DOCKER CONTAINER CLUSTER DEPLOYMENT ACROSS DIFFERENT NETWORKS

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Abstract

In this era, cloud computing plays a major role in IT organizations. Virtualization being major reason for the high growth of cloud computing, therefore it is in high focus in the industries. Virtualization is a technique which creates and imaginary of any resources and made available for multi-tenant or application. Virtual machine is the individual component which runs imaginary of entire computer system or an individual application. Improvement in virtualization moved to an another extent and brought kernel level virtualization such as Linux virtual machines and Linux container were virtual machine can be created in Linux environment. Though the improvement of virtualization process brought bene ts to the providers but left some challenges to deploy to the cloud. The Software De ned Networking (SDN) is network virtualizations were the networking functionality will work on two layers such as control plane (controller for the network which administrates the flow of the traffic) and date plane (which just forward the packets to the destinations). Open switch is a virtual or software switch which is used in the virtualized environment to make communication between the Virtual Machines. The major issues in docker container is resolved by software de ne networking and made available for cloud deployments. In this research, we present a novel approach that VxLAN cloud overlay network will leverage open vswitch docker networking for deployment of the container cluster in di erent network regions.

Keywords: Virtualization; Software Defined Networking; Open vSwitch; Docker containers; Mongodb.

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Declaration

I hereby declare that the dissertation entitled ‘Docker container cluster deployement across different networks’, is a bonafide record composed by myself, in partial fulfillment of the requirements for the MSc in Cloud Computing (2015/2016) programme. This thesis is a presentation of research and development carried under the guidance and supervision of Mr. Micheal Bradford.

Signed .... Date......................
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Chapter 1

Introduction

Cloud computing is an emerging technology in the eld of computing that many organization are migrating to a cloud. The term cloud refers to the services that is e ciently delivered to users based on their requirements and can access on the go. Buyya et al. [2009] defines that Cloud is provisioned by the interconnection of parallel computing and distributed computing in the virtualized environment. Cloud computing services are categorized into Infrastructure as a Service, Platform as a Service, and Software as a Service. In an Infrastructure as a Service, the computing resources such as server space, storage, network topology are provided through either physical or virtualized hardware. Implementing virtualization in Infrastructure will bene t to the service provider to reduce the investment and to provide the resources to multi-tenant. In this paper we going to look about docker containers will overcome the existing virtual machine technologies and the networking challenges in the docker containers.Docker contributes basic networking features that helps user to characterize ways to which various docker container are connected with each other over the network. This technology is growing very quick where we can take complicated application, Dockrizing every component of the application and disburse them among larger number of server and have good collaboration between them .The main component of networking in docker is an Ethernet bridge known as docker0.When docker is started on Linux server, it form default docker0 bridge inside the Linux kernel, and docker0 construct a virtual subgroup on the docker host. Furthermost, it transfer packets backwards and forwards within the container on that host. Docker also made up a pair of virtual Ethernet interfaces on every container, the containers randomly allot an IP address and a subnet from a private address range not already used by the host machine.(3) . First challenge was connection between the container between the host and it was resolved by various docker plug-in such as weave, pipework, and annel. For high availability and performance, the containers across di erent network regions. The plug-in will be running as a container in docker, which leads to lack of memory and process speed, resources and scalability. The problem is **" Is the docker cluster deployment across different network regions is possible with OVS-VXLAN cloud overlay networks "** - studies the docker container cluster deployment.

To address the approach, the research is categorized into four sections, section one Literature Review 2 highlights about the concept of virtualization, the comparative analysis between virtual machine, Linux containers and docker containers. Then we address several challenges faced while implementing this technology on to the cloud and solution approaches such as Network virtualization and software de ned networking to the virtual machines.

Further, In second Section Design 3 first half discusses about the proposed architecture of deploying the container cluster using VxLAN cloud overlay networks across different host in the di erent network regions. In the second half we have provided the speci cation/requirement to achieve our aim.

In section Implementation 4, the setup conguration is described into two parts. The rst part describes the basic open vswitch network con guration with Docker Bridge and connecting the entire server through VXLAN encapsulated tunnel. Whereas in second part, the main theme that is the deployment of the cluster using docker container. Additional, we also provided some important con guration algorithms that are behind the actual implementation.

Evaluation section 5 is the final section where we performed several test on the architecture to analyse the behaviour and compared with existing architecture. The comparison is made to prove better solution for the production deployments. The section also presents some of the observations that are captured during the analysis.

Expected Contribution: In an attempt to leverage the open vswitch docker networking by VXLAN for the container cluster deployment, the research may provide certain contribution such as:
1) The prototype can be deployed in the fewer requirements.
2) Server utilization will be less in terms of Memory and CPU utilization.
3)High bandwidth between the nodes and high scalability.

Chapter 2

Background

The literature review compares and evaluates the technologies that are essential in order to prove that OVS Networking is boon for the deployment of clusters using docker containers in di erent network regions and also discusses various strategies undertaken that are necessary for understanding the novel approach. Further, the review is divided into four sections. In First Virtualization and Virtual Machines 2.1. In the rst half we discuss and evaluate what is virtualization and what are the di erent stages of virtualization. In the next half we understand the architecture and the working of virtual machines and their importance in virtualizing a system. The review also addresses different states of virtual machines,such as System virtual machines and Process virtual machines.

2.1 Virtualization and Virtual Machines:

Cloud computing paradigm is rapidly using virtualization technology. Some extra software may use for virtualization for resource utilization is done and to solve native system problems virtualization technology is useful. Using OS raw image or disk image we can create virtual machine on Hypervisor Ku et al. [2011]. Virtualization in computer means request for system resources in a way that it cannot affects the underlying hardware. Hypervisor is an extra level place between hardware and host operating system. Hypervisor shares system resources using three virtualization techniques: Full virtualization, Para-virtualization and OS level virtualization. Full virtualization is totally based on underlying hardware of the system, responsible for creating Virtual machine for guest operating system. Hypervisor is acts as middle level manager or virtual machine manager (VMM). VMM is responsible to run each VM separately and manage system resources. In full virtualization technique VMs performance is less than the host OS because of hypervisor layer. In Para-virtualization technique we have to modify guest operating system. Virtualization can be done by coding guest OS and hypervisor itself. Operating system in para-virtualize framework running on the hypervisor so it could directly interact with the host hardware. Para-virtualization gives better performance with low computing overhead. OS-level virtualization not includes hypervisor layer in its framework. Host operating system is capable to virtualize any application or to create virtual machines. This method can virtualize server on host OS layer Costache et al. [2014]. Cloud Computing enhances the use of VMs to schedule the workload and distribute the workloads in the network.

2.1.1 Virtual Machines:

To aggregate the distributed resources over the network Virtual machine and network technology is used. Virtual machine is nothing but emulation technique of computing system. Virtual machine can be implemented in different ways and it depends on their usage. Native or bare metal virtual machine is executed directly on the system hardware. OS-level virtualization offers to run software application on the host OS which is design for different CPU architecture. In OS level virtualization system resources are shared using OS kernel. Hardware-assisted virtualization offers full virtualization with virtualize capabilities. System Virtual Machine: System VM allow to run multiple OS on a single HDD with virtual partitions. VMs can share files on either host OS or guest OS. All files and data will be stored on the host machines disk. It offers different Instruction Set Architecture than host machine using emulation technique. Process virtual machines: It is also called application virtual machine or managed runtime environment (MRE). It will execute as application programme on the host OS with single process. VM is created with process initialization and destroys with process completion. It offers programming environment with various platforms. Interpreter is used to implement the process VMs. Process VMs offers high level programming languages like java and .NET. The process VMs are used for communication systems with heterogeneous computer cluster. Cluster contains separate process per VM but VM does not contain only one process. After understanding the importance of virtualization and the architecture of virtual machines, the second section Linux containers and Virtualization 2.2 discusses what are Linux containers and how are they used to virtualize a system in a Linux environments. Further, we also discuss about different levels of virtualization, namely 1)Peer-to-Peer. 2)KVM and Linux Containers.

2.2 Linux Containers and Virualization:

Linux containers are used to distribute this workload by deploying VMs. As per Felter et al, 2015 containers performance is better than the virtual machines. They test the performance over KVM as a Hypervisor and Docker. Docker is used as a Container manager when works with Hypervisor applications are able to perform very well in cloud environment. Virtual machine and Container performance can check using KVM and Docker. KVM test results are increases its performance. Infrastructure in cloud computing can be implemented using virtual machine technology and platform services in cloud computing can be implemented using containers. But container can also use for infrastructure services in cloud and it gives better performance. Container completely removes the difference between infrastructure and bare-metal severs. Containers manage and control VMs separately. It is difficult to maintain different images of VMs for virtualization so, we can deploy same Docker image in system Felter et al. [2014]. As per cloud definition described in (National Institute of Standard and Technology) NIST, cloud offers on-demand and shared computing resources. HPC cloud offers ability to scheduling workloads. Infrastructure-as-a-Service is one of the service models of cloud computing, cloud service providers can use this to provide engineering and scientific services or applications Gentzsch [2014] .Virtualization technique helps to improve the performance of Linux container. Peer-to-Peer (P2P) networking will helpful to explore this kind of research. Widely used Peer-to-Peer network is popular in end users, organizations and scientists. BitTorrent protocol is used to measure performance and evaluation of P2P network. Different types of methods are used to measure the performance of P2P network, starting from tracker-centric to data collation of long time duration. Probes are used as a testing point for protocol that used for internal measurement Bardac et al. [2010]. High Performance Computing (HPC) technologies are used for cloud applications to allocate resources in network. Cloud computing is based on virtualization technology but there are some performance related issues. Especially for Message Passing Interface (MPI) virtualization presents poor performance with Beowulf Clusters Beserra et al. [2015]. Small/medium size organizations and college departments use HPC server to obtain better performance. But its cost expensive and hard to maintain a larger server. UberCloud HPC is new technology in cloud computing that offers big platform for researchers. End-to-end process in HPC cloud used to solve the end users issues. Linux Containers The various stakeholders like application software provider, HPC resource providers, HPC experts etc. are plays an important role in service-based HPC. The Application Software Provider in HPC stakeholder role, are holders of software such as ISVs, developers and public organizations. The industry end-users are nothing but small manufacturers who design and build new products; they are primary user of HPC-as-a-Service. The HPC resource providers are any stakeholder who holds the HPC resources including storage, compute and network. The HPC experts are those who are expert in HPC and clustering. It also includes PhD students who are studying applications and doing research on it Gentzsch [2014].

