# Enhancing Virtual Machine Performance in Cloud using Cache as a Service

Rushikesh Jadhav
PG Student
MET BKC, Comp Engg,
Nashik, Maharashtra

P. M. Yawalkar
Professor
MET BKC, Comp Engg,
Nashik, Maharashtra

## ABSTRACT
Caching is one of the important concept used for optimizing the performance gap across data hierarchies; in particular, disk storage systems. Cloud applications are generally resource hungry and may consist of high frequency of occasional resource consumption, which are common in the cloud; do benefit the most from caching. There are many levels of cache but the using local memory as cache might be a good alternative, this memory can be taken from main memory of the system or secondary storage with many well-known restrictions and effective use. There are many technical as well as business challenges such as meeting the service offering and billing accurately. Here it presents the cache as a service (CaaS) system as an additional service by cloud infrastructure service providers as one of their service to their existing consumers. CaaS alone may not be possible to avail as the consumer needs to have a Virtual machine or physical machine with the provider. The cloud infrastructure provider creates a cluster of memory resources in such a way that these collective resources can be divided on demand to the right consumer and can be offered on demand to them. This disk cache system need to have security while allocating memory blocks as well as while de-allocating them. CaaS model is proposed to leverage existing resources which can be idle or kept as redundancy and offer them as a service to the consumer with small overhead yet high performance improvement. This will not only increase the performance of the client but will also help service provider to use his idle capacity and offer better utilization.

## Keywords
Cloud Computing, Cache as a Service, Remote Memory, Block Cache, Cost Efficiency.

## 1. INTRODUCTION
A virtual machine (VM) is a logical service image from IaaS. [1] This logical image is created by partitioning the host with help of micro operating system. The cloud Virtual Machines can be created and destroyed on demand as well as programmatically hence have advantage in automation. Although cloud system can provision machines on demand, yet there are various penalties with it and to overcome them, optimization is needed at each level. All the computations done by Virtual Machine are time bound and latency sensitive. The fastest Virtual Machine has lowest latency of data processing. To have such low latency systems, one need to employ cache subsystem which can speed up the frequent used item access time thus decreasing overall application latency. Objective of this research is to investigate how cost efficiency in the cloud can be further improved, particularly with applications that involve heavy I/O activities; hence, I/O-intensive applications. [2]

To overcome low disk I/O performance, there have been extensive studies on memory-based cache systems. Addressing this particular issue of disk I/O performance in the context of caching in the cloud and hereby present a Cache as a Service (CaaS) system as an additional service to IaaS.

Datacenters are engineered for high capacity and store huge amount of data in redundant way such that the idle capacity in datacenter can come into play in case of any catastrophic event. For example, public cloud service providers like eNlight Cloud Service virtualize resources, and offer them as services on demand. With virtualization eNlight Cloud also gives ability to readjust the resources of running virtual machines according to their resource load. A virtual machine (VM) is a logical separation on physical hardware, also known as instance of IaaS.

Such virtual machine has four vital logically hardware component such as Processor, Memory, Disk and Network. VM is a logical partition inside the physical host and can have various services running inside it as part of its service. Every Virtual Machine has an operating system inside with a kernel as central logical part. Even if the VM is logically partitioned, it has access to the shared physical resources of the underlying machine often Processors, Memory, Disk and Network.

The service is expected to be cost effective, accurate and give performance improvement over existing techniques. The service is novel yet not limited to its own and can easily adapt other techniques available to extend the service.

There are various techniques that enable caching in cloud in some way today and have their own advantages as well as disadvantages.

## 2. LITERATURE REVIEW
### 2.1 Cooperative Caching: Using Remote Client Memory to Improve File System Performance
The network speed is increasing day by day and the distance of communication between two systems is drastically reducing. Thus this allows systems to share data in faster way. Such advantage comes with an opportunity to use cooperative caching: coordinating the file caches of many machines distributed on a LAN to form a more effective overall cache.

With Cooperative caching it might be possible to a group of computer to leverage their free pool of memory to needy application and use them up. With this paper and research they found cooperative caching to be effective in performance improvement. [3]

## 2.2 Diagnosing Performance overheads in the xen Virtual Machine Environment

For Virtualized environment, to convert a host into physical machine that can be logically partitioned and its hardware resources to be made available in virtualized way, the system needs a special purpose micro operating system known as Hypervisor. The author are reviewing Xen as hypervisor which facilitates creation of Virtual Machine on standard x86 hardware. Xen is also an industry standard platform for many IaaS Cloud Service provider companies like Amazon EC2 Web service as well as ESDS eNlight Cloud.

