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Configurable and Scalable IITBombayX MOOC platform on commodity servers

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Certificate

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0.1 Acknowledgement

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0.2 Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the institute.

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Chapter 1

Introduction

1.1 Introduction

The aim of this project is to deploy an instance of Open edX MOOC platform on a multi-node cluster using Kubernetes as the container orchestrator and Docker as the container runtime environment.

Technologies used:

- Docker
- Kubernetes
- Ansible
- Shell scripting
- Git
- Cluster management and configuration

1.2 Open edX

Open edX is an open source online MOOC platform to create and deliver online courses. It provides both web and mobile platforms to clone the basic template of e-learning platform. In this project, we have worked on the web platform.

1.2.1 Releases

Open edX has multiple releases. Some of the most recent ones are:

- Ironwood
- Hawthorn
- Ginkgo

We have used the Ironwood.1 release in this project.

1.2.2 Installation

Open edX can be installed in two ways:

- Native installation
- Docker-based installation

1.2.2.1 Native installation

i) Prerequisites

- Ubuntu 16.04 amd64

ii) Set-up configurations

Ubuntu package sources need to be updated:

$ sudo apt-get update -y
$ sudo apt-get upgrade -y
$ sudo reboot

iii) Installation procedure

1. Set the OPENEDX_RELEASE variable to the Git Tag corresponding to the Ironwood release of Open edX:

   export OPENEDX_RELEASE=open-release/ironwood.1

2. Next, create a config.yml file, which states the hostname of the Learning Management System (LMS) and the Content Management System (CMS):

   EDXAPP_LMS_BASE: 127.0.0.1
   EDXAPP_CMS_BASE: 127.0.0.1:8080

   (works only when the LMS hostname and the CMS hostnames are the same, or the CMS hostname is a subdomain of the LMS hostname).

3. Now bootstrap the Ansible installation.

4. Retrieve the ansible-bootstrap.sh bash script from the Github server and execute it:

   wget https://raw.githubusercontent.com/edx/configuration/
   $OPENEDX_RELEASE/util/install/ansible-bootstrap.sh -O - | sudo bash

5. Use the generate-password.sh file from the Github server to randomize password:

   wget https://raw.githubusercontent.com/edx/configuration/
   $OPENEDX_RELEASE/util/install/generate-passwords.sh -O - | bash

6. Finally, use the native.sh script from the Github server to install Open edX:

   wget https://raw.githubusercontent.com/edx/configuration/
   $OPENEDX_RELEASE/util/install/native.sh -O - | bash

1.2.2.2 Docker-based installation

i) Installing docker engine, docker machine and docker compose:

The docker based installation allows the resources of our system to be utilized in an optimal way. Docker is based on the principle of containerization. For Open edX Devstack to work properly, we would need the Docker engine, Docker Machine and Docker Compose tools.

For installing the docker engine, the following commands need to be run:

1. $ sudo apt-get update
2. $ sudo apt-get install \
   apt-transport-https \
   ca-certificates \
   curl \
   gnupg-agent \
   software-properties-common
3. $ curl -fsSL https://download.docker.com/linux/ubuntu/gpg — sudo apt-key add -
4. $ sudo apt-key fingerprint 0EBFCD88
5. $ sudo add-apt-repository \
   "deb [arch=amd64] https://download.docker.com/linux/ubuntu \
   $(lsb_release -cs) \
   stable"
6. $ sudo apt-get update
7. $ sudo apt-get install docker-ce docker-ce-cli containerd.io
8. $ apt-cache madison docker-ce
9. $ sudo apt-get install docker-ce=$< VERSION\_STRING >$
   docker-ce-cli=$< VERSION\_STRING >$ containerd.io

In order to test if Docker has been installed properly, one can run the following command:
$ sudo docker run hello-world

For installing docker machine, run the following commands:

base=https://github.com/docker/machine/releases/download/v0.16.0 &&
curl -L $base/docker-machine-$(uname -s)-$(uname -m)>/tmp/docker-machine &&
sudo install /tmp/docker-machine /usr/local/bin/docker-machine

For installing docker compose, run the following commands:

1. $ sudo curl -L "https://github.com/docker/compose/releases/download/1.24.0/docker-compose-$(uname -s)-$(uname -m)" -o /usr/local/bin/docker-compose

2. $ sudo chmod +x /usr/local/bin/docker-compose

For checking if the tools mentioned above have been installed properly, you can use the - -version flag with the corresponding command to check the installed version.

ii) Installing Ironwood Devstack:

The three most recent versions of the Open edX Devstack are Ginkgo, Hawthorn and Ironwood.

The following commands perform the Ironwood-release installation of Devstack:

1. git clone https://github.com/edx/devstack
2. cd devstack
3. git checkout open-release/ironwood.master
4. export OPENEDX_RELEASE=ironwood.master
5. make dev.checkout
6. make dev.clone
7. make dev.provision

On successfully running dev.provision, you will have 15 docker-containers running. The list of them can be obtained using the command: docker ps

The list of docker-containers are: Docker-containers List

The Provision Log for the tasks executed are: provision.log

iii) Errors:

1. ./provision.sh: line 21: /usr/local/bin/docker-compose: Permission denied Makefile:59: recipe for target 'dev.provision.run' failed make: *** [dev.provision.run] Error 126

   Solution :

   $ sudo -i
   $ curl -L https://github.com/docker/compose/releases/download/1.18.0/docker-compose-‘uname -s‘-‘uname -m‘ -o /usr/local/bin/docker-compose
   $ chmod 755 /usr/local/bin/docker-compose
   $ exit

2. TASK [common : Update expired apt keys] ************** fatal: [127.0.0.1]: FAILED! =¿ ”changed”: true, ”cmd”: ”apt-key adv --recv-keys –keyserver keyserver.ubuntu.com 69464050”, ”delta”: ”0:02:00.744139”, ”end”: ”2019-05-24 07:49:07.605347”, ”failed”: true, ”rc”: 2, ”start”: ”2019-05-24 07:47:06.861208”, ”stderr”: ”gpg: requesting key 69464050 from hkp server keyserver.ubuntu.com\ngpg: keyserver timed out\ngpg: keyserver receive failed: keyserver error”, ”stdout”: ”Executing: /tmp/tmp.NmWIivV5Jo/gpg.1.sh --recv-keys\n--keyserver\nkeyserver.ubuntu.com\n69464050”, ”stdout_lines”: [”Executing: /tmp/tmp.NmWIivV5Jo/gpg.1.sh --recv-keys”, ”--keyserver”, ”keyserver.ubuntu.com”, ”69464050”], ”warnings”: [] to retry, use: --limit @/edx/app/edx_ansible/edx_ansible/playbooks/demo.retry

   Solution :

   This error occurs due to the fetching to apt-keys from an expired link.
   To resolve follow the following steps :

   (a) sudo exec -it edx.devstack.lms bash
   (b) cd app/edx_ansible/edx_ansible/playbooks/roles/common_vars/defaults/
   (c) vi main.yml
   (d) On entering the main.yml file in vim editor change the link for the keyword COMMON_EDX_PPA_KEY from keyserver.ubuntu.com to hkp://keyserver.ubuntu.com:80
   (e) exit

Chapter 2

Docker

2.1 Docker [12]

2.1.1 About Docker

Docker is an open-source software tool designed to automate and ease the process of creating, packaging, and deploying applications using an environment called a container. Using application running as a docker conatiner removes the system dependency of the application. No changes has to be made in applications to run them in different environments or machines. Docker based application provides liberty to the developer,tester and deployer to run the same application which any changes specific to their environment.

2.1.2 Terms related to Docker

2.1.2.1 Containerization

Containerization is a lightweight alternative to full machine virtualization that involves encapsulating an application within a container with its own operating environment. Essentially, containers share the kernel space with the host OS, but have a separate user space. This makes them lightweight.

2.1.2.2 Docker Image

A *Docker Image* is the basic unit for deploying a Docker container. A Docker image is essentially a static snapshot of a container, incorporating all of the objects needed to run a container.

TLS handshake timeout error in pulling Docker image :

In case there is a TLS handshake timeout error while pulling a Docker image from an online repository, try running the command again and again and eventually the image will be pulled:

2.1.2.3 Docker Container

A *Docker Container* encapsulates a Docker image and when live and running, is considered a container. Each container runs in an isolated environment on the host machine.