2.2.1 Peer-to-Peer:

It is a distributed networking system, where various peers or nodes are connected with each other through their resources, especially disk storage. This frame work is different than client server design that each peer can act as a client and server both. eDonkey, Napster and Gnutella protocols are used to established P2P network in collaboration with Bit Torrent. Bit Torrent is very popular in Internet era as it uses low bandwidthBardac et al. [2010]. Full virtualization framework contains the guest OS is running on the top of the hardware without any kernel level modification. Virtual machine outcome becomes poor in this full virtualization environment. Hardware assisted virtualization can run by running some instructions to run the processor and IO operations. In Para virtualized mode, guest OS kernel need to be modifiedNussbaum et al. [2009]. Operating System (OS) level virtualization builds containers with individual processes. Each process is present with its own resource without any binary code translation. Container is present in one system and can share kernel and host OS but each container having its own OS. HPC performance already measured by comparing KVM and Xen. CPU consumption, network results and CPU overhead tests were taken into consideration. To share one native host VM sends the packets, KVM is better performed than Xen in this paradigm. By evaluating OS level performance of VMs who running HPC, Xen gives performance like native one. In packet forwarding it takes some time in network and it depends on size of packets. LXC give better result in packet transferring so it is good for HPC based on container system. Cluster network where processes communicate with each other Linux Container is the best option. LXC gives less fluctuation in performing most of the tests. LXC is useful in cloud framework to offer scientific computing services. In such type of service end user require same availability and performance in service. In cloud computing environment to give better performance LXC is better than KVM for HPC solutions. LXC is also useful to minimize and control the issues related to Virtualization overheadBeserra et al. [2015] . UberCloud is container service cloud to run software packages. Different tools can depend on these packages for testing multiple users. UberCloud allows multiple users because they are vary from server to server and one cloud to another cloud. Organizations need not be installing important software they can depends on UberCloud. UberCloud Containers uses Linux platform for and its services like LXC, lib container and cGroups. To toss the UberCloud Containers, Docker is used as an Open Source outcome. UberCloud Containers consists of Linux OS, C Libraries, utilities and cloud connectors. UberCloud is compatible with Ubuntu and CentOS and user can select any of them. Linux OS is used when UberCloud launches new Container. UberCloud offers utilities like screen sharing and remote visualizing applications. Data connectors are used by different cloud providers like Amazon S3to transfer data of services. Administration is done by using tools like password generation, and to check performance Gentzsch [2014]. Linux containers include multiple methods of OS-level virtualization. Number of separate Linux containers works on one host OS, so kernel offers the process level isolation and resource scheduling. Docker is used for open source platform to manage Linux containers. Dockers can produces very lightweight VMs and execute code with separate containers Costache et al. [2014] . The developers are able to develop new software and deploy it in cloud architecture using Linux Container. Its an ideal technology in developers perspective, because Linux Containers are runs information intensive scientific operations. Skyport is new technology invented by Gerlach et al. [2015], it is next version of AWE/Shock. Docker Containers are used to automatically deploy and schedule workload on the VMs through Skyport. To gain a scientific better scientific results software installation need to be done separately to avoid conflicts of different library versions. AWE/Shock is a platform with core component Shock. Shock is mainly used to store and manage data in the form of object like Amazon S3. Resource management and scheduling work is done by AWE server. AWE server verifies the documents of workflow and then makes it smaller so they can be compiled by AWE workers. Workflows can be managed using directed acyclic graph to show co-relation between processes and their workloads. AWE Workers do all necessary operation including checking workflows and downloading necessary inputs and data from Shock Gerlach et al.. Skyport executes the Docker Container images using Shock. The Docker image contains necessary input files to run Docker; these are stores in Shock database. After finishing execution all process files in Shock database will be deleted. In multi-cloud architecture HTTP request in used to establish the connection with the Shock from its clients. This connection will work out in multiple domains so AWE can work in multi cloud architecture. Skyport is mainly used to achieve the software separation in Docker containers. AWE workloads may runs on VMs; tasks running on the Docker container are given better performance with high throughput than the bare metal architecture. If Skyport will run on Docker by executing AWE worker on bare metal architecture we can achieve various runtime results of workflows Gerlach et al. [2015]. The novel purpose behind usage of container is nothing but High Availability (HA). HA means offers services whose functional availability is 99.999% for some period of time. It is possible to deploy cloud applications with good management of scheduling methods. Monitoring to these containers is necessary thing those who run the critical components. Monitor with check points is easy to recover in case of failure. It is easy to recover from the recent check point with its full working state. Cloud computing technology offers VMs with IaaS (Infrastructure as a Service) in multitenant framework with on-demand self-service. Linux containers provide execution framework for cloud bases services and applications. Containers are do virtualization in Operating System (OS) using isolated sandboxes for each running application to provide secured framework. The best option to achieve HA in cloud application for virtualized environment is by using Linux and Containers. Some middleware tools and techniques can also use as a set of agents to help containers in HA. Each application wrapped up inside the separate container, which offers transparency with containers to achieve HA Liu and Zhao [2014] .

2.2.2 KVM and Linux Container:

KVM is kernel based VM and used as open source tool for virtualized environment. Figure 2 shows architecture of KVM and LXC Beserra et al. [2015]. IO and network monitoring is done by QEMU in KVM. Every request for IO in KVM is sent to the QEMU that further send to the host OS. LCX is responsible for lightweight virtualization so native emulation is not required. LCX executes whole copy of Linux kernel OS in Linux Container without any Hypervisor. Tasks and file system can share between host OS and LCX. Containers can do resource allocation and is good replacement of legacy virtual machines. In case of group services it is necessary to offer isolation between each service inside the container. These services are call on demand by end users. Linux Containers are light weight in nature so the cloud service providers can reach to the high availability of containers with same amount of resourcesCostache et al. [2014]
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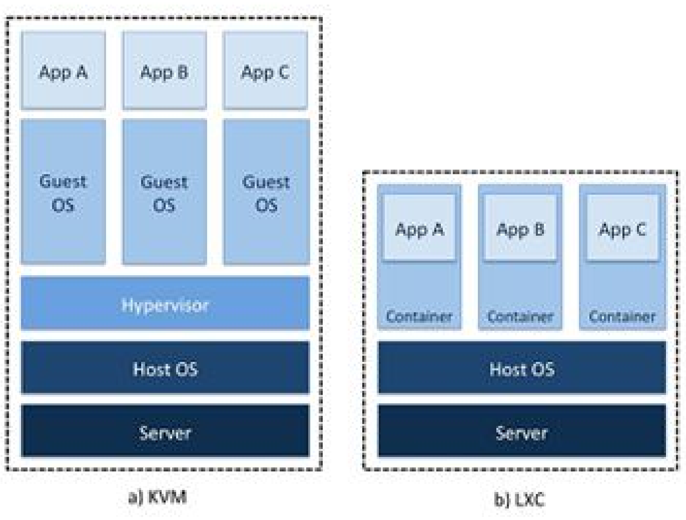


Figure 2.1: KVM and LXC Architecture Beserra et al. [2015]

To design the network multiple techniques need to be implement from design models to physical infrastructure. Many simulation tools are available to implement network framework, they are cheap and repeatable and offer reliable network. Netmap/VALE is interconnection technology that achieves high performance and less computational overhead with LCX containers Casoni et al. [2013]. The above topics briefly explain what virtualization is and also we discuss the difference between virtualizing a system through virtual machine and virtualizing a system through Linux container and also help understanding which of these techniques are more efficient. Although in the third section Dockers 2.3, we analyse how dockers use light weight VMs to virtualize containers and how they prove to be much more efficient than the virtual machines or Linux containers itself. Thereafter, we also explain the levels of QOS Docker two tier architecture and why they are important, they are 1) Node level QOS. 2) Cluster level QOS

2.3 Docker:

Docker is nothing but process to virtualize containers using light weight VM. The problem focus in Docker is VM is heavy weight machine to compute workload. Docker can achieve high scalability by installing Hypervisor on Host OS. Due to light weight its easy for developer to build Docker stack and execute their application on their laptops. Docker is built on containers which offers separate framework for user code. Cgroup technique is known as control groups which controls the resources available for containers. Linux kernel is another technology on which containers are based upon. Namespaces is a system call to create new process Anderson [2015]. Docker is a program for open source framework used for Linux applications and their containers. Containers are responsible to separate applications from each other with virtualization technique. These applications are run in user space of Host OS to utilize the resources Ludvigh et al. [2015]]. Docker offers Quality-of-Service (QoS) to end users on the network. Dockers assigned multiple service based on the priority. Docker minimizes the operation cost and cost to access resources. To handle high traffic network Docker configuration is required. But configuration methods are limited and resulting performance for critical operations is not good. To boot up process docker0 is build is also called as virtual Ethernet Bridge. Each container has its own IP address and use bandwidth of same share. Figure describes the process of implementing docker . Two important components are process scheduler and packet classifier. Incoming packets are classified into one of the three queues i.e. high, medium and low. Packet scheduler decodes the packets and forwards them to respective container. Medium priority is default priority valued that is assigned to the packetDusia et al. [2015]. Virtualization technology is something about generating virtual version of system. Docker is packaging tool used in application installation. A dotCloud is powered by Docker as a deployment machine; it is clouds Platform-as-a-Service. Containerization is popular method of sandboxing to provide isolated container for each application. Docker is developed in Go and core system is has its namespaces and cGroups. Control group feature of Dockers makes hardware resources available to containers. Union File System or UFS acts as a building blocks and Docker may use multiple UFS like Device Mapper, btrfs and AUFS Liu and Zhao [2014]. Docker expands Linux Containers using Linux kernel and Application programming Interface (API). Kernel and API will run multiple processes simultaneously. These processes are related to CPU, Memory, Network and IO operations. Virtual machine image can be created using Docker, each instruction or command creates a new layer on old one. Command can run through Docker files, is a command script and run automatically. Unlike VM Container offer only some part of OS and you can run application directly on that OS. Docker Containers are behaving well in PaaS environment and they are well performed in distributed system framework Bernstein [2014].

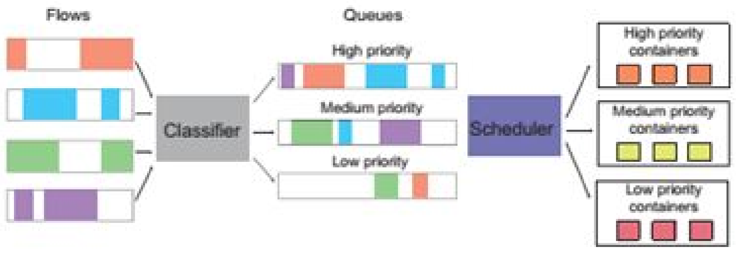


Figure 2.2: Implementation of Docker Dusia et al. [2015]

Linux containers reduce the memory overhead on OS due to virtual machines. Various applications may use same system resources; it will result in performance degradation. IO contention problem is major issue in two tier Docker architecture. To achieve QoS Docker container two tier architecture can be use McDaniel et al. [2015].
Node level QoS: The main goal in node level QoS is achieve the capacity to enforce the resources on cluster level. High, medium and low level priorities are used to schedule containers. Blkio controller use flag to force the container to achieve capacity for IO operations McDaniel et al. [2015].
Cluster level QoS: Entire cluster is responsible to maintain QoS so its necessary to monitor all containers. Docker swarm is group of native clusters that behave like a single system. Swarm is used to manage the clusters in the container and check IO performanceMcDaniel et al. [2015]. Now we have idea about the vietualization and how the virtul machine /container plays a major role in cloud computing. Next Section we going to dig into the idea cluster and how they are deployed in the data centre using above technologies.

