The Pennsylvania State University  
  
The Graduate School  
  
Department of Computer Science and Engineering

**MEMORY ANALYSIS TOWARDS MORE EFFICIENT LIVE MIGRATION OF**

**APACHE WEB SERVER**

A Thesis in  
  
Computer Science and Engineering  
  
by  
  
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ABSTRACT

Virtual Machine live migration is a key technique in the clouds. It can benefit for the workload balance and data backup. During the virtual machine live migration, memory is an important part that needs to be transferred from the source to the destination. Current techniques can be divided into two categories: pre-copy and post-copy. Both approaches migrate all memory blocks from source to target without memory analysis. However, some memory blocks are not necessarily transferred through live migration process, because these memory data always remain the same. Moreover, modern operating system use unused memory to cache recently accessed blocks of permanent storage device. This technique is called PreFetcher or SuperFetch. Although Prefetcher can speed up the amount of time that system stakes to art up programs, it occupies more memory spaces which might not be used by users.

These observations lead us to propose an approach to analyze the Virtual Machine memory page table and divide the memory data into two parts (active memory and inactive memory). Instead of migrating all Virtual Machine memory thorough live migration, we can only migrate the active part. The inactive part can be merged into Virtual Machine image file. Thus, during startup process, target machine can directly load inactive data into its physical memory through image file stored in shared storage. This can considerably reduce the amount of data sent between the two hosts involved in the live migration and has the potential to shorten the total migration time.

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# Introduction

Live Migration of Virtual Machine across distinct physical hosts is a very important feature of virtualization technology for maintenance, load-balancing and energy reduction, especially for data centers operators. Over the past few years, the availability of fast networks has led to a shift from running services on privately owned and managed hardware to co-locating those services in data center. Along with the wide spread availability of fast networks, the key technology that enable this shift is virtualization []. In a virtualized environment, the software does not run directly on bare metal hardware anymore but instead on virtualized hardware. The environment, such as the number of CPUs, the amount of RAM, the disk space and so forth, can be tailored to the customer’s exact needs. From the perspective of the data center operator, virtualization provides the opportunity to co-locate several VMs on one physical server. This consolidation reduces the cost for hardware, space and energy.

An important feature of virtualization technology is live migration []. A running Virtual Machine is moved from one physical host to another. To migrate a running VM across distinct physical hosts, its complete state has to be transferred from the source to the target host. The state of a VM includes the permanent storage (data in disks), volatile storage (data in memory), the state of connected devices (network interface cards) and the internal state of virtual CPUs. In most setups the permanent storage is provided through network-attached storage and does thus not need to be moved. The state of the virtual CPUs and the virtual devices comprise a few kilobytes of data and can be easily sent to the target host. The main caveat in migrating live Virtual Machines with several gigabytes of main memory is thus moving the volatile storage efficiently from one host to the other.

However, the problem of memory data migration is very challenging. Firstly, modern operating systems use unused memory to cache recently accessed blocks of permanent storage device. This technique usually is called Perfetcher or SuperFetch, which is a component of Memory Manager that can speed up the operating system boot process and shorten the amount of time it takes to start up programs. It accomplishes this by caching files that are needed by an application to RAM as the application is launched, thus consolidating disk reads and reducing disk seeks. Although Prefetcher can speed up the amount of time that operating system takes to startup programs, it occupies more memory spaces which might not be used by users.

Secondly, generally speaking, there are three kinds of web servers. They are static content server, dynamic web application server and video streaming server. They dynamic web workload generates a large number of writes in bursts. The static web workload generates a medium, roughly constant number of writes. And the video streaming workload creates relatively few writes but is very latency sensitive []. These results mean that memory changing rate and age dirty rate of dynamic web application server and video streaming server change greatly and are very unpredictable.

Thirdly, current techniques of Virtual Machine live migration can be divided into two categories: pre-copy [] and post-copy []. Both approaches migrate all memory blocks from source to target without memory analysis. However, some memory blocks are not necessarily transferred through live migration process, because they always remain the same.

Live migration process can be considered as three phases: **Push Phase** The source Virtual Machine continues running while certain pages are pushed across the network to the new destination. To ensure consistency, pages modified during this process must be re-sent. **Stop-and-copy Phase** The source Virtual Machine is stopped, pages are copied across to the destination Virtual Machine, then the new Virtual Machine is started. **Pull Phase** The new Virtual Machine executes and, if it accesses a page that has not yet been copied, this page is faulted in across the network from the source Virtual Machine [].

Base on the three phases, in this thesis, our goal is to reduce the amount of memory data is shipped through analyzing the Virtual Machine memory page table and dividing the memory data into two parts (active memory and inactive memory). Instead of migrating all Virtual Machine memory data through live migration, we can only migrate the active memory data. The inactive memory data can be merged into Virtual Machine image file. Thus, during startup process, the target machine can directly load inactive memory data into its physical memory through image file stored I shared storage. This can considerably reduce the amount of data sent between two hosts involved in the live migration and has the potential to shorten the total migration time.

Our proposed approach measures memory changing rate before live migration in order to divide active memory data and inactive memory data. We monitor the static web server, which has roughly constant number of write operations, and only look at the write operation and new allocation inside memory. We define memory changing rate based on the sequence of write operations and use memory changing rate a lot. In contrast, the existing techniques only monitor page fault during live migration. They don’t measure and use memory changing rate.

Before live migration, analyze source machine’s memory and find out the active memory data and inactive memory data.