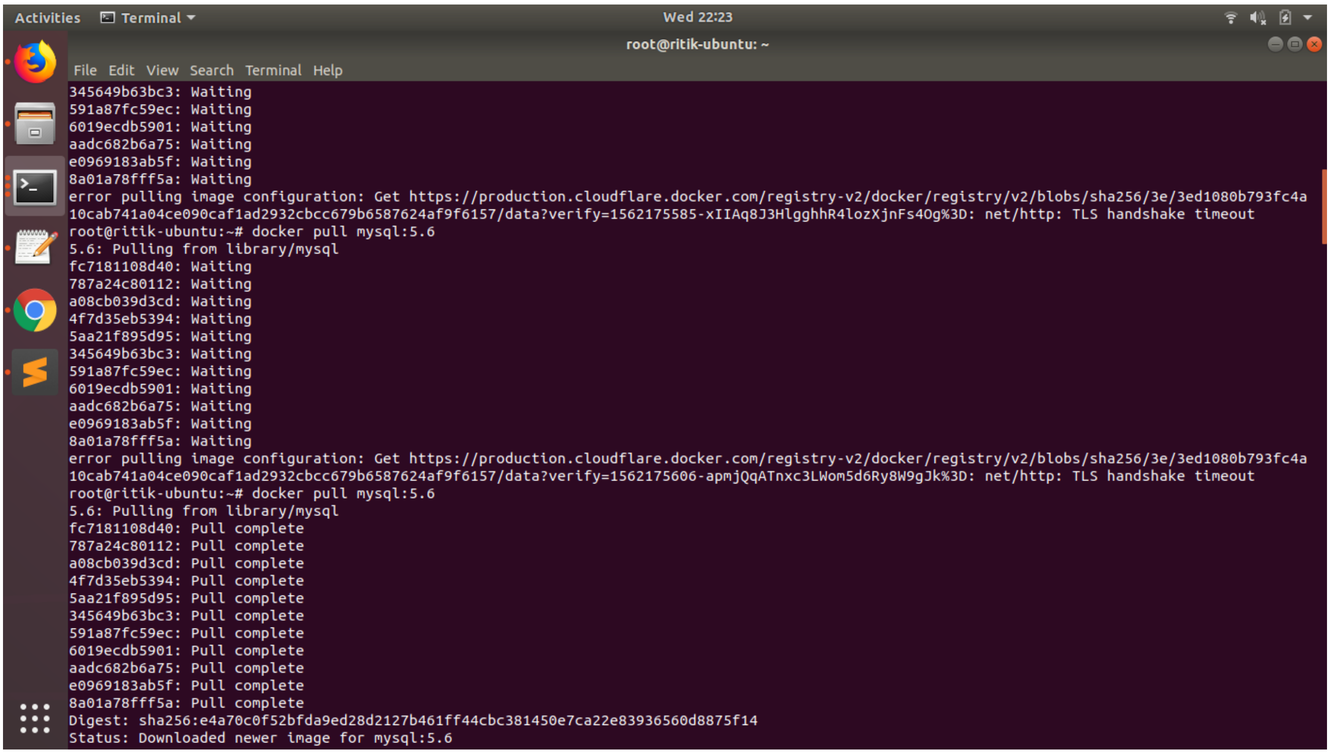


Figure 2.1: TLS handshake timeout error

2.1.2.4 Docker Registry

The *Docker Registry* is a stateless, highly scalable server-side application that stores and distributes Docker images. This registry holds Docker images, along with their versions and, it can provide both public and private storage location. There is a public Docker registry called Docker Hub which provides a free-to-use, hosted Registry, plus additional features like organization accounts, automated builds, and more. Users interact with a registry by using Docker push or pull commands.

2.1.2.5 Docker Engine

The *Docker Engine* is a layer which exists between containers and the Linux kernel and runs the containers. It is also known as the Docker daemon. Any Docker container can run on any server that has the Docker-daemon enabled, regardless of the underlying operating system.

2.1.2.6 Docker Compose

Docker Compose is a tool that defines, manages and controls multi-container Docker applications. With Compose, a single configuration file is used to set up all of your applications services. Then, using a single command, you can create and start all the services from that file.

2.1.2.7 Dockerfiles

Dockerfiles are merely YAML configuration files that contains all of the configuration information and commands needed to assemble a container image. With a Dockerfile, the Docker daemon can automatically build the container image.

2.1.3 Docker-Machine

Docker Machine can be used to :

- Manage and provision multiple remote Docker hosts.
- Provision Swarm clusters.

Docker Machine is a tool that lets you install Docker Engine on virtual hosts, and manage hosts with docker-machine commands. Using docker-machine command you can start, inspect, stop and restart a managed host, upgrade the Docker client and daemon, and configure a Docker client to talk to your host.

2.1.3.1 Install Docker Machine:

- For Linux systems, execute the following command:

  $ base=https://githubcom/docker/machine/releases/download/v0.16 && curl -L $base/docker-machine-$(uname -s)-$(uname -m) >/usr/local/bin/docker-machine && chmod +x /usr/local/bin/docker-machine

- Check the installation by displaying the Machine version:

  $ docker-machine version

2.1.3.2 Use Docker Machine to run Docker Containers:

- Create a new docker virtual machine.
- Switch your environment to your new VM.
- Use the docker client to create, load and manage containers.

2.1.3.3 Create a Machine

$ docker-machine create –driver virtualbox default

2.1.3.4 Connect your shell to the new machine

$eval $(docker-machine env default)

2.1.3.5 Run containers and experiment with machine commands

- Use **docker-run** to download and run images
- Run **docker-machine ip default** to get the host IP address.
- Run **docker-machine stop default** to stop the host default.
- Run **docker-machine start default** to start the host default.
- Run **docker-machine env -u** to see which Docker variables we need to unset to switch to the current shell.

2.1.4 Docker Swarm

Docker swarm is used to create a cluster of nodes. Multi-container, multi-machine applications are made possible by joining multiple machines into a Dockerized cluster called a swarm. Docker swarm is a group of machines running docker and are connected to each other by means of an overlay network. There can be one or multiple nodes that can manage the swarm, these nodes are called manager nodes. The rest of the nodes only provide capacity to run the containers and are called worker nodes.

2.1.4.1 Types of networks in docker

- **Bridge Network :** This is the type of network that allows the docker containers to communicate within a single host system. This type of network is not feasible to communicate between multiple host systems.

  A bridge network can be created by :
  $ docker network create --driver bridge mynetwork

  User-defined bridge networks are best when you need multiple containers to communicate on the same Docker host.

- **Overlay Network :** An overlay network is used for multi host network communication. It connects multiple docker daemons together and enables swarm services to communicate with each other. A docker swarm must always be connected via an overlay network.

  An overlay network can be created by :
  $ docker network create –driver overlay mynetwork

  Overlay networks are best when you need containers running on different Docker hosts to communicate, or when multiple applications work together using swarm services.

- **Macvlan Network :** Macvlan networks allow you to assign a MAC address to a container, making it appear as a physical device on your network. The Docker daemon routes traffic to containers by their MAC addresses.

  A Macvlan Network can be created by :

**$ docker network create -d macvlan **
**--subnet=192.168.40.0/24 **
**--gateway=192.168.40.1 **
-o parent=eth0 my-macvlan-net

Macvlan networks are best when you are migrating from a VM setup or need your containers to look like physical hosts on your network, each with a unique MAC address.

- **Host Network :** For standalone containers, remove network isolation between the container and the Docker host, and use the hosts networking directly.

  We can use the hosts system network to at a particular port to allow the container to share data. Host networks are best when the network stack should not be isolated from the Docker host, but you want other aspects of the container to be isolated.

2.1.4.2 Initialising a Swarm Node as Manager

In order to initialize a swarm node a manager we need to find the IP address of the node using the command **ifconfig**. Then run the command:

$ docker swarm init –advertise-addr IP_OF_THE_MANAGER

The join token for another node as a manager can be found by :

$ docker swarm join-token manager

The join token of another node as a worker can be found by :

$ docker swarm join-token worker

2.1.4.3 Docker Stack

For multiple services that are dependent on each other to communicate with each other on a swarm network, we may use the Docker Stack command. Docker stack deployment is used to deploy a list of interdependent services on a swarm network.