2.4 Clusters and Deployment of cluster using Virtualization technology:

Sadashiv and Kumar [2011] defined cluster as an assembly of hooked parallel or distributed computers using high-speed networks such as gigabit Ethernet, SCI, Myrinet and Infiniband. The interconnected computers co-operate each other for executing data intensive and compute intensive tasks which are suitable to execute on single computer. According to Sadashiv and Kumar [2011] clusters are needed for high availability, load balancing and for computing. Cluster provide superfluous nodes which provides service during failure of system component so that they are used for high-availability purpose. This advantage of clusters enhance the performance of the system as the standby node handle the task. The computational workload is shared among the interconnected computers in the cluster. The clusters are generally used for computational purpose rather than handling IO operations. From users perspective clusters are the multiple machines who works as a single virtual machine. Sadashiv and Kumar [2011] states that the number of users requests are accepted and shared between the standalone computers to form a cluster. Sharing computational load among different standalone computers helps to improve the performance. Uthayopas et al. [2013]defined virtual cluster and advantages of its usage. According to Uthayopas et al. [2013] benefit of using virtual cluster in high performance computing (HPC) operations is elimination of complex physical infrastructure and contribute native HPC environment to users. Virtual Cluster is set of virtual machines arranged to work together as a single system. According to Uthayopas et al. [2013]flexibility of creation and distortion of virtual cluster whenever it is required. Along with advantages Uthayopas et al. [2013]also state the difficult process involved in virtual cluster system originating from preparing a physical infrastructure, creating virtual machine templates, disk images, to defining network configurations. A large virtual cluster is hosted on multiple physical infrastructure for larger computing resources for users. Uthayopas et al. [2013] address challenges in organizing number of physical machines from different sites and work these machines together. According to Uthayopas et al. [2013] for deploying multi-site virtual cluster there should be typical way for creating virtualized network over multiple sites that virtually link the system into one typical network. For the complex multi-site infrastructure the configuration of virtual cluster should be custom fit. Murphy et al. [2009]also describe virtual organization clusters are systems which is combination of virtual machines that gives dedicated computing clusters for respective virtual organization. According to also describe virtual organization virtual organization cluster design allows each virtual machines to be independent of the underlying physical hardware, to span number of grid sites. Also describe virtual organization focus the issue of scheduling and provisioning of physical resources to virtual machine when adopting virtual organization cluster as grid computing. Also describe virtual organization explain a virtual cluster scheduler based on the Condor High Throughput Computing system. The virtual machines to respective virtual organizations are provisioned and booted using the real-time monitoring of Condor job queue. The jobs assigned to individual virtual organization are then execute on the particular virtual machines that helps to create clusters devoted to particular organization. As the queued job is completed the virtual machines are eliminated and allow the physical resources to be restored. Guedes et al. [2014] explain the container based operating system virtualization. The container based operating system virtualization provides number of isolated execution environments in a single operating system kernel. According to Guedes et al. [2014] Container is an isolated program execution environment, which behaves as an independent physical server, with its individual set of processes, file systems, users and network resources.Guedes et al. [2014] list that OpenVZ is an example of a container based virtualization implementation for Linux systems. OpenVZ kernel accumulate virtualization and isolation, that set up loads of containers in a single kernel, resource management, that restrict subsystem resources, just as CPU, RAM and disk access, on a per-container basis; check pointing maintain the state of container which makes the migration of containers possible. The guest OSs of OpenVZ are instantiated according to the templates. The templates are prior images which can generated a chrooted environment. The programs that running on the guest OS as a normal applications required system call interface from host operating system.Guedes et al. [2014] also describe the KVM. KVM(Kernel-based Virtual Machine) is a Virtual Machine Monitor(VMM) which converts code execution of guest operating systems. KVM contains loadable kernel module that gives core virtualization execution. KVM depends on the hardware virtualization technology like Intel-VT and AMD-V, to accomplish better performance.Guedes et al. [2014] states that KVM is more flexible than the OpenVZ because of full virtualization solution. Due to full virtualization solution, there is no need of kernel correlation between guest OS and Host OS. Pahl and Lee [2015] state virtualization techniques such as virtual machines and containers. According to Pahl and Lee [2015] virtual machines are at the main element of the compute infrastructure layer that gives virtualized operating systems.Pahl and Lee [2015] state that though VMs and containers are virtualization techniques but they resolve different problems. Containers are a resolution for number of interoperable application packaging in the cloud. Compare to VMs, containers are more flexible tool for packaging, delivering, and orchestrating both software infrastructure services and applications that is tasks that are typically a PaaS (Platform-as-a-Service). According toPahl and Lee [2015] Containers are developed on current advances in virtualization but allows more interoperability while utilizing operating systems virtualization. Furthermore VMs are about hardware allocation and management. With VMs Infrastructure-as-a-Service(IaaS) targets hardware virtualization.Pahl and Lee [2015] state that containers can replace VMs for some specific cases such as allocation of hardware resources is done through containers by componentizing workloads in between clouds. Pahl and Lee [2015] state the basic features of containerization such as a lightweight portable runtime, the capability to develop, test and deploy applications to a large number of servers and the capability to interconnect containers. According to Pahl and Lee [2015] Containers have reference to the cloud PaaS level. They also related to the IaaS level through sharing and isolation aspects that exemplify the evolution of OS and virtualization technology. In the fifth section, we discuss about the Networking 2.4 component. Here we discuss what SDN is. SDN is the current approach used for networking. We mainly argue over how SDN is used for networking in virtual machines verses how they are used for networking in containers and which one is a better approach among them for networking. The different approaches for networking through SDN are: 1) SDN for Virtual Machines 2) SDN in Containers 3) Open VSwitch

2.5 Networking virtual machines and containers:

2.5.1 Network Virtualization:

Virtualization is the key element in cloud infrastructure. It has the changed the way of the computing. Virtualization provides the features like easy provisioning, high availability and much more. In Virtualization, An operating system, server storage, networks can be virtualized. By virtualizing network, we can provision the services. According to the Gartner report, that there no decrease in acceptance of virtualization to the computing infrastructure. Network virtualization is a process of combining the available resources in network by separating the available bandwidth into channels. Each bandwidth is independent of the other bandwidth and assigned (or reassigned) to a unique server or device in the network. Every channel is individually protected. Every tenant has a shared access to all the resources on the network from a single computer Pfaff et al. [2009]. Network virtualization is projected to the improve latency, cost efficiency to develop the infrastructure. Network virtualization is intended to enhance availability, high bandwidth, consistency, elasticity, scalability, and firewall. Network virtualization is said to be effective for the networks that are sudden, large and unforeseen surges in usage. Virtualizing the network environments will implement lots of service such as high availability, scalability, which is beyond to the services that are available in a physical network. For instance, if lots of tenants use the same resources in the infrastructure lots of issues arises in the physical network but network virtualization isolates the tenant by providing Virtual LAN ID to overcome the availability issues. Network virtualization indicated as a source for creating new networking approaches in the paralyzed Internet architecture and brought lots of development in the network services Friis-Christensen et al. [2009]. Network virtualization reduces us to provision the network is made easy. Network virtualization differs from Software defined Networking where the networking function are been separated from the underlying network hardware. Which give efficient management of the networking and benefits the infrastructure.

2.5.2 Software Defined Networking:

The term SDN (Software-Defined Networking) was originally coined to represent the ideas and work around Open Flow at Stanford University. As originally defined, SDN refers to a network architecture where the forwarding state in the data plane is managed by a remote control plane decoupled from the former Kreutz et al. [2015]. Those conveyed control, Whats more, transport organize conventions running. Inside those routers Also switches would the magic advances. That permit information, in the manifestation about advanced packets, will. Head out around the globe. Regardless of their broad adoption, Accepted IP networks are perplexing and hard will wrist bindings. With express the fancied high-keyed system policies, organize. Operators necessity will design each unique system gadget. Independently utilizing low-level whats more frequently all the vendor-specific commands. Furthermore of the setup complexity, organize. Situations must continue the Progress of faults Also. Adjust on load transforms. Programmed reconfiguration and reaction. Components need aid basically non-existent previously, present IP networks. Enforcing the required approaches done such a changing surroundings. Will be accordingly exceedingly testing.

Features of SDN: Software-Defined Networking (SDN) gives really intriguing offers which will change whats to come networks in. Concentrate control system /expense efficiency, innovation, programmability, versatility, security, Virtualization, cloud support, automation, unwavering quality, Whats more, proficient natures domain should back Big-Data. Clinched alongside paper the thing that SDN offers us is stated. It provides for us an incorporated control instrument from claiming Different systems administration fittings gadgets starting with. Numerous vendors, further organize mechanization will be significantly moved forward with the assistance about APIs which need aid used to unique. System points a standout amongst those fundamental targets of SDN is should furnish improvement through the web alternately that network, this guarantee. Challenges of SDN; Troubleshooting and visualization. Determining the network state at any given time. Inspecting and replaying events learned both from the controller and the network devices. Comparing routing state and paths when a service/application is performing well and when it is not. Monitoring paths for changes in hops, metric, delay, and bandwidth.

Software Defined Networking For virtual machine: Software Defined Network (SDN) is one network architecture used to control the network traffic using open network protocols. SDN is containing three layers in its framework: Physical Layer, SDN controller and Application Layer. SDN Controller works at central level uses Open

Flow protocol to established communication in network. The SDN used in Linux containers. Now a days containers are used as VMs. They are light weight in nature with better performance result than VMs. Time to start the VM in container is in seconds because container never uses hypervisor. Containers performance is very near to bare metal performance. Figure shows, VMs with their GRE configuration. GRE is Generic Routing Encapsulation used for tunneling between VMs. open vSwitch is software used for open source switches. Every instance of open vSwitch is connected through GRE tunnels. Tunnel Bridge can build on every isolated switch for network interface Costache et al. [2014]

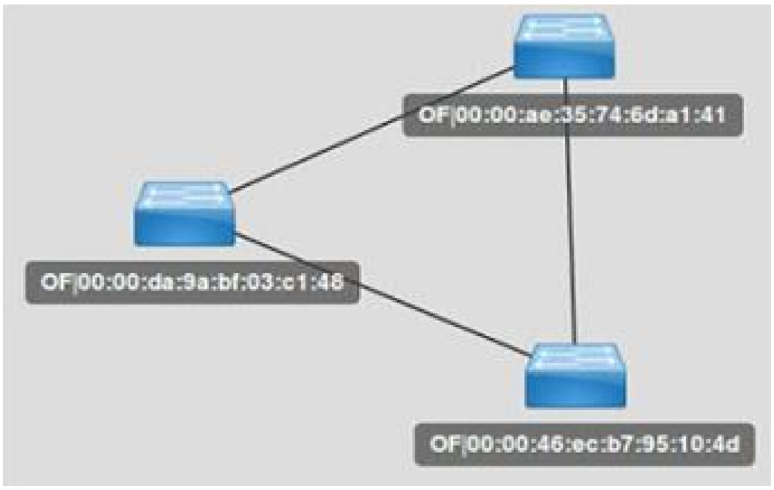

OF|00:00:ae:35:74:6d:a1:41
OF|00:00:da:9a:bf:03:c1:48
OF|00:00:46:ec:b7:95:10:4d

Figure 2.3: Virtual Machines with GRE Tunnels Costache et al. [2014]

SDN for Containers: Docker programming makes holder situations that can host multiple applications, with that objective of settling on them more lightweight furthermore convenient. Holders permit it with conveying another provision without devoting a whole committed Operating system (OS) occurrence Also virtual machine (VM) to it - various holders can run on an absolute VM alternately a committed physical server. As a result a Docker deployed provision will be composed of the compartment interface instead of a particular working system; it likewise revels in more stupendous portability. Clients might get those apps in a holder running under At whatever working framework that dockers needs to be been ported to, including the vast majority Linux OS, CentOS, Mac Operating system X, Windows and the significant cloud platforms De Simone [2014] . Docker does, however, need An association should todays looser understanding about SDN - which could envelop organize virtualization, network programmability and the detachment of the control and information plane, independently or On any consolidation. Docker employments virtual networks will interface containerized provisions for that network, and join compartments with other compartments on the same host. It disappointments and outrage on his/her staff might also define, specifically through docker or through connected instruments for overseeing docker environments, for example, Flocker alternately Rancher, virtual overlay networks should associate compartments over hosts Whats more again bigger networks (such data centres, WAN, and the Internet). Containers permit to manage and oversee the app server itself and additionally those cloud infrastructures, including network resources. Thus, that requisition server might scale with respect to interest controlled by the provision itself and balanced for optimized system works that need aid outlined requisition particular. For addition, every last bit about these preferences needs aid contributed with a cloud provider. The key advantage containers have over the more traditional hypervisor and virtual machine-based approach is that each container workload can share a host OS, rather than each virtual machine having its own host or guest OS image. A virtual machine takes up considerably more space in memory, and takes more time (minutes rather than fractions of seconds) to deploy and provision De Simone [2014].

2.5.3 Open vswitch:

Open vswitch act as a virtual software switch in virtual environment and it offers various features for managing the network like VLAN, QoS, and flow control Rao and Rao [2015]. The Open vSwitch is an Open-Flow based open source switch implementation which is used as a virtual switch in virtualized environments. The OpenFlow specifications are targeted for Layer2 and layer3 functionality. The latest networking shift is to enable the switch with L4-L7 services like load balancers, proxies, firewalls, IPSec, etc. This would make the middle boxes redundant in the networking deploymentsGorja and Kurapati [2014]. Performance of Open vswitch is measured by three ways namely Security Evaluation QoS Evaluation Network performance Evaluation.
Security Evaluation: Rao and Rao [2015] suggests a method to evaluate the performance of security in Open vswitch, Making two virtual LAN to four virtual machines Also each virtual machine will regulate ARP show with separate VMs clinched alongside notable LAN, and view if ARP broadcast might transverse different VLAN alternately not. Furthermore, those creators Moreover lead those ping tests around dissimilar virtual machines will see if VM Might adequately join with other VM done different VLAN.
QoS Evaluation: Utilize the QoS characteristic of an open switch with execute those stream control for every one framework interface. The target is will exhibit that fine-grained managerial assistance for open vswitch. Network performance Evaluation: To find the overhead caused by the software switching. Comparison of performance with and without virtual machine is carried out.

