the VMs in the range of 2–11 GB. The total migration time of the VMs under different loads was measured.

4.2. Experiment Results

Figure 5 shows the experimental results obtained for the variation of the total migration time with the VM memory load for each of the considered migration methods. The results support the following main conclusions:

(1) The migration methods can be ranked in terms of the total migration time (shortest to longest) as follows: Parallel < Simultaneous < Delay < Sequential.

(2) For a memory load of 11 GB, the total migration time of the simultaneous method is close to that of the sequential method.

(3) The delay method generally results in a longer total migration time than the simultaneous method. However, the performance of the delay method depends on the delay time applied. For example, given a memory load of 11 GB and a delay time of 120 s, the delay method results in a shorter total migration time than the simultaneous method.

Figure 6 shows the throughputs obtained for each of the four migration methods given a VM memory load of 4 GB. The migration methods can be ranked in terms of the throughput performance (high to low) as follows: Parallel ≈ Sequential > Delay > Simultaneous.

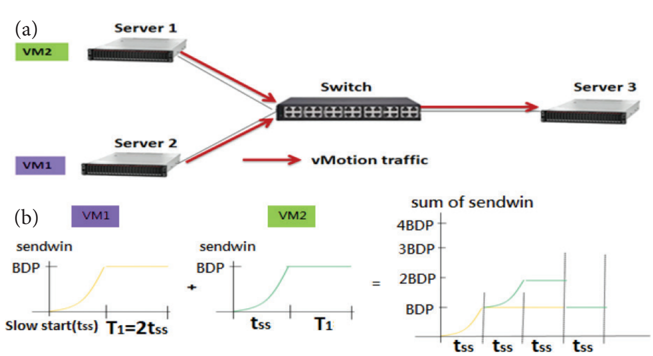

Figure 4 | (a) Delay method. (b) Sum of sendwin.

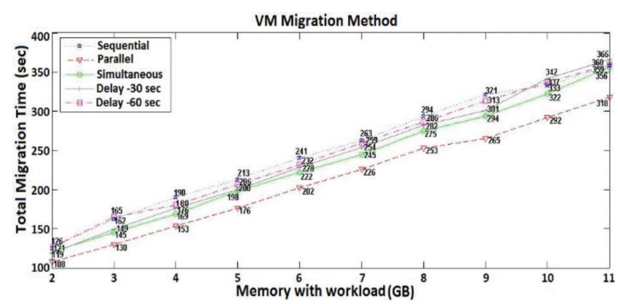

Figure 5 | Total migration times of different VM migration methods.

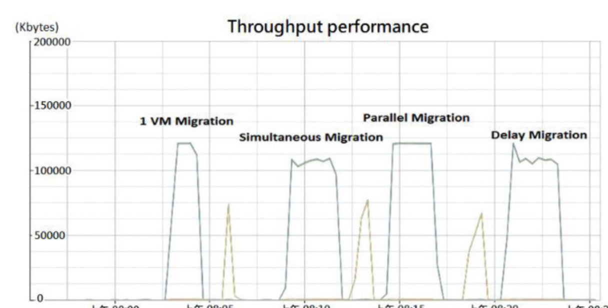

Figure 6 | Throughputs obtained under different VM migration methods.

Table 1 | A comparative analysis table of different VM migration methods

Items \ Methods	Sequential	Parallel	Simultaneous	Delay
If the bandwidths of the links between the switch and the servers (sources and destination) are the same				
Migration overheads processed at the same time	No	Yes	Yes	No
Slow start time	t_{ss}	$t < t_{ss}$	$t < t_{ss}$	$t \leq t_{ss}$, if delay time $\geq t_{ss}$, then $t = t_{ss}$
Overlap time of VMs migration	No	Yes, shorter than Simultaneous	Yes, longer than other methods	Yes, delay time = 0, i.e., the same as Simultaneous
TCP-Incast	No	No	Yes	Yes
Throughput	highest (1st)	higher (2nd)	lower (4th)	low (3rd)
Total migration time	longest (4th)	shortest (1st)	shorter (2nd)	short (3rd)

4.3. Migration Selection Strategy

Based on the experimental results presented above for the total VM migration time, the following migration selection strategies are proposed:

(1) Selection strategy 1: If the switch-server 3 link bandwidth is much higher than that of the source-switch links:

Selection order: Simultaneous → Parallel → Delay → Sequential method.

(2) Selection strategy 2: If the bandwidths of the links between the switch and the servers (sources and destination) are the same:

Selection order: Parallel → Simultaneous → Delay → Sequential method.

5. CONCLUSION AND FUTURE WORK

This paper has analyzed the migration time and throughput performance of four different VM migration methods (sequential, delay, parallel, and simultaneous) under different VM memory loads. In general, the results have shown that when the link bandwidth of the migration destination is much higher than that of the source(s), the simultaneous method results in the shortest migration time. By contrast, if the link bandwidth of the migration destination is equal to that of the source(s), the parallel migration method provides the shortest total migration time. In future work, we will continue to study how to improve the throughput performance and total migration time of VM simultaneous migration method.

CONFLICTS OF INTEREST

There is no conflicts of interest.

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