To deploy a stack we create a docker-compose file with an additional feature in each service as deploy.

$ docker stack deploy -c docker-compose.yml myapp

The -c flag is used to execute the docker compose file and create multiple interdependent services which can communicate with each other via the swarm network.

An example of docker-compose file for stack deployment: example-voting-app.yml

Chapter 3

Ansible

3.1 Ansible

Installing docker, kubernetes, and all the other components in each node in a multi-node cluster, which contains many nodes, can be a tedious task. To overcome this issue, Ansible can be used for configuration management. Furthermore, Ansible can be used to configure the nodes too. By default Ansible uses a native openSSH connection and runs commands simultaneously on multiple nodes. We have created Ansible Playbooks for all the needed configurations.

3.1.1 Installing openssh

$ sudo apt-get install openssh-server
$ sudo apt-get install openssh-client

3.1.2 Generating key at server and copying in client

$ ssh-keygen (generate ssh-key)
Copy this key to all nodes to avoid the need to enter a password each time while connecting to the node.
To copy ssh-key type command:
$ ssh-copy-id *username*@*IP_address*

3.1.3 Ansible setup

3.1.3.1 Adding repository

$ sudo apt-add-repository ppa:ansible/ansible
$ sudo apt-get update

3.1.3.2 Installing ansible

$ sudo apt-get install ansible

3.1.3.3 Checking version

$ ansible –version

3.1.3.4 Ansible directories

$ ls -lha /etc/ansible/

3.1.3.5 Making a copy a directory for our use

$ cp -R /etc/ansible/ myplatform
vi ansible.cfg (uncomment the inventory = hosts)
vi hosts (remove all and write all nodes in new line)

You can check if all the nodes working by running:
$ ansible -m ping all

3.1.4 Some useful commands for ansible

3.1.4.1 To see the hostnames of all nodes

$ ansible -m shell -a 'hostname' all

3.1.4.2 To see the volumes used by all nodes

$ ansible -m shell -a 'df -h' all

3.1.4.3 To run an ansible-playbook

$ ansible-playbook -K playbook-docker.yml

Chapter 4

Kubernetes

4.1 Kubernetes[13]

4.1.1 What is Kubernetes

Kubernetes is a container-orchestration tool developed by Google in 2015 and later donated to CNCF (Cloud Native Computing Foundation). Kubernetes provides a smart way for orchestration in setting a multi-node cluster. Kubernetes comes with a lot of functionalities such as load balancing, pod scaling, process scheduling and process management.

4.1.2 Main Features Of Kubernetes

- Service discovery and load balancing
- Storage orchestration
- Automatic bin packing
- Self-healing
- Automated rollouts and rollbacks
- Secret and configuration management
- Batch execution
- Horizontal scaling

4.1.3 Terminologies in Kubernetes

4.1.3.1 Pod

The most fundamental unit in a kubernetes cluster is a pod. A pod is a collection of container and volumes. Each pod is assigned an IP address.

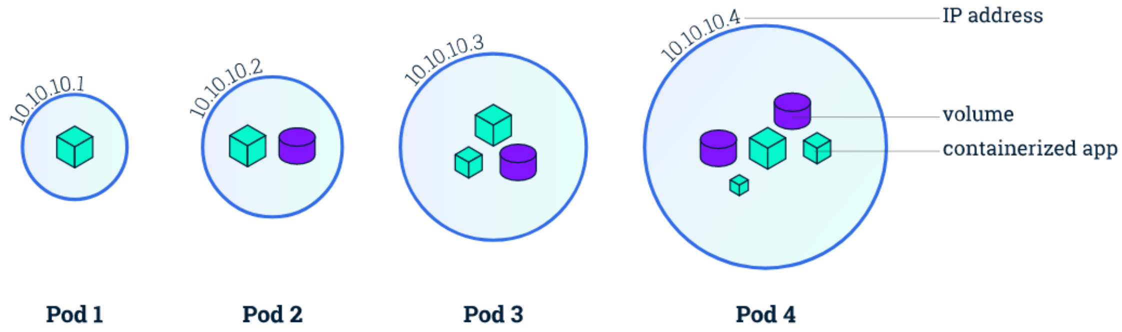


Figure 4.1: Kubernetes pods [1]

4.1.3.2 Deployment

A deployment can be seen as a stateless state of the pod. A deployment is used to provide pod definition and rolling updates to the pod. A deployment contains information such as number of replicas, image, volume mount, hostname and restart policy.

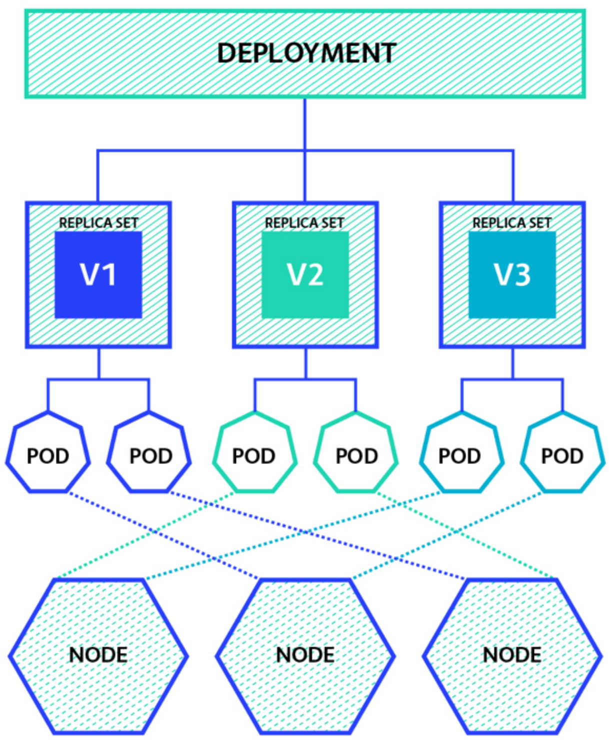


Figure 4.2: Kubernetes deployment [2]

4.1.3.3 Service

A service exposes a deployment as a network service. A deployment is stateless whereas a service can be considered as a stateful definition. The three types of services in kubernetes are: ClusterIP, NodePort and LoadBalancer.

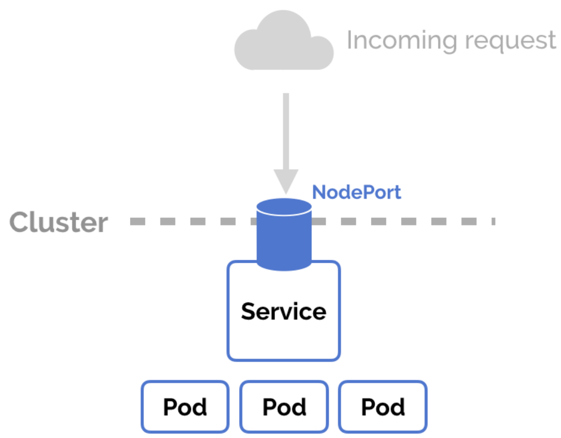


Figure 4.3: Kubernetes service [3]

4.1.3.4 Ingress network

An ingress network exposes the services in the cluster to the outside network i.e. to the clients. An ingress helps us in handling the outside traffic and routing it based on the context.

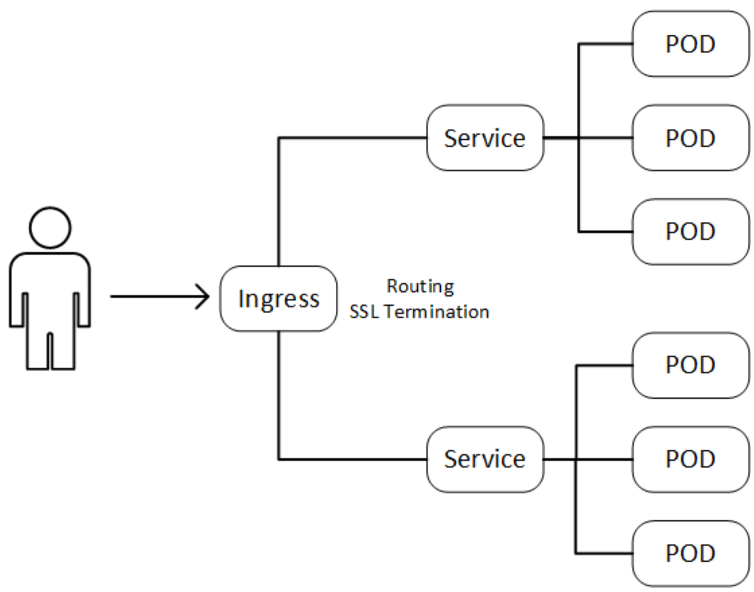


Figure 4.4: Ingress network [4]

4.1.4 Networking in Kubernetes

Kubernetes supports a large number of network plugins using different protocols. The type of networking to be used completely depends on the type of cluster you want to set up and your cluster requirements.