Chapter 3

Design

The study provides the detailed description of the tools which we used to build our prototype to deploy cluster using docker containers and interconnecting the host using VxLAN tunnels. The Fig 3.1 shows that we have deployed three server in different network regions and these servers are cluster together using cloud overlay networks. The below describe the tool specification for implementing our design and for testing our prototype.

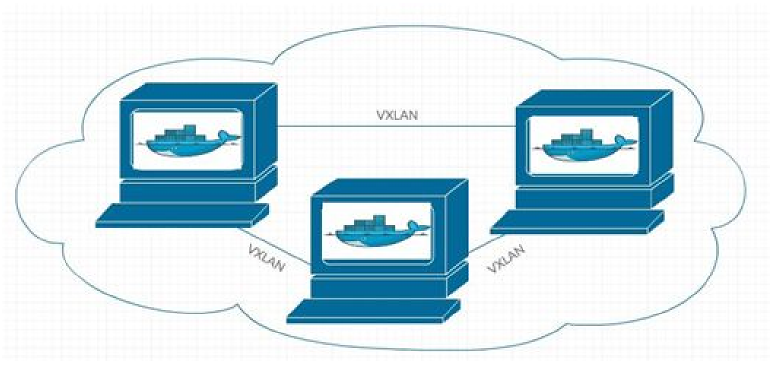


Figure 3.1: Proposed Architecture

3.1 Specification:

3.1.1 Cloud overlay networks:

Virtual Extensible Local Area Network: In cloud, the virtual machines are located at separate physical servers on different locations. If the servers are located in same location we could your underlay network (layer 2 physical network) for communication between different VMs. At present layer 2 network use Spanning tree Protocol (STP model) to eliminate duplicate path and frame replications. STP model has limitation such as no multipath communication; Inter-VM communication is not possible over layer 2 networks. This limitation can be avoided by configuring servers over layer 3 networks (cloud overlay networks). For the communication between the virtual machines that are located at different network using underlay network is not a right architect. In cloud computing and multi-tenancy well they go hand and hand. So does the requirement for an application is on demand. It just makes good sense for the tenants and their applications to be isolated from each other. A three tire app can have multiple virtual machines in each tier require a logical isolation between them. The problem with is only 4096 VLAN Ids and isolation options. To overcome a new technique called VXLAN is introduced by CISCO, VMware and citrix. The first thing to tackle the VLAN Ids by placing 24 bit VXLAN ID, which increased to 16 million logical networks Mahalingam et al. [2014].

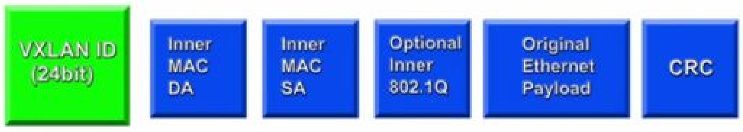


Figure 3.2: VXLAN FRAME

Figure 3.2: VxLAN FRAME

Mahalingam et al. [2014] states that advantage of this is that the packets are transmitted at layer 3 networks. In VXLAN, the Mac/UDP uses switch hashing to look at the UDP packets and distribute the data across all the links in port channel group. Where in MAC/MAC or MAC/GRE the packets are transferred inefficiently and cannot be distributed in all port channels were the bandwidth in data center is wasted. VXLAN IN CLUSTER NETWORK: Actually, VXLAN works like a layer 2 bridges. VXLAN Bridge learns containers Mac host VXLAN and IP tupples. Then the Encapsulated traffic is distributed according to the port profile of the containers attached. Here the IP address is actual multi-casters.

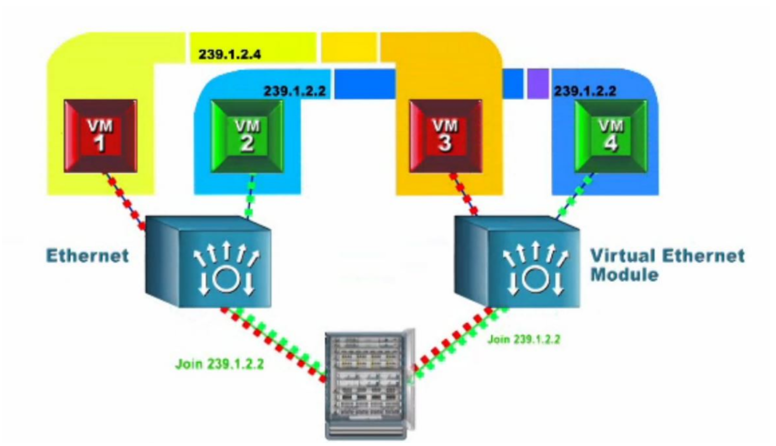


Figure 3.3: VXLAN Multicasting.

As the tenant comes online will be assigned to the multicast group by the containers to carry broadcast, multicast and unknown unicast are carried through the segment but unicast traffics are not directed to the destination. When all the containers are in same multi-cast group. If a container receives a broadcast from red container the bridge looks at the segment ID and drops the packet to the green container because the ID doesnt match to the destination container.

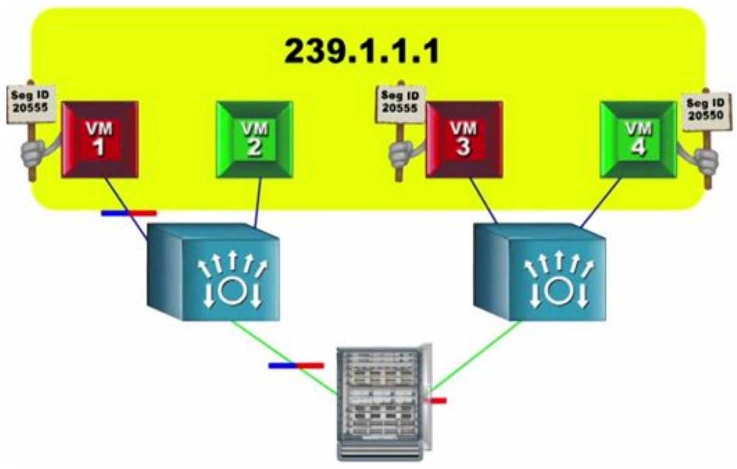


Figure 3.4: Container Segments

3.2 YCSB:

YCSB v0.4.0 is a tool which is optimize for benchmarking system. In order to work with this tool we need to download the updated version from the sources or we get it from the git repository. The primitive role of this tool is to compare and contrast the performance of various cloud platform database. Furthermost, its framework include of package of the standard workload units taking into consideration the other parameters such as read-heavy load, scan workload ,write work load and so on. Among all the feature attain by YCSB one of the parameter which is consider as the best part of YCSB is the workload generators which depends on the various parameters confine to it. By using workload generator, designing and generating of any kind of data required for comparing the performance of the database can be performed easily. This incomparable character of YCSB leads to evolution of the new data frames to benchmark cloud data serving system is the major achievement for the usage of YCSB. Extensibility is one of the basic objectives of YCSB so that it is possible to implement on different latest cloud database system and benchmark its performance. This section depict the architecture of YCSB client, it will also brief on some of the challenges in providing distribution for the workloads in database. Initially, YCSB client is a java program which is using for generating the data to be transfer to the database; similarly it will generate the specific operations which will perform the work load. The architecture below shows the architecture of the YCSB client.

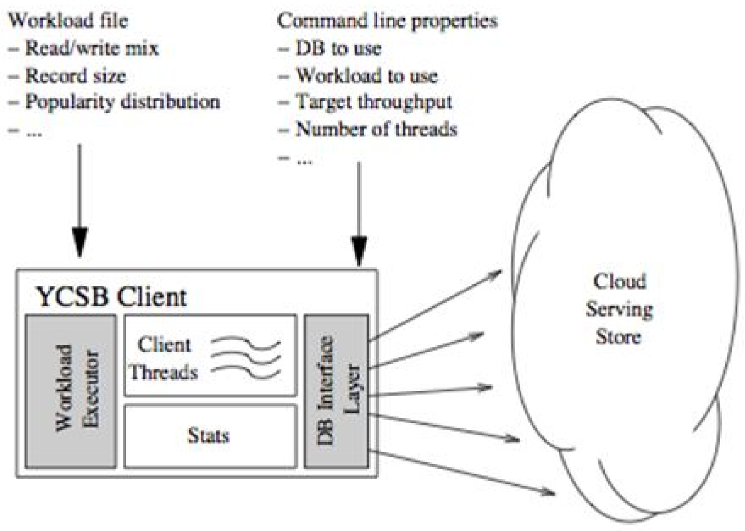


Figure 3.5: YCSB Architecture Cooper et al. [2010]

Workload properties characterize the work load, sovereign of the provided database or experimental run .For instance, the read or write property falls under this category, for distribution to use zipfian, latest etc and the size and various numbers of fields in records. However, runtime properties are explicitly to a provided experiment. Illustrating this, let us consider HBase database interface layer to be used in our experiment, so this properties used to initialize that layer like the database service host-names and various client threads.

3.2.1 Benchmark Tiers:

This section we will illustrate the purpose of two benchmarking tiers for evaluating the performance and scalability of cloud distributing system Cooper et al. [2010]. These two tiers are said to be basic benchmark tier of YCSB their properties are discuss individually below

Tier 1:- Performance: The performance tier of the benchmark spotlights highly on the latency of request at the time when the database is under load. Latency is been considered to be very essential in cloud serving system, because it make the impatient user waiting for the web page to load. Moreover, we present the natural adjustment between latency and throughput, on a provided hardware setup, consequently as the chunk of loads increase it tends to increase the latency request of the users because there is more conflict for disk ,CPU ,network ,and many more. The main goal of this tier is to define the trade-off for every database system by analyzing latency as we raise the throughput, till the time where the database system is saturated and the throughput stops rising. Concerning to work with this benchmark tier, we need a workload generator, they serve two major desires, firstly to characterize the data set and push them in the database, secondly to execute operation across the dataset when checking the performance. On implementing YCSB client specifically for both purposes, a group of parameter files depicts the environment of the dataset and the transaction performed against the data. YCSB client permits the client to describe the offered throughput as command line parameter and the instruct

Tier 2:- Scaling: Cloud system mainly focus on their ability to scale elastically, in order to be able to manage raise of load as the application increase the features and become advance in popularity. Scaling tier of the database analyze the effect on the performance as more number of machines are updated to the system. There are two main metrics available for analyzing in this tier they are scale up and elastic search and we will discuss in detail individually. **Scale up:** This metrics characterize the kind of question like what will be the performance of database as the number of machines is added to the system. In this instance, we load the provided chunk of server with the data and perform the workload. Following, we then erase the data, add more servers, perform higher load of data on the larger cluster, and then run the workload ones again. In case if the database system seem to produce good scale up properties ,then the performance should stay constant .as the number of servers, chunks of data and the offered throughput measure proportionally show that it is equal to the scale up. **Elastic speedup:** This kind of metrics we answer to the question which is similar like how does the database perform with the raise of machines in the system while the system is uder processing state in the other words we can say when the system is running. In such case, we push the provided amount of server with the data and run the workload .We add more than on server to the workload which is running currently and we check the effect on the performance. Henceforth, the system that provides good elasticity should display improvement in the performance with the addition to the new servers, without any conflicts while the system is configuring itself when it try to use the newly added server. To sum up this is said to be similar comparatively to the speedup metrics, with the added curves to the new server added on the time when the workload is running.