When a hypervisor such as Xen runs VMs, these VMs operate at relatively lower performance than the physical hardware performance. Prime reason for it is the overheads imposed by Hypervisor to secure VMs from host access as well as accessing other virtual machines memory. Hypervisors such as Xen also emulates hardware for Virtual Machine so that the guest operating system does not see that whether it is running on a Physical machine or a Hypervisor. Here they studied the overheads in Xen Hypervisor for Virtualized memory access. [4]

## 2.3 Efficient Remote Block-Level I/O using an RDMA-Capable NIC

They examine the support to see the possibility of having a remote block device IO over RDMA capable NIC. The main focus of their study was to check whether host CPU gets bypassed while doing IO.

Essentially the RDMA NIC did DMA based data management. This allowed the RDMA device to directly write on to host memory and read from it without letting host cpu participate in IO. This opened opportunities to do remote block-level I/O using an RDMA-capable NIC.

Such RDMA NICs can not only be used for one to one system communication but also one to many. This allows to lay high speed Storage Area Network [5]

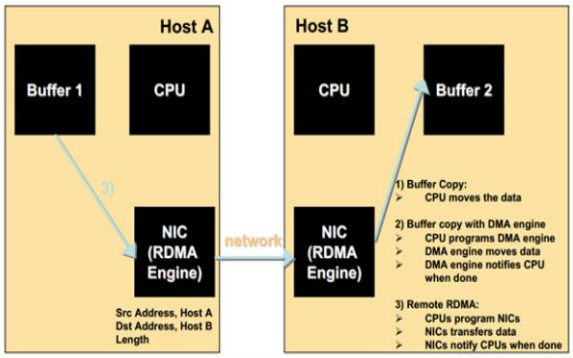


**Fig 1: RDMA Connectivity**

## 2.4 Dynamic Block-level Storage Caching

dm-cache is a kernel module introduced by Linux kernel community which effectively uses client-side storage as cache to temporarily store Virtual Machines data on the host. This typically uses SSD storage so that there can be enough room for most of the virtual machines temporary data.

With this kernel patch, a block device such as SSD can be used to improve the caching of data inside any server. [6]

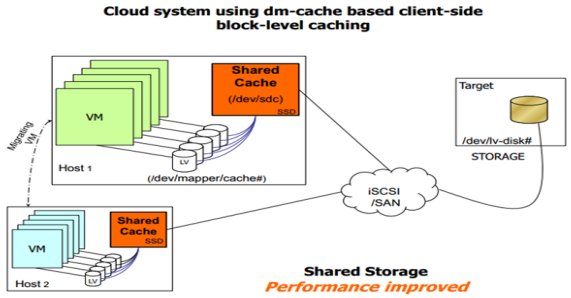


**Fig 2: Dynamic Block-level Storage Caching**

Cloud is a new computing paradigm that is built on virtualization, parallel distributed computing, utility computing and service oriented architecture. The great benefits brought by cloud computing are exciting for IT companies, Academic researcher and potential cloud users. In last several years, cloud computing has emerged as one of the most influential paradigms in IT industry.

In Cloud computing, everything is offered as service or utility. Cache being one of the key element in accelerating disk IO, the problem definition says to offer cache as a service in cost effective and easy billable model.

Current Cache Techniques include the following and are limited to:

Use of SSD as a disk cache [7]

NAND flash memory ( SD Card )

NVRAM-based buffer

DRAM of distributed systems using rm-cache

# 3. SYSTEM ARCHITECTURE

## 3.1 High Level Strategy

To achieve, Cache as a Service (CaaS), the elastic cache system architecture uses Remote Memory concept where in the memory is not directly addressable to the client. This remote memory can be provided by Virtual or Physical machines from same or different network with routing. The system can make use of any of the cache replacement algorithms that are provided with Operating System kernel. Since the Cloud datacenter provider provides infrastructure, the client operating system would need to reuse its cache mechanisms.

Here proposes an approach where a set of memory servers are running as the memory server and they collectively form a memory pool which is made available to the clients using feasible fast connectivity media.