In a kubernetes network, each pod is assigned its own IP address. Pods can communicate with pods, nodes and services in a node without NAT.

The networking in kubernetes can be primarily broken down into 4 parts :

1. Container to container communication
2. Pod to pod communication
3. Pod to service communication
4. Service to external Communication

The major plugins used for achieving these communications are :

4.1.4.1 Flannel

Flannel is the simplest kubernetes network which satisfies all kubernetes requirements. Flannel is basically an overlay network.

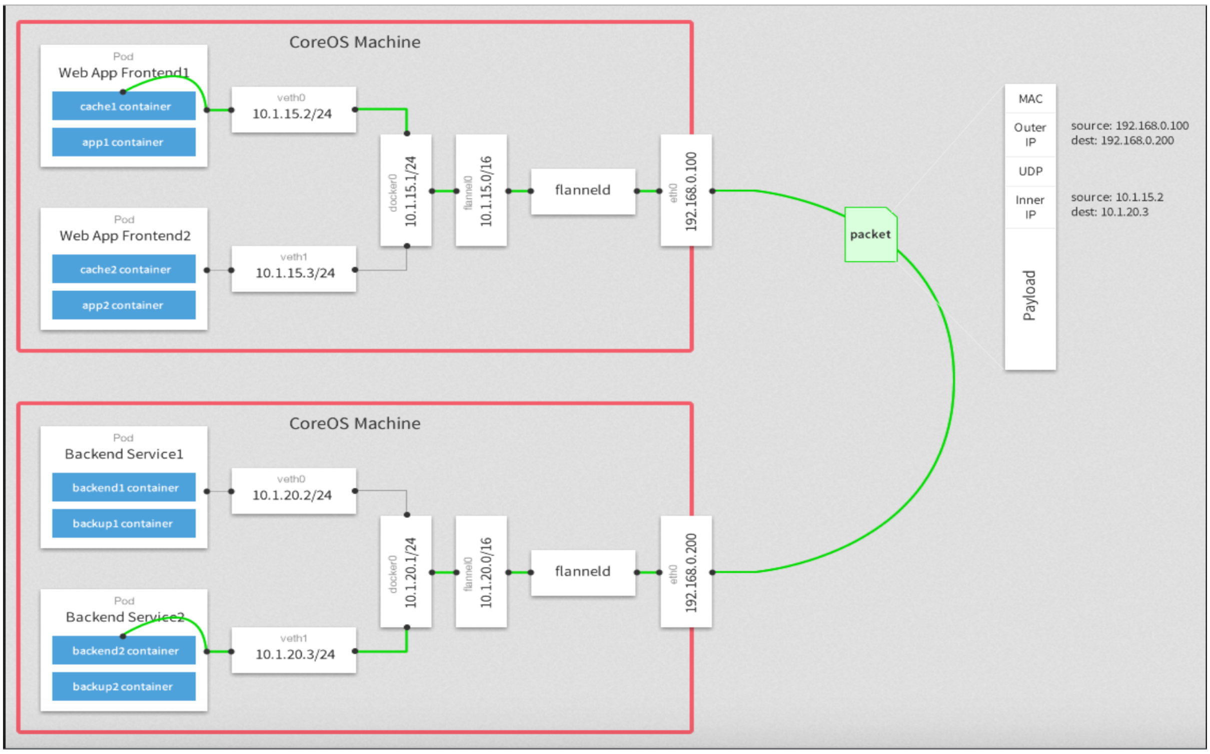


Figure 4.5: Flannel network [5]

4.1.4.2 Calico

Calico provides a highly scalable networking and network policy solution for connecting Kubernetes pods based on the same IP networking principles as the internet, for both Linux and Windows. Calico can be deployed without encapsulation or overlays to provide high-performance, high-scale data center networking.

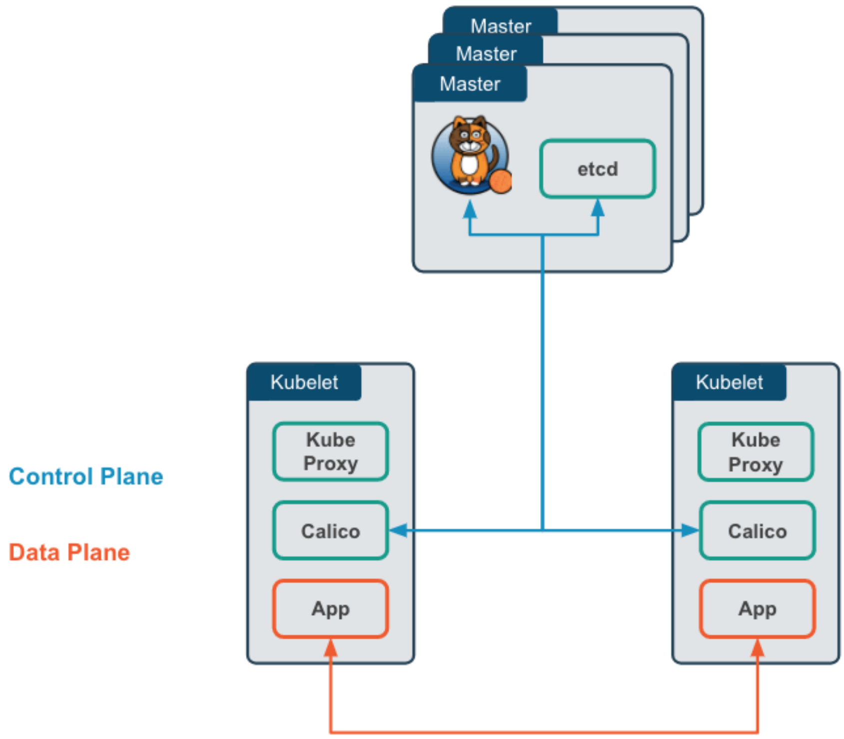


Figure 4.6: Calico network [6]

4.1.4.3 Weavenet

Weavenet is a simple network for kubernetes and its hosted applications. Weave Net runs as a CNI plug-in or stand-alone.

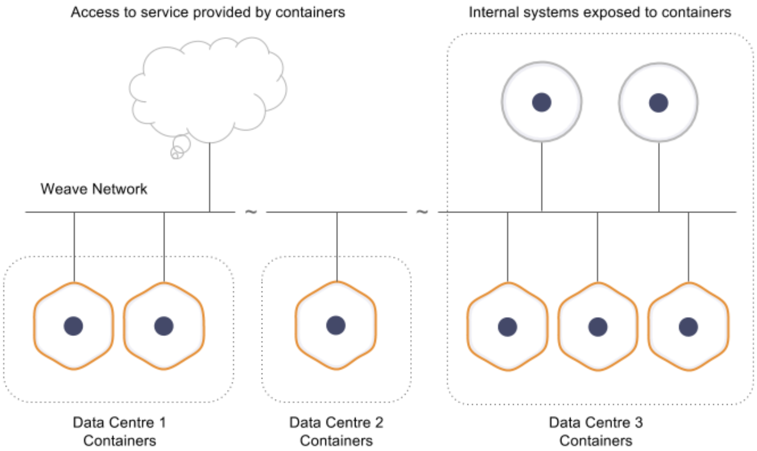


Figure 4.7: Weavenet [7]

In addition to these, kubernetes supports many other plugins too. A list of them can be found in the official documentation page of kubernetes (Networking in Kubernetes).

4.1.5 Prerequisites for running kubernetes [14]

4.1.5.1 Disable Swap Space

In order to set up a kubernetes cluster, all nodes including the master must have swap space disabled.