3.3 Weave Docker plug-in:

Weave are optimize in such a way that it creates virtual network which is connecting to the docker container where is then deploy across end number of host and enables automatic discovery. The application in weave utilize the network in such a way as if the container were all connected into the single switch, likewise no configuration of port mapped links and many more need not to be performed as its all done by it. The application container in weave provides the services which is accessible to the external world specifically to where the containers are operated. On the other hand the current system is accessible to internal container irrespective to their location. Weave has special features of bisecting the firewall and perform in passively connected network, in which network traffic can be encrypted and permitting host to be connected over the untrusted network Kereki [2015]. Weave router creates network bridge locally over the server where it runs and vapidly known as weave. They also add virtual Ethernet connections from every container and from weave router itself to the bridge. Likewise, when the local container request for association with remote one, the packets are transferred to the other weave router probably with multi hop, till the packets reached the remote weave router to the weave container. The following figure demonstrate on how weave adds various virtual gadgets to switch the traffic finally to the other servers.

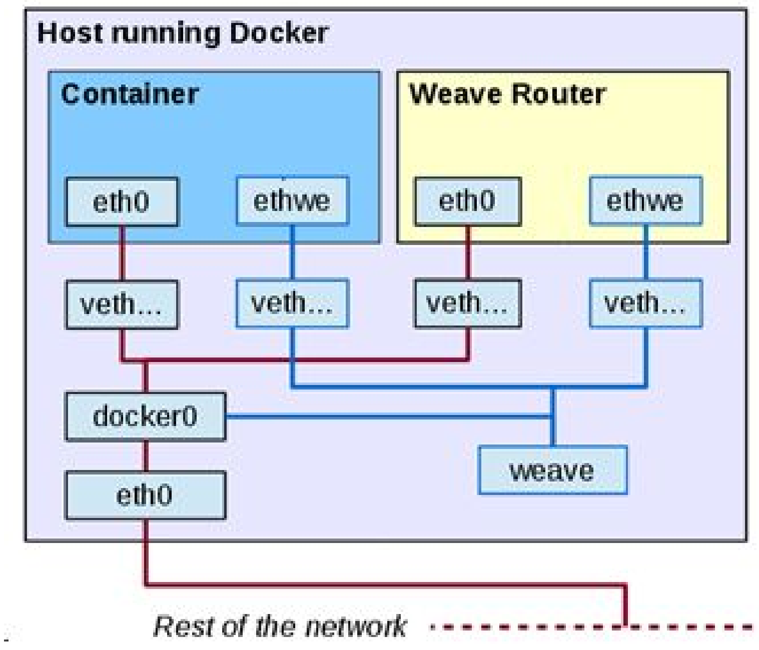


Figure 3.6: Weave Plug-in Kereki [2015]

Figure 3.6: Weave plug-in On connections of dual weave routers, they swap the topology data to have knowledge about the rest of the network. The collected data are used for routing the resolution to keep away from the unwanted broadcast of packets. In order to encounter the feasible changes and to perform across any network error that might pop up, weave router sequentially monitor the connection. To detect possible changes and to work around any network problems that might pop up, Weave routers routinely monitor connections. To connect dual routers, on a server, type the weave connect the .ip.of.another.server command. To drop a Weave router, do weave forget ip.of.the.dropped.host.On connecting new weave router to the available network, we need not to connect to every existing router. Everything you need to do is to provide the address of any one existing weave instance in the single network, so straight away from that point it will collect all topology information on its own. The remaining routers will update their own information in the processor in the similar form.

3.4 MongoDB sharding cluster:

The aim is to deploy the cluster in docker container and we have chosen for mongodb cluster. Below we have given the detailed description of the Sharding is the way to which the data are distributes and stored across end numbers on machines. Mongodb make use of sharding methods to hold up the deployments of very massive dataset and high throughput operations. The primitive goals of sharding is to improve load balancing when the huge data is to be loaded to the database, also possess improvement in failover of the system and no single point of failure . Purpose of Sharding: Database system having huge data set and high throughput application which may challenge the capacity of ingle server. Adding to this, huge query rate can cripple the capability of the CPU of that server. The impact of larger data set extends the storage capacity of the single server. Database systems with large data sets and high throughput applications can challenge the capacity of a single server. High query rates can exhaust the CPU capacity of the server. Larger data sets exceed the storage capacity of a single machine. Finally, working set sizes larger than the systems RAM stress the I/O capacity of disk drives. To address these issues of scales, database systems have two basic approaches: vertical scaling and sharding. Vertical scaling adds more CPU and storage resources to increase capacity. Scaling by adding capacity has limitations: high performance systems with large numbers of CPUs and large amount of RAM are disproportionately more expensive than smaller systems. Additionally, cloud-based providers may only allow users to provision smaller instances. As a result there is a practical maximum capability for vertical scaling. Sharding, or horizontal scaling, breaks the data set and transfer the data across multiple servers, or shards. Each shard said to be independence database, additionally, as a group the shards make up a single logical database.

3.4.1 Auto-Sharding Architecture:

The primitive approach of MongoDB sharding is to divide group of data into smaller chunks. The chunk which was scattered among the various shards is responsible for the subset of the whole data set. In order to separate the group of chunk, MongoDB will define a group of shard key which name many fields to specify the key to which we shared the data Liu et al. [2012]. The architecture of Auto-Sharding is exhibit below:

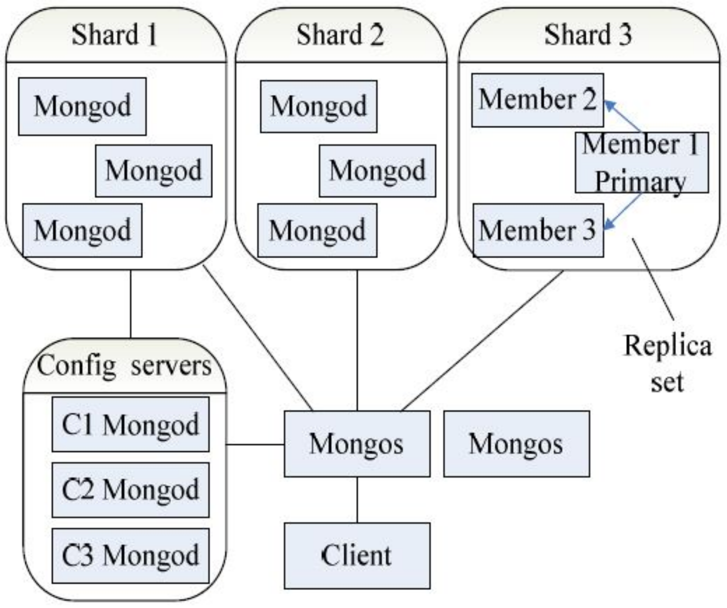


Figure 3.7: MongoDB Auto-sharding Setup Liu et al. [2012]

MongoDB Shard clusters consists of three major components: shards, config server) and query routers. Each component are characterize in detail below:

1)Mongod(Shard server): The major role of shards is to store the data. Every shard attains of one or more servers and the data are stores using mongod process. In production section of shared cluster, in order to maintain high availability and data consistency every shard is a replica set.

2)Mongod (Config server): This component store the clusters metadata. This data abide of the outline clusters data set to the shards. Furthermost, query router makes use of this metadata to target operations to specific shards. Production sharded clusters have accurately three config server.

3)Mongos(Router server): It can be assumed as the routing and coordinating process as its other name is query router. When the client make the request to mongodb server, the mongos routes that request to the specific server and match the result to be transfer back to the client machine. A sharded cluster may contain more than one query router to balance the client request load; however sharded clusters have many query routers.

Chapter 4

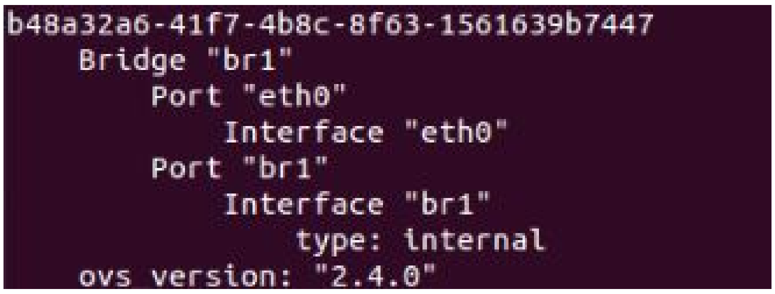
Implementation

In our implementation we are using the three virtual private servers (VPS) with Ubuntu 14.04 as operating system and Docker 1.9.1 on different network locations. The setup could be categorized into two steps such as (1) Basic ovs configuration. (2) Cluster deployment.

4.1 The basic networking for the server using Ovs Bridge:

4.1.1 Creating virtual ovs bridge br0:

A Linux bridge can be utilized to unite two different interfaces at layer 2 level (as like a normal switch). Normal applications incorporate proxying, separating by utilizing iptables and which reduces physical resources for networking. In our implementation we going to bridge the interface of the server eth) and the default docker bridge docker0. In order to bridge these interface we use open vswitch. The details of the docker0 and ovs bridge is briefly explained in the chapter 4. We create an ovs bridge with br1 as a bridge name, the bridge name can be user defined. The description of new bridge is given below:



```
b48a32a6-41f7-4b8c-8f63-1561639b7447
    Bridge "br1"
        Port "eth0"
            Interface "eth0"
        Port "br1"
            Interface "br1"
                type: internal
    ovs_version: "2.4.0"
```

Figure 4.1: Description of OVS Bridge

The bridge br1 has to be enabled to attach the interface to the server. The bridge br1 will be isolated until the bridge is connected to an interface. To make bridge br1 to communicate to the outer world, it should be attached to the eth0 of the server.

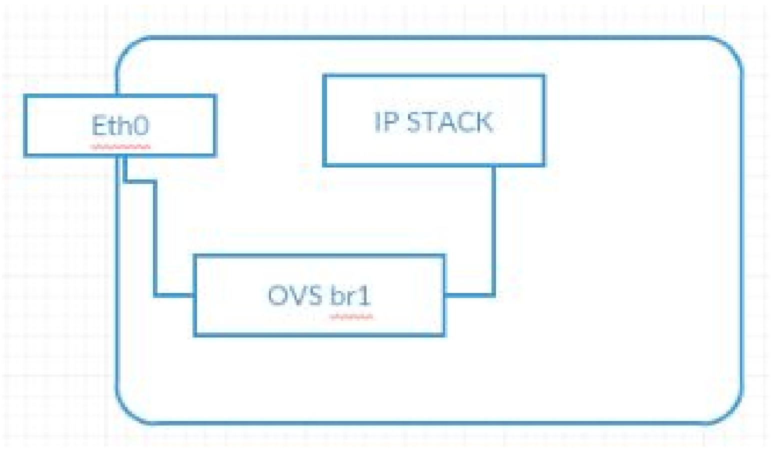


Figure 4.2: Attaching OVS bridge br1 to eth0 of the server.

4.1.2 Attaching ovs bridge to docker0 bridge:

Docker bridge docker0 is the default docker bridge which connects all the containers together for communication between the containers. The docker bridge as default IP sub netting such as 172.17.41.0/16. If we spin the container the IP of the containers will assigned accordingly form subnet. Here we going to disable this docker bridge and build our own bridge with our IP configuration and sub netting. For building our own bridge we used a small automation script that shown in appendices. We use new docker bridge for connecting to the ovs bridge using vtep interface, the vtep interface will be the medium in connection between docker bridge and ovs bridge. The IP address for new docker bridge should be of same network subnet but will different host address.