The rest of this paper is organized as follows. Chapter 2 discusses related work to this study. Chapter 3 describes the mythology of this work. Chapter 4 presents and discusses the experimental setup and result. I end the study with concluding remarks and a discussion of possible future work in Chapter 5.

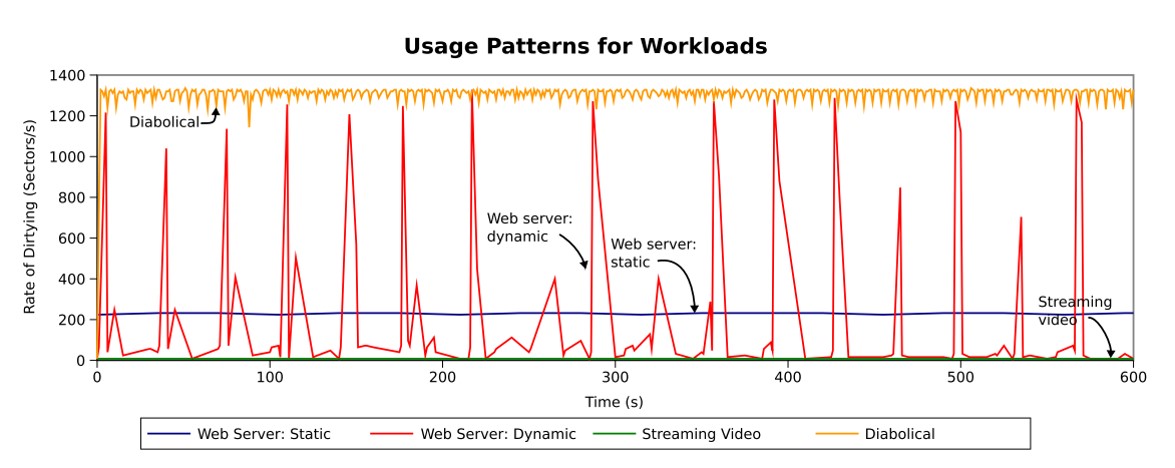


Figure ‑. The Waterfall of Tranquility.

# Background of Previous Research

This text is in the type style called “Normal” and should be used for the body of your thesis. Great as the differences are between the breeds of pigeons, I am fully convinced that the common opinion of naturalists is correct, namely, that all have descended from the rock-pigeon (Columba livia), including under this term several geographical races or sub-species, which differ from each other in the most trifling respects.

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As several of the reasons which have led me to this belief are in some degree applicable in other cases, I will here briefly give them. If the several breeds are not var the present domestic breeds by the crossing of any lesser number: how, for instance, could a pouter be produced by crossing two breeds unless one of the parent-stocks possessed the characteristic enormous crop?

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Figure ‑. A church in the woods.

The supposed aboriginal stocks must all have been rock-pigeons, that is, not breeding or willingly perching on trees. But besides C. livia, with its geographical sub-species, only two or three other species of rock-pigeons are known; and these have not any of the characters of the domestic breeds.

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Hence the supposed aboriginal stocks must either still exist in the countries where they were originally domesticated, and yet be unknown to ornithologists; and this, considering their size, habits, and remarkable characters, seems very improbable; or they must have become extinct in the wild state. But birds breeding on precipices, and good fliers, are unlikely to be exterminated; and the common rock-pigeon, which has the same habits with the domestic breeds, has not been exterminated even on several of the smaller British islets.

Hence the supposed extermination of so many species having similar habits with the rock-pigeon seems to me a very rash assumption. Moreover, the several above-named become wild or feral, though the dovecot-pigeon, which is the rock-pigeon in a very slightly altered state, has become feral in several places.

Table ‑. Another table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 11/09/09 | 11/16/09 | 11/23/09 | 11/30/09 | 12/07/09 |
| 18 | 15 | 7 | 14 | 16 |
| 16 | 13 | 5 | 18 | 20 |
| 34 | 28 | 12 | 32 | 36 |
| 33 | 28 | 11 | 32 | 34 |

An argument, as it seems to me, of great weight, and applicable in several other cases, is, that the above-specified breeds, though agreeing generally in constitution, habits, voice, colouring, and in most parts of their structure, with the wild rock-pigeon, yet are certainly highly abnormal in other parts of their structure: we may look in vain throughout the whole great family of Columbidae for a beak like that of the English carrier, or that of the short-faced tumbler, or barb; for reversed feathers like those of the jacobin; for a crop like that of the pouter; for tail-feathers

Table ‑. Yet another table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 11/09/09 | 11/16/09 | 11/23/09 | 11/30/09 | 12/07/09 |
| 18 | 15 | 7 | 14 | 16 |
| 16 | 13 | 5 | 18 | 20 |
| 34 | 28 | 12 | 32 | 36 |
| 33 | 28 | 11 | 32 | 34 |

like those of the fantail. Hence it must be assumed not only that half-civilized man succeeded in thoroughly domesticating several species, but that he intentionally or by chance picked out extraordinarily abnormal species; and further, that these very species have since all become extinct or unknown. So many strange contingencies seem to me improbable in the highest degree.

Some facts in regard to the colouring of pigeons well deserve consideration. The rock-pigeon is of a slaty-blue, and has a white rump (the Indian sub-species, C. intermedia of Strickland, having it bluish); the tail has a terminal dark bar, with the bases of the outer feathers externally edged with white; the wings have two black bars: some semi-domestic breeds and some apparently truly wild breeds have, besides the two black bars, the wings chequered with black. These several marks do not occur together in any other species of the whole family. Now, in every one of the domestic breeds, taking thoroughly well-bred birds, all the above marks, even to the white edging of

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