- To disable swap space for curren There are a lot of plugins available that can be used as per the requirements. In this project, we have used a calico pod network as CNI.

  t session, run:
  $ sudo swapoff -a

- To permanently disable swap space, go to /etc/fstab and comment the swap space line.

4.1.5.2 Make IP static

All nodes in cluster including master must have a static IP address.
In order to manually make the IP static add the following lines to the file /etc/network/interfaces:

auto wlo1
iface wlo1 inet static
address YOUR_IP_ADDRESS

4.1.6 Kubernetes setup

1. Install docker (follow the steps given here to successfully install docker).
2. Enable docker to run automatically on startup:
   $ sudo systemctl enable docker
3. Install curl:
   $ curl -s https://packages.cloud.google.com/apt/doc/apt-key.gpg | sudo apt-key add
4. Add Googles kubernetes repository:
   $ sudo apt-add-repository "deb http://apt.kubernetes.io/ kubernetes-xenial main"
5. Install kubeadm, kubectl and kubelet:
   $ sudo apt-get install kubeadm
   $ sudo apt-get install kubectl
   $ sudo apt-get install kubelet

4.1.7 Setting up your Kubernetes cluster

In order to set up your cluster first, initialise your master with kubeadm:

$ kubeadm init --apiserver-advertise-address=YOUR_IP_ADDRESS --pod-network-cidr=40.196.0.0/16

On successful execution of the command, we get a join command for the worker nodes to join the cluster. Preserve this command to bring nodes into the cluster once the dashboard is created.

You can also generate the join token by running the command :

$ kubeadm token create

And the SHA256 key can be generated by running the command:

$ openssl x509 -pubkey -in /etc/kubernetes/pki/ca.crt | openssl rsa -pubin -outform der 2>/dev/null | openssl dgst -sha256 -hex — sed 's/ˆ.* //'

Now to bring any node into the cluster run the following command into the cluster after changing the IP with your master systems IP address, token and SHA256 key with that generated by running the above command:

$ kubeadm join IP_OF_MASTER:6443 --token GENERATED_TOKEN --discovery-token-ca-cert-hash sha256:GENERATED_HASH

Once the cluster has been successfully initialised, run the following commands :

$ mkdir -p $HOME/.kube

$ sudo cp -i /etc/kubernetes/admin.conf $HOME/.kube/config
$ sudo chown $(id -u):$(id -g) $HOME/.kube/config

4.1.7.1 Setting up a pod network

There are a lot of plugins available that can be used as per the requirements. In this project, we have used a calico pod network as CNI.
Once the network is set up, we need to install and host the dashboard on localhost.Flannel is a overlay network whereas calico is an L3 network. The advantages in detail can be read from this medium Blog.

i) To install and set up a calico pod network, run the command :

$ kubectl apply -f https://docs.projectcalico.org/v3.1/getting-started/kubernetes/installation/hosted/kubeadm/1.7/calico.yaml

ii) To install and set up flannel pod network, run the command :

$ sudo kubectl apply -f https://raw.githubusercontent.com/coreos/flannel/master/Documentation/kube-flannel.yml

Run **kubectl get pods -o wide –all-namespaces** to view all the running pods:

In case you face a CrashLoopBackOff error in running the coredns pods. Resolve the issue using the stackoverflow link https://stackoverflow.com/questions/53075796/coredns-pods-have-crashloopbackoff-or-error-state/53414041#53414041[17]

Once the network is set up, we need to install and host the dashboard on localhost.

4.1.7.2 Setting up and hosting the dashboard [15]

i) For installation and hosting in localhost :

$ kubectl create -f https://raw.githubusercontent.com/kubernetes/dashboard/v1.8.3/src/deploy/recommended/kubernetes-dashboard.yaml

ii) For Creating service account:

$ kubectl create serviceaccount dashboard -n default

iii) To add cluster binding rules to the dashboard:

$ kubectl create clusterrolebinding dashboard-admin -n default
--clusterrole=cluster-admin
--serviceaccount=default:dashboard

iv) To generate token for login

$ kubectl get secret $(kubectl get serviceaccount dashboard

-o jsonpath=".secrets[0].name") -o jsonpath=".data.token" | base64 --decode

After the token is generated you can run the dashboard on localhost on port 8001(default). To bring up the dashboard run the command :

$ kubectl proxy

Now you can visit the dashboard on the localhost:8001 at url:

http://localhost:8001/api/v1/namespaces/kube-system/services/https:kubernetes-dashboard:/proxy/

The dashboard can be accessed by entering the token generated. We can see the pods running, deployments, services and volumes created. We can also scale up and scale down the number of replicas.

4.1.7.3 Kubernetes commands for getting resource info

In order to get the complete details of the pods via command line run the command :

$ kubectl get pods -o wide --all-namespaces

For viewing pods in default namespace run the command:

$ kubectl get pods

Similarly for viewing deployments and services run the corresponding commands:

$ kubectl get deployments
$ kubectl get services

Once the cluster is set up, we can create deployments for the running in the cluster. We can expose these deployments to endpoints via services and to external traffic by creating an ingress network.

4.1.8 Kubernetes API Server

The Gateway to the Kubernetes cluster is the Kubernetes API server. It is a centralized system that is accessed by all users, automation, and components in the Kubernetes cluster. The API server implements a RESTful API over HTTP, performs all API operations, and is responsible for storing API objects into a tent storage backend.

4.1.8.1 Pieces of API Server

Kubernetes API server has three core functions:

- **API management:**

  In API management process, APIs are exposed and managed by the server.

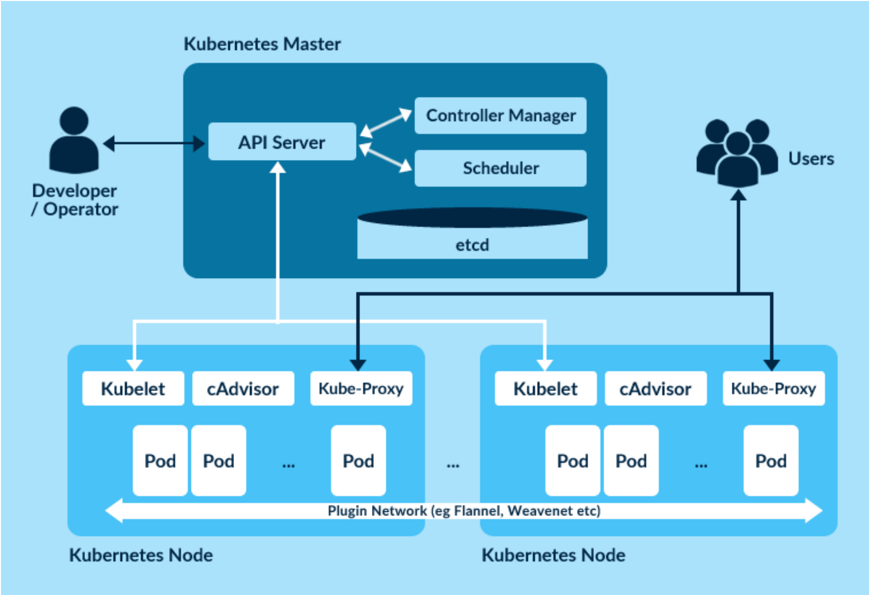


Figure 4.8: Kubernetes architecture [8]

- **Request processing:**

  Request processing processes individual API requests from a client.

- **Internal control loops:**

  Internal control loops has internals responsibilities for background operations necessary to the successful operation of the API server.

4.1.8.2 API Management [16]

The API server is an HTTP serverthus, every API request is an HTTP request. But the characteristics of those HTTP requests must be described so that the client and server know how to communicate. For the purposes of exploration, its great to have an API server actually up and running so that you can poke at it. You can either use an existing Kubernetes cluster that you have access to, or you can use the minikube tool for a local Kubernetes cluster. To make it easy to use the curl tool to explore the API server, run the kubectl tool in proxy mode to expose an unauthenticated API server on localhost:8001 using the following command:

$ kubectl proxy

4.1.9 Request Management

The main aim of the API server is to receive and process API calls in the form of HTTP requests.
Type of request performed by the API server are as follows:

- GET

- LIST
- POST
- DELETE

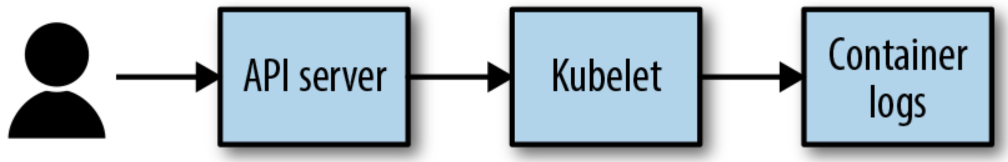


Figure 4.9: Request management [9]

4.1.10 ETCD

A key-value storage for kubernetes backing store for all cluster data.