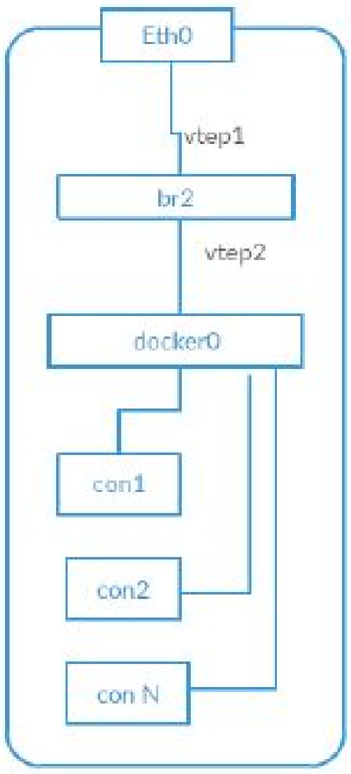


Figure 4.3: Bridging docker0 and eth0 via OVS bridge

4.1.3 Creating new IP pool for the docker0:

Even though, if we launch containers with new docker bridge there will be IP conflicts when we deploy a cluster system. To resolve the IP conflicts we define another IP stack in a docker network. To configure new IP pool the below configuration can be added in the DOCkER OPTS:

```
"newbr=newbr1
CIDR=<ip_address>
wait_ip() { address=$(ip add show $newbr | grep inet  | awk  {print $2} ) [ -z "-
$address" ] && sleep $1 || : } wait_ip 5 wait_ip 15
DOCKER_OPTS= -H unix:///var/run/docker.sock -H tcp://0.0.0.0:2375 fixed-cidr=$<ip address>
--bridge $newbr"
```

Listing 4.1: creating New IP Stack

4.1.4 Connecting the servers with the VxLAN tunnels:

Right now we have three remote servers with full network configurations using open vswitch as show in fig(complete config) and these server will be connected each other using Encapsulated tunnel called virtual Extensible Local Area Network (VXLAN). To connect we need two create another two vtep interface will be created in ovs bridge; the tunnel which connects two servers should have the same interface name. We are using three tunnels so the vtep interface name will be vx1, vx2, vx3. More interfaces can be created if we use more the three servers. After the interface has been created we trigger the below command to connect the remote servers as show below.

```
ovs-vsctl add-port br1 vx1 -- set interface vx1 type=vxlan options:remote_ip=<remote_ip> option:key=flow ofport_request=10
```

Listing 4.2: Vxlan Tunnel command

Note: we execute the above command to connect multiple server we have to change remot ip and interface.

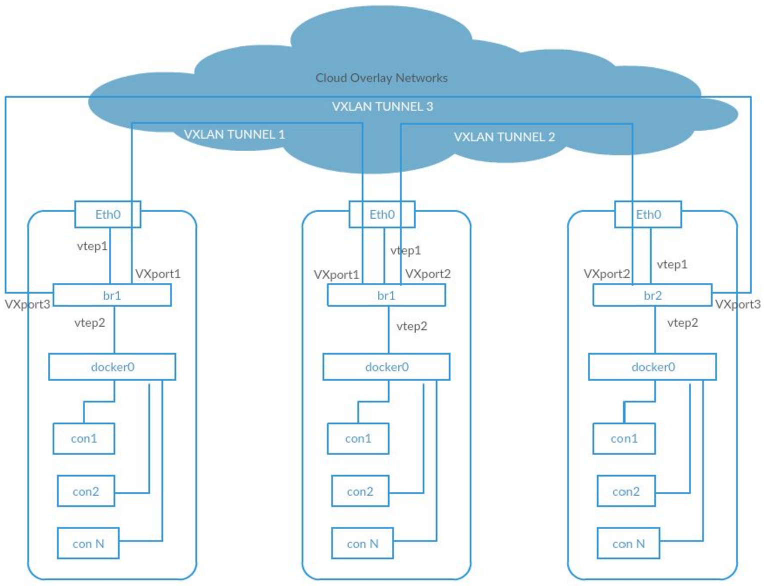


Figure 4.4: servers connected to via VXLAN tunnel

4.2 Deploying MongoDB cluster:

In this section we going look about that how can we deploy high availability mongodb cluster using docker containers among different server that are distributed across different regions. This section categorizes of following section and detailed implementation is given below: 1) Creating base image. 2) Creating server containers. 3) Sharded cluster setup.

4.2.1 Creating Mongodb dockerfile:

Docker file is the small automation process with set of argument and definitions are place in a stack to build our own pre-defined base image for the containers. The major advantage of building an image using dockerfile is that we can reduce the amount of time take for installing an application. In our case we need to create containers with mongodb server application running and to create a database path were the meta-datas and documents can be stored. For our setup, we need total of 12 containers; each server runs 4 containers, installing mongodb application and to provide user permission for the path or directory in 12 containers requires more time.In our docker file we use the base image as Ubuntu 14.04, Mongodb server version 3.1 as an application and creating list of directories for dbpath. Refer appendix for the script of Dockerfile.

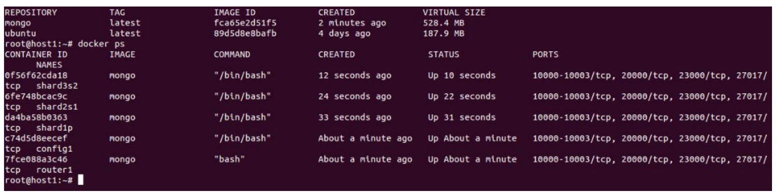
4.2.2 Creating containers for the cluster configuration:

As we said that we have created an image and named as mongo. Now we can use this image for create mongo containers by using following command:

```
docker run restart=always -it -P name <container name><image_name>
```

Listing 4.3: Creating Node container with mongodb image

Note: In above command we used: restart=always to keep the container running and to start when the docker service is started in server. -P= To Expose the ports to the container. We have 12 independent container running, these container take their desired action by implementing shard cluster setup among them



```
REPOSITORY          TAG                 IMAGE ID            CREATED             VIRTUAL SIZE
mongo               latest              fca65e2d51f5        2 minutes ago       528.4 MB
ubuntu              latest              89d5d8e8bafb        4 days ago          187.9 MB
root@host1:~# docker ps
CONTAINER ID        IMAGE               COMMAND             CREATED             STATUS              PORTS
      NAMES
0f56f62cda18        mongo               "/bin/bash"         12 seconds ago      Up 10 seconds       10000-10003/tcp, 20000/tcp, 23000/tcp, 27017/
tcp   shard3s2
6fe748bcac9c        mongo               "/bin/bash"         24 seconds ago      Up 22 seconds       10000-10003/tcp, 20000/tcp, 23000/tcp, 27017/
tcp   shard2s1
da4ba58b0363        mongo               "/bin/bash"         33 seconds ago      Up 31 seconds       10000-10003/tcp, 20000/tcp, 23000/tcp, 27017/
tcp   shard1p
c74d5d8eecef        mongo               "/bin/bash"         About a minute ago  Up About a minute   10000-10003/tcp, 20000/tcp, 23000/tcp, 27017/
tcp   config1
7fce088a3c46        mongo               "bash"              About a minute ago  Up About a minute   10000-10003/tcp, 20000/tcp, 23000/tcp, 27017/
tcp   router1
root@host1:~# █
```

Figure 4.5: Containers created with mongodb image

.

4.2.3 Container shard cluster setup:

For Mongodb shard cluster setup we are advised to run the shard cluster setup that was released by mongodb organization. We going to modify the IP address for the setup, were the container will get it IP form the new docker bridge which is defined by us. The Configuration setup is available in appendix. The figure shows the complete sharded cluster setup and VXLAN tunnelling network to other server in different network regions for the communication.

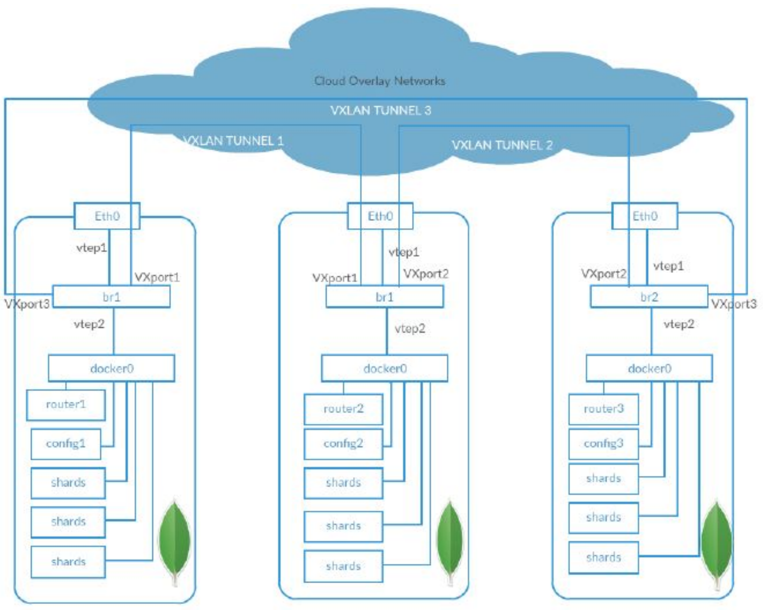


Figure 4.6: Container Cluster

Chapter 5

Evaluation

In this chapter, we will analyse the outgrowth of our prototype with respect to various experiment which we have tested and review the performance of our proposed architecture. The test performance is evaluated between OVS architecture networking and compare with the performance of Weave networking architecture. We will provide the evaluation result with regards to various categories firstly, resources usage where we will check the amount of resources used when clustered is deployed, secondly we will measure the network bandwidth, followed by finding the performance of the cluster and finally we will provide the scalability of cluster.

5.1 Server Resource Utilization:

The main approach of server consolidation is to achieve no resource is being idle, which will benefit an organization it term of using less number of physical servers. The face that we have to keep in mind that consolidation shouldnt utilize more resource of the server which will reduce the performance. In our experiment we are going to evaluate the amount of resource utilized by the networking configuration with online monitoring tool called newrelic. In Newrelic monitoring tool, we could capture the amount of resources being utilized (1) Before cluster deployment. (2) After cluster deployment. The resource utilization of the network configuration is analysed in terms of CPU and Memory using Newrelic online monitoring tool.

5.1.1 Before the deployment of the cluster:

The below figure depicts the amount of memory resource utilized by the OVS-VXLAN architecture with comparison of weave architecture in this contrary, we could claim efficiently that OVS-VxLAN consume 56% less resources than the weave before the cluster is being deployed. In the weave architecture, docker utilizes more memory because the weave plug-in are running as a container in the docker. Whereas ovs is a separate piece of virtual software that run on the host server.

Table 5.1: Memory Utilized by weave Plug-in before clustering

weave	Memory (mb)
docker	42
weave	30
weave proxy	29
total	101

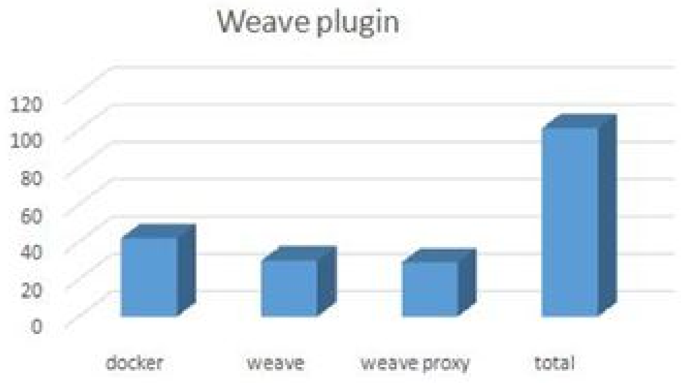


Figure 5.1: Memory Utilization of Weave plug-in

Table 5.2: Memory Utilized by OVS-VXLAN

ovs	Memory(mb)
docker	11
ovs-switchd	31
ovs-db	2
total	44

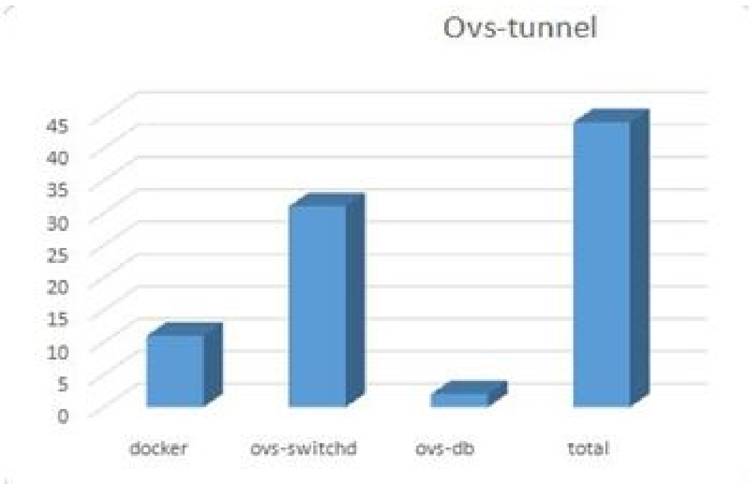


Figure 5.2: Memory Utilization of OVS-VXLAN

Fig below characterize the amount of CPU consumed by OVS and Weave. The chart clearly explain that OVS consume lesser amount of CPU which is almost half of which consumed by the Weave.