There are few important components needed before one can use this service. These components range from Self Service Portal, Automated workflows for Virtual Machine creation and enablement of CaaS. The CaaS model consists of two cache service types (CaaS types) based on whether Local Memory or Remote Memory is allocated to the required Virtual Machine or Pool of machines.

Cloud computing system under consideration consists of Cloud Cluster, Physical Hosts, Virtual Machines and their high speed Interconnect Network.

Three key components are given as below:

1. Idle Physical Host Memory

2. Idle Virtual Machine Memory
3. Interconnect Network

The Idle memory of Physical Host and Virtual Machine is exposed via system module for remote usage. Virtual Machines of same network do an RPC calls to access these memory chunks[8]. Memory is divided in to the chunks & system module keeps track of these chunks and their access. Remote client machines use these memory chunks over RDMA or suitable high speed network protocol making it act as local cache. These chunks are extended as part of Local Virtual Memory of the client. Since these memory chunks are now accessible to clients as part of Local Memory, they start using as cache which accelerates overall system.

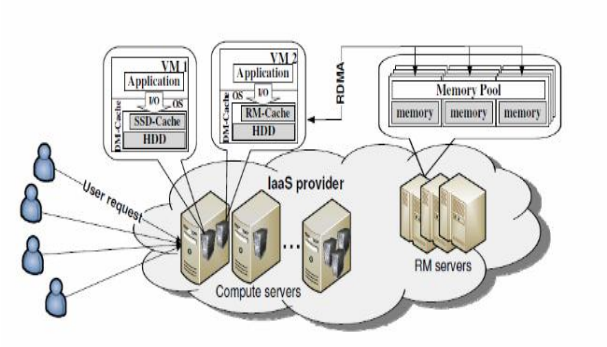


**Fig 3: Remote-memory architecture**

## 3.2 Elastic Cache

An Elastic cache is the key component in realizing CaaS. Vital part in implementing the elastic cache is the cache medium used. In proposed system memory is being used as cache medium yet it's limited in local physical host and distant on remote machines.

Thus two types of Elastic Cache are conceptualized. One to be Local Memory Cache and other to be Remote Memory cache. When the local memory of the physical host would be used as cache there won't be any connectivity media between the cache server and Virtual machine thus being the fastest and lowest latency. However the Local Memory cache system will be limited by the amount of memory being provided by the physical host. Another approach to solve this limitation is to use Remote Memory Cache server. These remote memory cache servers will expose their memory in terms of blocks and that remote memory can be mounted by the client by making use of any available remote block device protocol. A dm-cache can be used as a part of kernel module and swap space as part of Linux system.

Whenever the Virtual Machine client demands memory, a cloud cache memory manager would see if the need can be satisfied from the local host itself, if it can then the local host memory of that Virtual machine is offered as virtual block device to the VM. If the physical host is pre-occupied and does not have enough threshold to avail required memory then the cloud cache memory manager would allocate memory from memory cluster over network.

Thus these virtual blocks can be used as second level cache to main memory which is also termed as swap.

## 3.3 RDMA vs. TCP/IP

Despite the popularity of TCP/IP, its use in high performance clusters has some restrictions due to its higher protocol processing overhead and less throughput than other cutting-edge interconnects, such as Myrinet and Infiniband. Since disk cache in any system requires a low latency communication channel, here it is proposed a RDMA-enabled interface to guarantee fast and uniform access time to RM space. Large cloud service provides may find this intriguing to their business benefits as RDMA has big cost overhead than TCP/IP network. These large datacenters already have a wide TCP/IP network deployed and may refuse for another RDMA capable dedicated network to memory cluster. Thus for lowest latency over network; RDMA is suitable but TCP/IP can also be employed as a staging solution.

# 4. CONCLUSION

There is ever growing need of the compute and storage over internet. Cloud service providers are gearing up day by day to provide faster secure and reliable compute and storage. Such compute and storage needs to be fast. IO is one of the bottleneck which is addressed in this paper. Proposed cache as a service would initially allow cloud consumers to opt for cache on demand and pay as you go model. With advancements in Cache as a Service, a cloud service provider can improvise IO performance to individual machines and in turn improve the performance of his service. Proposed system can use IP or RDMA communication protocol to handle such cache devices. In future, more protocols or physical interfaces can be introduced to provide necessary IO acceleration. This system can be further improved by implementing redundancy & encryption to remote memory.

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