4.1.11 Kube-Scheduler

If there is a newly created pod which is not allocated any node then Kube-Scheduler select a node for them to run.

4.1.12 Kube-Control-Manager

Kube-Control-Manager is a component on master that runs controllers. Each controller is a separate process but they are all merged.

These controllers include:

- **Node controller:** Responsible for noticing and responding when nodes go down.
- **Replication controller:** Responsible for maintaining the correct number of pods for every replication controller object in the system.
- **Endpoints controller:** Populates the Endpoints object (that is, joins Services & Pods).
- **Service Account & Token Controllers:** Create default accounts and API access tokens for new namespaces.

4.1.13 Converting docker-compose file to its Kubernetes equivalent

As we have docker-compose in docker we similarly have a kompose file with kubernetes. We can deploy a docker-compose created stack on a docker-swarm cluster.

4.1.13.1 Kompose

Kompose is tool provided by kubernetes which converts a docker-compose file into kompose files for providers like kubernetes and openshift. For each service in a compose file we have a deployment, service and persistent volume claim file in kompose. We can also create our persistent volume file is we require a persistent volume for our services.

Installing Kompose on Linux :

1. Download the latest release and install in the system:

   $ curl -L https://github.com/kubernetes/kompose/releases/download/v1.17.0/kompose-linux-amd64 -o kompose

2. Give executable permission and move the directory:

   $ chmod +x kompose
   $ sudo mv ./kompose /usr/local/bin/kompose

In order to convert the compose file into kompose run the command :

$ kompose convert -f docker-compose.yml

In order to run yaml file in kubernetes we use the command :

$ kubectl apply -f FILE_NAME.yaml

Kompose provides an easy solution for converting a docker-compose file into kompose. Docker-compose is an easy to write file whereas kompose files are a bit lengthy and it get a bit tedious to code. So kompose provides an easy alternative. The files provided by kompose does not have a 100% conversion rate but we can change files as per our requirements.

We have converted the docker-compose.yml and docker-compose-host.yml file in devstack to kompose file. We have created a PersistentVolume.yml for each service which creates a pool of space from where a persistentvolumeclaim can claim a volume for the pod. The kompose converts the file in kompose objects and then into kuebernetes objects and then into yaml or json output as per out requirements.
The persistent volumes present are created by admin so that a developer can attach a claim and use the volume for the pod.

4.1.13.2 Compose on Kubernetes

We also have a tool compose-on-kubernetes provided by docker which converts a docker-compose file into compose file. It is an open source tool and can be explored to check its accuracy and efficiency.(https://github.com/docker/compose-on-kubernetes.git)

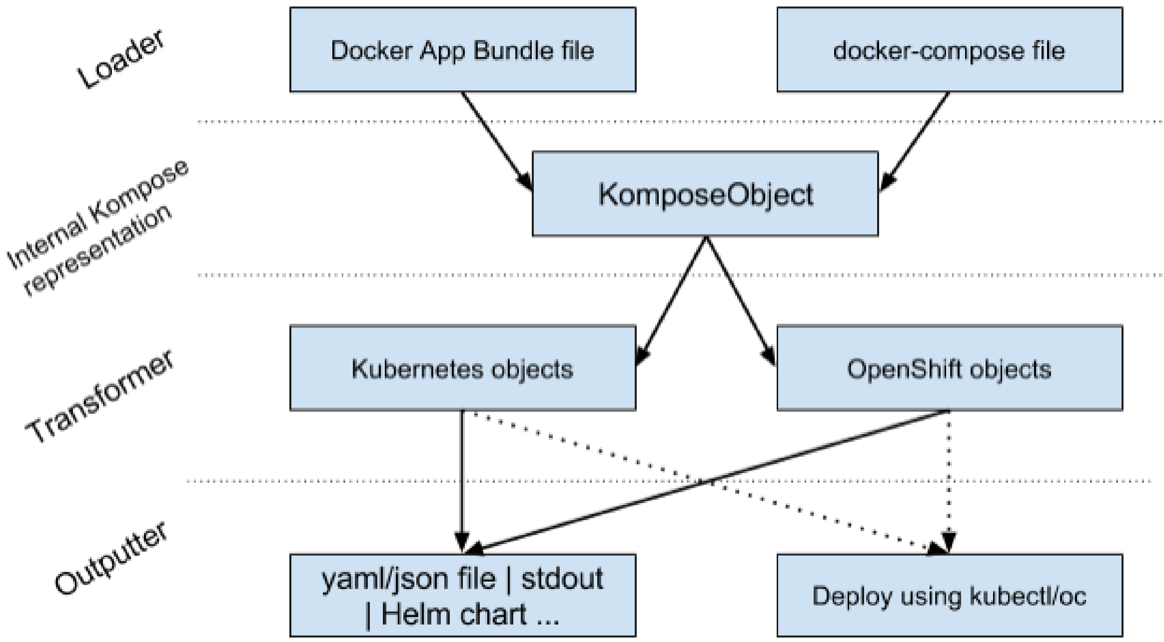


Figure 4.10: Kompose [10]

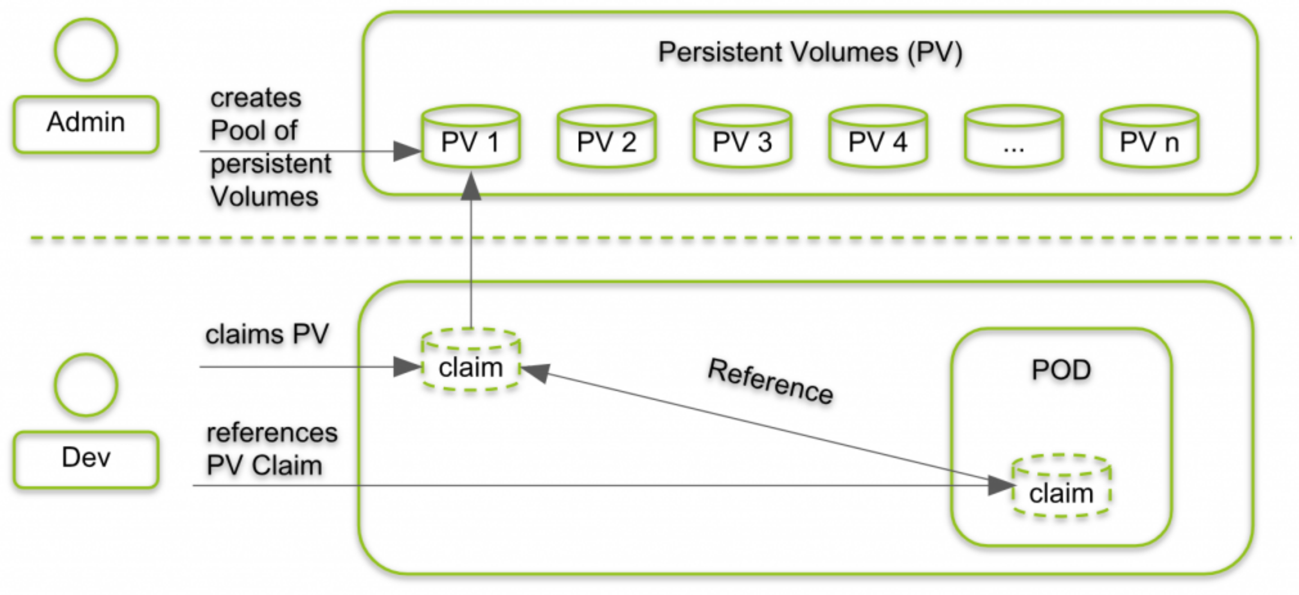


Figure 4.11: Persistent volumes [11]

Chapter 5

Our progress

5.1 Our progress

In this project, our aim was to deploy an instance of Open edX on a Kubernetes cluster.