Table 5.3: CPU Utilization rate between weave and OVS-VXLAN

	CPU utilization
OVS-VxLAN	0.15%
weave	0.41%

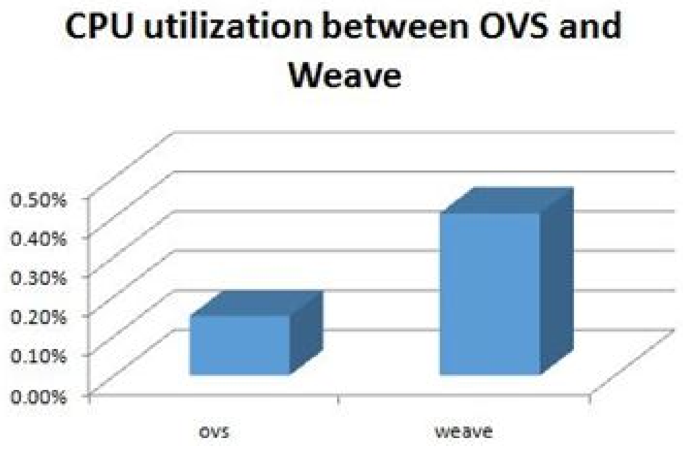


Figure 5.3: CPU Utilization between weave and OVS-VXLAN

5.1.2 Resource utilization after deployment of a cluster:

In first half of server resource utilization we have captured the amount of resource is consumed by our prototype and weave plug-in when the server is not been clusters or being idle. Now the server is configured to cluster and some communication is made between the cluster nodes. The fig below shows the memory utilized by OVS-VXLAN and weave. There in 10% increment in memory and CPU process of both architecture.

Table 5.4: Memory Utilized by weave plug-in after clustering

weave	Memory(mb)
docker	80
weave	38
weaveproxy	32
total	150

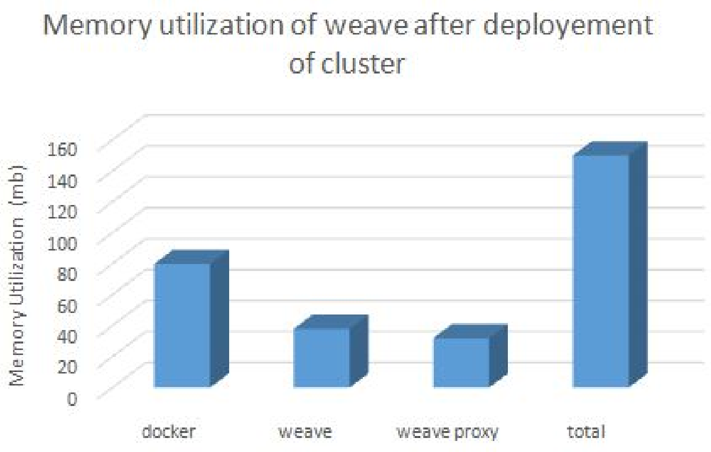


Figure 5.4: Memory Utilization of Weave plug-in after clustering

Table 5.5: Memory Utilized by OVS-VXLAN after Clustering

ovs	Memory(mb)
docker	35
ovs	40
total	75

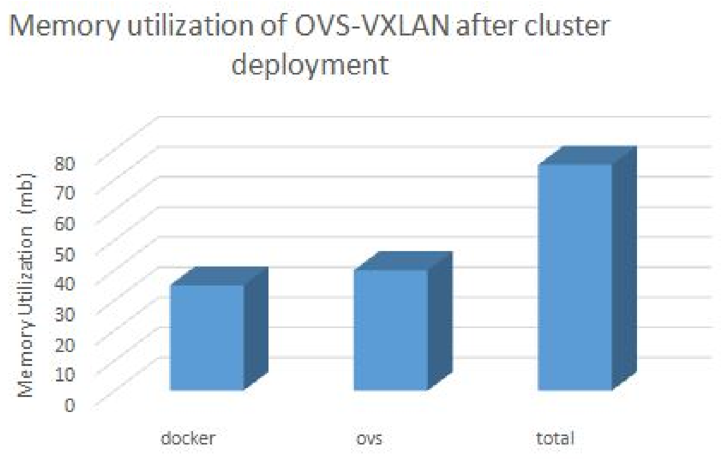


Figure 5.5: Memory Utilization of OVS-VXLAN after clustering

The Figure Below shows the amount of Processing power is consumed by weave plug-in and OVS-VxLAN after MongoDB cluster is deployed.

Table 5.6: CPU utilization rate between weave and OVS-VXLAN

	CPU utilization
OVS-VxLAN	0.27%
weave	0.64%

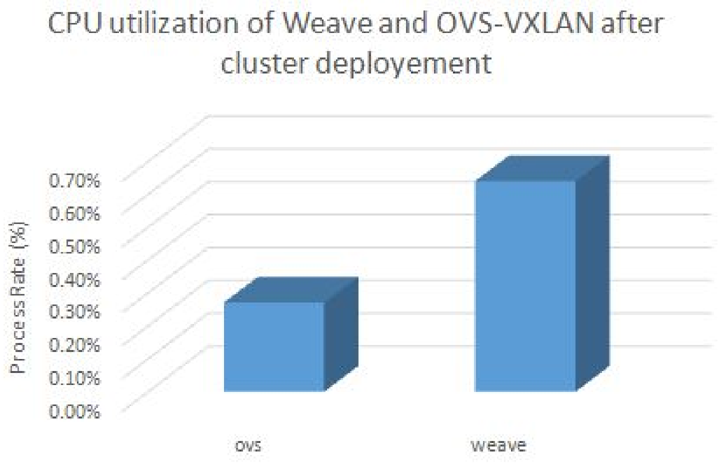


Figure 5.6: CPU Utilization between weave and OVS-VXLAN after clustering

5.2 Bandwidth Availability:

It is important to monitor the available bandwidth of a cluster because the lower bandwidth will reduce the performance speed of a cluster. The Bandwidth between two nodes is evaluated using network monitoring tool called IPERF by client and server model. One container node will be acting as a server and another will be as a client. The bandwidth is calculated by making request form server to client as shown in the fig. After performing the test it shows that the available bandwidth is high in OVS than weave. The result is described in the chart below.

Table 5.7: Available bandwidth between cluster node that deployed in weave and OVS-VXLAN

	Bandwidth(MBs)
ovs	237
Weave	160

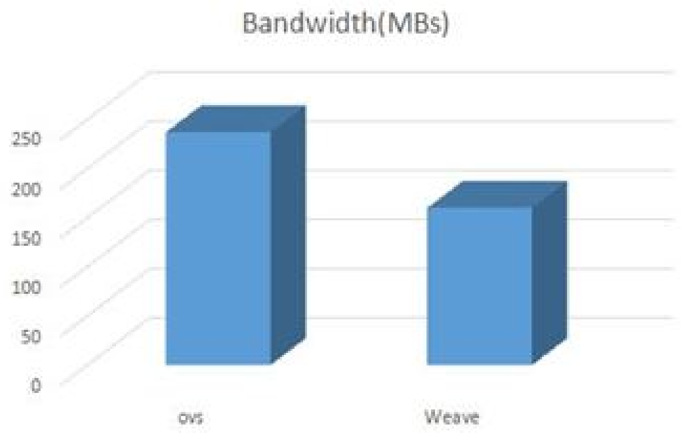


Figure 5.7: Average bandwidth between cluster nodes in Weave and OVS-VxLAN architecture.

5.3 Performance of the Cluster:

In this section the performance of the cluster is evaluated using a benchmarking tool called YCSB by Yahoo. We use database benchmarking tool because we have deployed a mongodb database cluster. The performance of mongodb is captured by triggering set of workloads into the database and analysed on different parameter such as the workload read/ write latency and throughput. The workloads properties such as record counts, operation counts and read/update prepositions are listed in the below tables:

Table 5.8: Test Operation for MongoDB Cluster

Properties	**Test A**	**Test B**	**Test C**	**Test D**	**Test E**
Read/Update	50/50	50/50	50/50	50/50	50/50
Record Update	1000	10000	20000	50000	100000
Operation Count	1000	10000	20000	50000	100000
Read Operation	0.5	0.5	0.5	0.5	0.5
Update Operation	0.5	0.5	0.5	0.5	0.5

Table 5.9: MongoDB Configuration Parameters

Properties	Default Value	
mongodb.url	mongodb://¡svr_ip:23000/ycsb?w=1	DB= ycsb
mongodb.batchsize	1	
mongodb.writeConcern	acknowledged	
mongodb.readPreference	primary	
mongodb.maxconnections	100	

All the tests are performed 10 times in each experiment and result is given below.

5.3.1 Read Operation:

The read operation is the set of data is pulling out from the database and the latency is calculated by the time taken to return the out from the database. The Fig show () that the test is executed in both OVS-VXLAN and weave architecture with five different workloads and the average read latency is around 966 us(min) to 1461us (max), whereas in weave the latency is around the 4337 us(min) to 5836 us (max).

Table 5.10: Average Read Latency of the MongoDB cluster Between Weave and OVS-VXLAN

	Average Read Latency	
Record Count	OVS(VXLAN)	WEAVE
1000	1081	4407
10000	982	5782
20000	966	4337
50000	1013	4683
100000	1461	5863

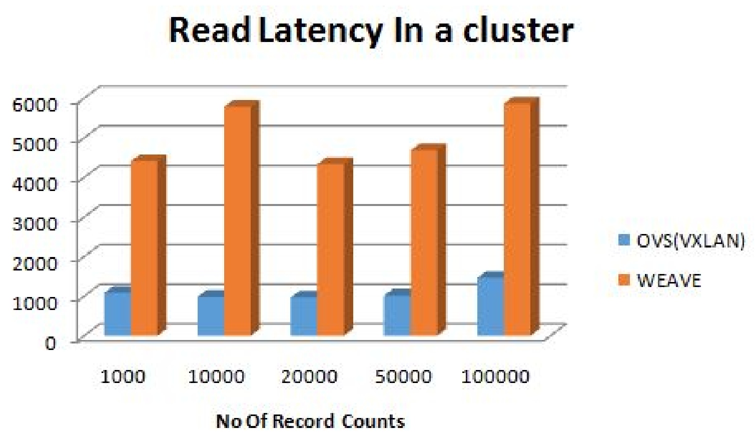


Figure 5.8: Average read latency in Weave and OVS-VxLAN architecture.

5.3.2 Update operation:

The read operation is the set of data is written into the database and the latency is calculated by the time taken to write in the database. the Fig() shows that the average update latency is less in OVS-VXLAN ranging from 933 us(min) to 1461 us(max) than the latency in weave ranges from 628 us(min) to 2921 us(max).

Table 5.11: Average Update latency of MongoDB cluster between weave and OVS-VXLAN

	Average update Latency	
Record Counts	OVS(VXLAN)	WEAVE
1000	933	2921
10000	572	904
20000	560	706
50000	492	628
100000	537	965

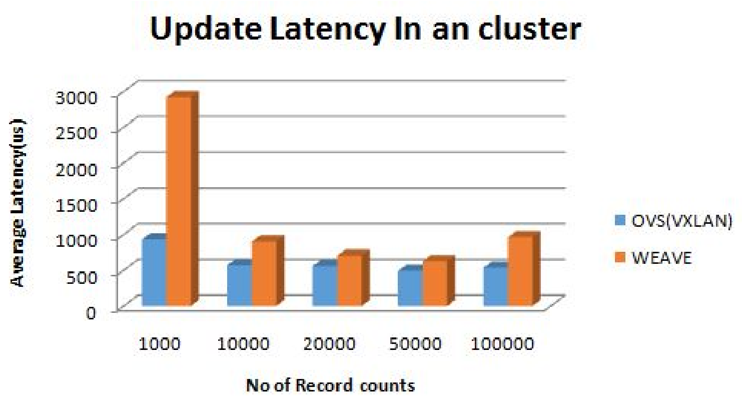


Figure 5.9: Average update latency in Weave and OVS-VxLAN architecture.

5.4 Throughput of a cluster:

The more important thing is to find the overall throughput of the clusters. Throughput is the amount of the instruction or operations are performed in given period of time. In throughput the lesser time indicates the high throughput; this is based on the system configuration and network speed. Since our research s based on the networking of container cluster, we trigger set of workload such as 1000, 10000, 20000, 50000 and 100000 to evaluate the amount of through operation is executed in a second. From our experiment the overall throughput is higher in OVS-VXLAN than weave.

Table 5.12: Throughput of the cluster between weave and OVS-VXLAN

Total ops	OVS-VxLAN	Weave
1000	470	253
10000	990	460
20000	1046	415
50000	1074	603
100000	985	401

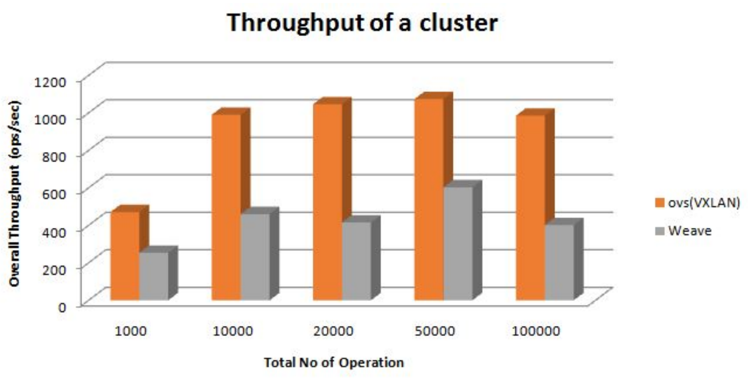


Figure 5.10: Throughput between Weave and OVS-VxLAN architecture.

5.5 Scalability of a cluster:

Scalability is the ability of a computer system or an application to perform well and to provide full availability, even though the set of operation/instruction is increased. To check the Scalability of mongodb cluster we increase the number of workload that is triggered by the YCSB in mongodb. Since we have mongodb sharded database cluster with 3 replicated shards which have 12 shard servers. Scalability of sharded cluster is, If all these serves are up (i.e. works fine) without any down time as long as we increase the workload in the cluster.

Table 5.13: Scalability of the cluster

	OVS-VXLAN	weave
Scalability	170000	130000

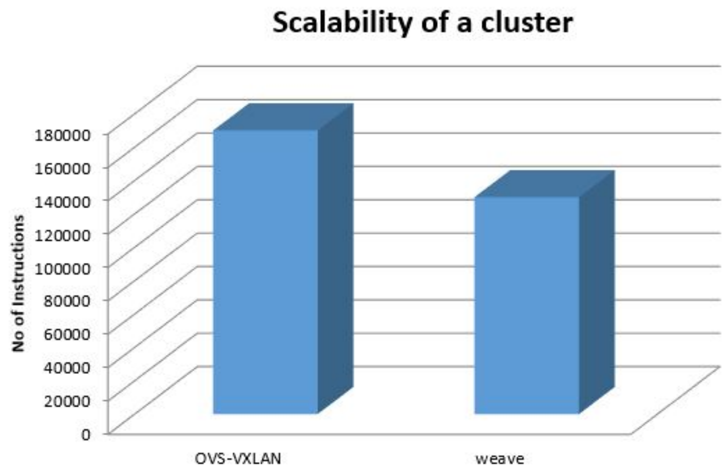


Figure 5.11: Scalability between Weave and OVS-VxLAN architecture.

Chapter 6

Conclusion:

The research present novel approach that VxlAN will leverage open vswitch docker networking for deployment of the container cluster in different network regions.We have reviewed the challenges of docker networking that are arised during cloud deployment in the section 4 and provided a novel solution 4by using VxLAN tunnelling in openvswitch. we have tested the behaviour of the prototype in section 5 with different parameters such resource utilization, network performance and cluster behaviour; achived expected result.

6.1 Future Work:

Since docker and open vswitch is receving lots innovation our research could be still continued for the following approaches:
Migrating cluster nodes: Each nodes can be migrated to nearest regions or accross different cloup providers for the high avaiblilty.
Static routing in openvswitch: By implementing static routing in open vswitch to exten the routing protocols to upper layers of OSI model.

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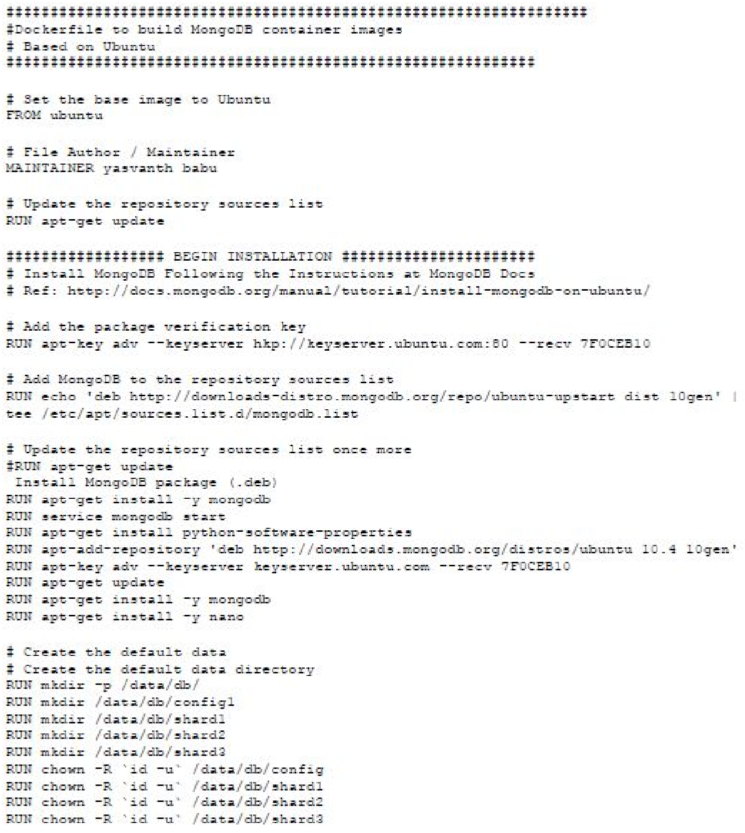
Appendix

.1 MongoDB image Dockerfile



```
##################################################################
#Dockerfile to build MongoDB container images
# Based on Ubuntu
############################################################

# Set the base image to Ubuntu
FROM ubuntu

# File Author / Maintainer
MAINTAINER yasvanth babu

# Update the repository sources list
RUN apt-get update

################## BEGIN INSTALLATION ######################
# Install MongoDB Following the Instructions at MongoDB Docs
# Ref: http://docs.mongodb.org/manual/tutorial/install-mongodb-on-ubuntu/

# Add the package verification key
RUN apt-key adv --keyserver hkp://keyserver.ubuntu.com:80 --recv 7F0CEB10

# Add MongoDB to the repository sources list
RUN echo 'deb http://downloads-distro.mongodb.org/repo/ubuntu-upstart dist 10gen' |
tee /etc/apt/sources.list.d/mongodb.list

# Update the repository sources list once more
#RUN apt-get update
 Install MongoDB package (.deb)
RUN apt-get install -y mongodb
RUN service mongodb start
RUN apt-get install python-software-properties
RUN apt-add-repository 'deb http://downloads.mongodb.org/distros/ubuntu 10.4 10gen'
RUN apt-key adv --keyserver keyserver.ubuntu.com --recv 7F0CEB10
RUN apt-get update
RUN apt-get install -y mongodb
RUN apt-get install -y nano

# Create the default data
# Create the default data directory
RUN mkdir -p /data/db/
RUN mkdir /data/db/config1
RUN mkdir /data/db/shard1
RUN mkdir /data/db/shard2
RUN mkdir /data/db/shard3
RUN chown -R `id -u` /data/db/config
RUN chown -R `id -u` /data/db/shard1
RUN chown -R `id -u` /data/db/shard2
RUN chown -R `id -u` /data/db/shard3
```

.2 Shard Setup

```
"Shard setup code below:
  config server 1
mongod --configsvr --dbpath /data/db/config --port 20000
      config server 2
mongod --configsvr --dbpath /data/db/config2 --port 20000
      config server 3
mongod --configsvr --dbpath /data/db/config3 --port 20000

    Adding config db to the router
mongos --configdb 172.17.10.1:20000,172.17.11.1:20000,172.17.12.1:20000 -
-port 23000

Droplet 1
mongod --shardsvr --dbpath /data/db/shard1 --port 10000 --rest --replSet
repset1
Droplet 2
mongod --shardsvr --dbpath /data/db/shard1 --port 10000 --rest --replSet
repset2
Droplet 3
mongod --shardsvr --dbpath /data/db/shard1 --port 10000 --rest --replSet
repset3
#creating replicaset on shard1 primary
mlocalhostongo 172.17.64.0:10000/admin

config={_id: 'repset1', members: [
... {_id: 0, host: '172.17.64.2:10000'},
... {_id: 1, host: '172.17.128.1:10000'},
... {_id: 2, host: '172.17.192.1:10000'}]
... }

rs.initiate(config)
rs.status()

                 Droplet 1
mongod --shardsvr --dbpath /data/db/shard2 --port 10001 --rest --replSet
repset1
                 Droplet 2
mongod --shardsvr --dbpath /data/db/shard2 --port 10001 --rest --replSet
repset2
                 Droplet 3
mongod --shardsvr --dbpath /data/db/shard2 --port 10001 --rest --replSet
repset3
#creating replicaset on shard2 primary
mongo localhost:10001/admin

config=_id: 's2repset', members: [
... {_id: 0, host: '172.17.10.3:10001'},
... {_id: 1, host: '172.17.11.3:10001'},
... {_id: 2, host: '172.17.12.3:10001'}]
... }

rs.initiate(config)
rs.status()

#creating replicaset on shard2 primary
mongo localhost:1001/admin

config=_id: 'repset3', members: [
... {_id: 0, host: '172.17.10.3:10002'},
... {_id: 1, host: '172.17.11.3:10002'},
... {_id: 2, host: '172.17.12.3:10002'}]
... }

rs.initiate(config)
rs.status()

                 Droplet 1
mongod --shardsvr --dbpath /data/db/shard2 --port 10002 --rest --replSet
repset1
                 Droplet 2
mongod --shardsvr --dbpath /data/db/shard2 --port 10002 --rest --replSet
repset2
                 Droplet 3
mongod --shardsvr --dbpath /data/db/shard2 --port 10002 --rest --replSet
repset3

#Adding Shard to the routers the below set has to be repeated in all
other two servers with different router ip"

Routr1
mongo 172.17.10.0:23000/admin
db.runCommand({addshard
:"repset1/172.17.10.2:10000,172.17.11.3:10000,172.17.12.4:10000"})
db.runCommand({addshard
:"repset2/172.17.10.3:10001,172.17.11.2:10001,172.17.12.4:10001"})
db.runCommand({addshard
:"repset3/172.17.10.4:10001,172.17.11.3:10002,172.17.12.2:10002"})"
```

.3 Abbrivation

AWE=Address Windowing Exentension.
VxLAN= Virtual Extensible Local Area Network.
OVS= Open Virtual Switch.
YCSB= Yahoo! Cloud Serving Benchmark.
LXC= Linux Container.
VM= Virtual machine.