5.1.1 Kubernetes cluster

At first, we set up a Kubernetes cluster as mentioned above with one master and three nodes.

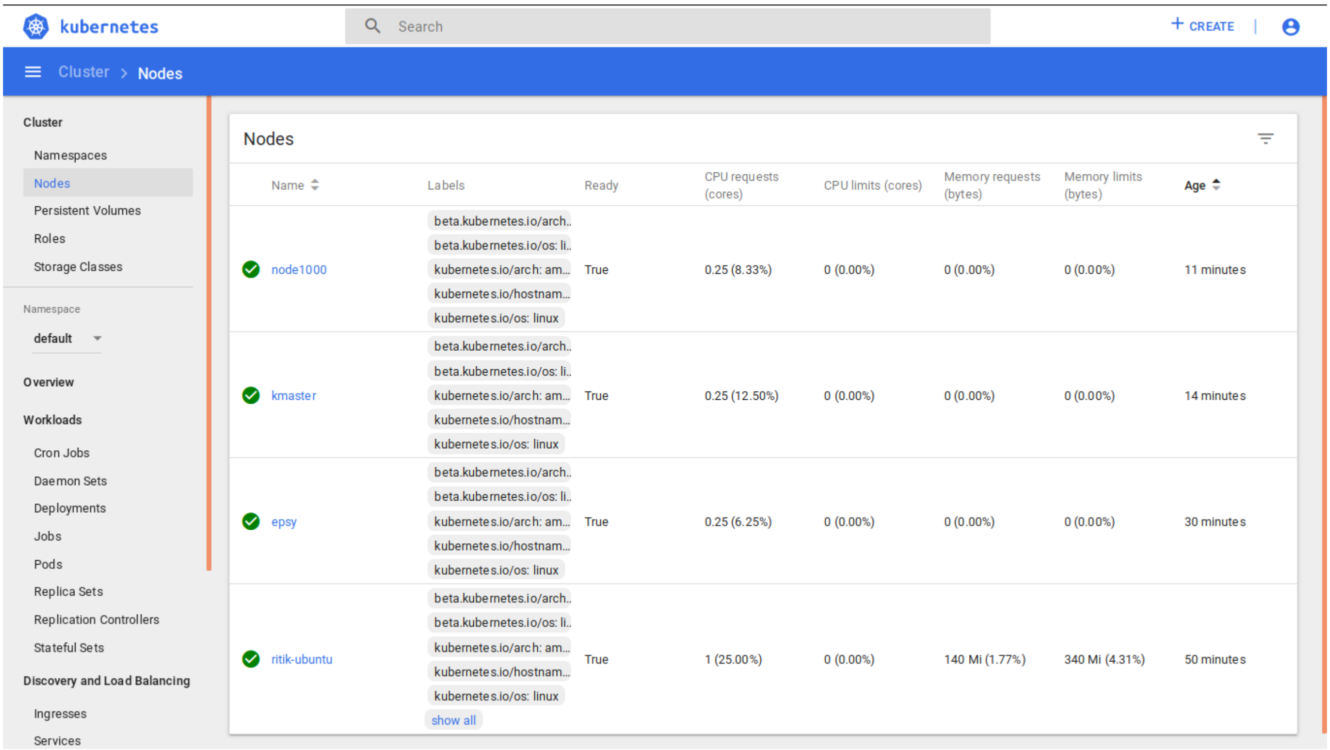


Figure 5.1: Nodes connected in a Kuberentes cluster

5.1.2 Kompose

We converted the docker-compose.yaml file for Open edX containers to multiple Kubernetes deployment files (YAML). But, since the conversion rate was not 100%, we had to create persistent volumes and claims for those volumes on our own.

The converted files can be found in the github repository :
https://github.com/fresearchgroup/Configurable-and-Scalable-IITBombayX-MOOC-platform-on-Commodity-Servers/tree/master/kompose_files [18]

5.1.3 Persistent volumes and Persistent volume claims

We made YAML files to create persistent volumes and then attached each volume to a claim using its corresponding persistent-volume-claim.yaml file.

The persistent volume and claim files can be found in the github repository :

https://github.com/fresearchgroup/Configurable-and-Scalable-IITBombayX-MOOC-platform-on-Commodity-Servers/tree/master/host_volumes [19].

You need not create all the persistent volume and claim files manually, we have created a bash script **volumes.sh** in the same directory that does the job.

5.1.4 Kubernetes deployment

We then deployed all the 15 containers on the cluster. Kubernetes assigned the appropriate node (one among the two) for each container to run.
The gradebook and forum deployments were unsuccessful. But, those two are not necessary for running the bare minimum Open edX instance and hence can be removed:

5.1.5 Fault handling

We removed one node from the cluster and found out that Kubernetes deployed all the containers running on that node to the node that was still a part of the cluster.

The pods running in the cluster:

- Before deleting the node epsy:

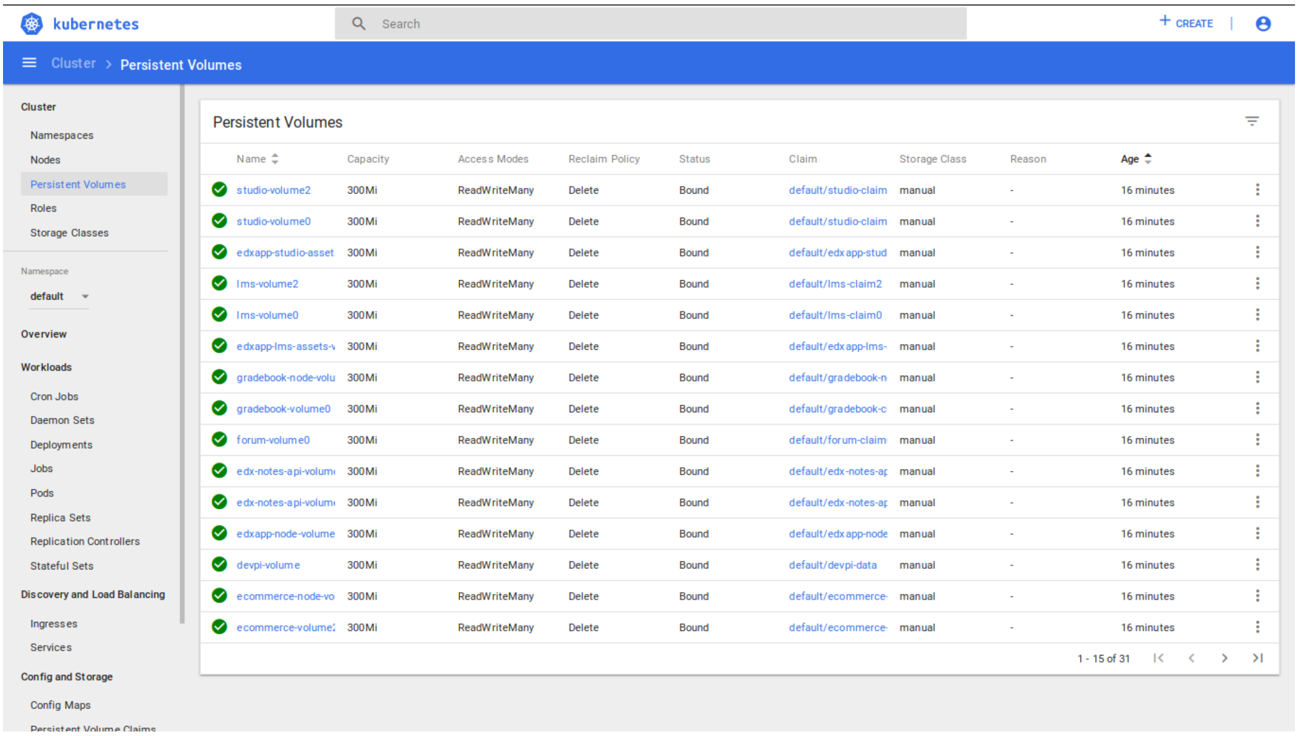


Figure 5.2: Persistent Volumes

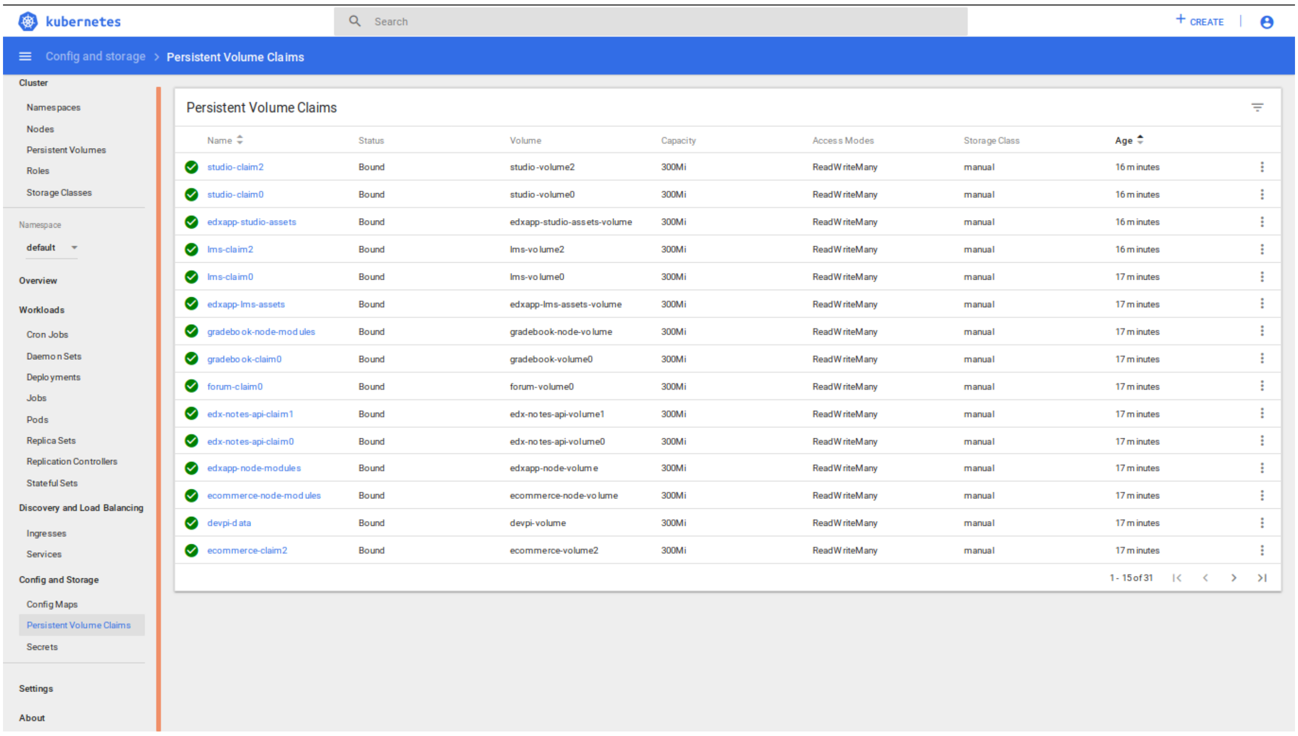


Figure 5.3: Persistent Volume Claims

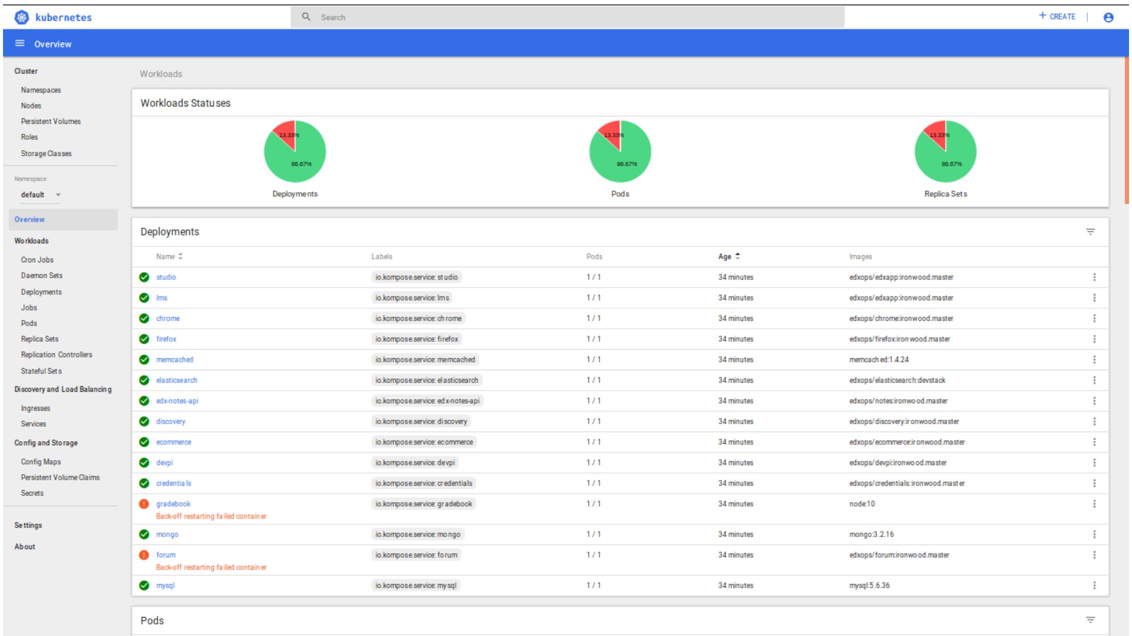


Figure 5.4: Kubernetes deployments

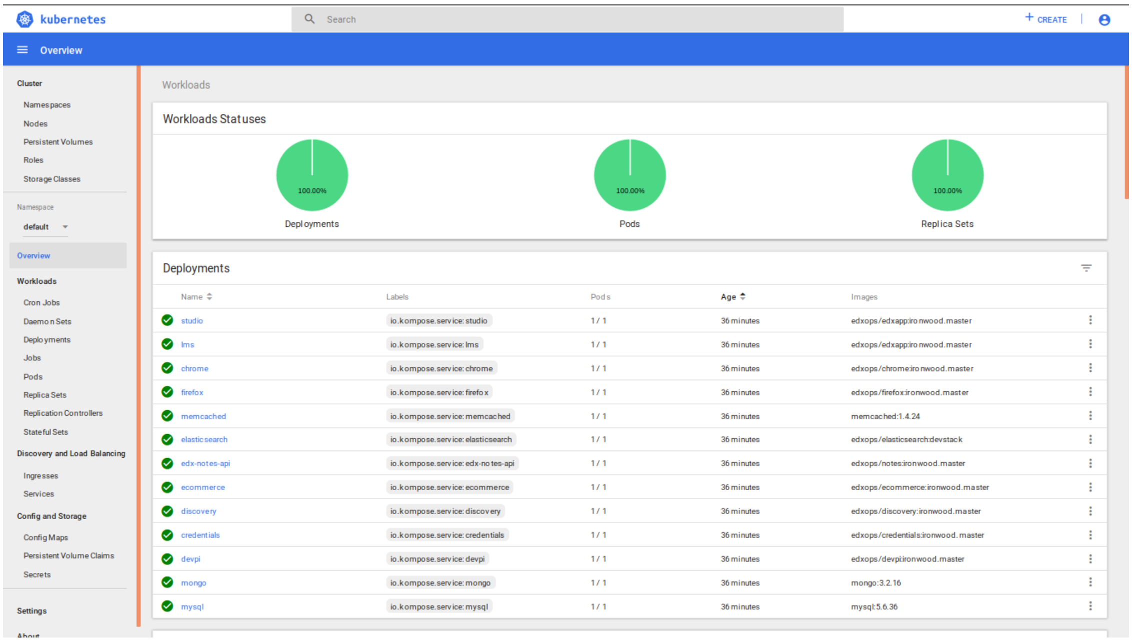


Figure 5.5: Kubernetes deployments after removing gradebook and forum

- After deleting the node epsy:

As we can see, the pods which were earlier running on the node epsy, now run on the remaining nodes after, their host node is deleted. This rescheduling of the pods is done automatically by Kubernetes once a node goes down. The reshudiling takes very less time as is clear from the image (15-16 seconds in this case).

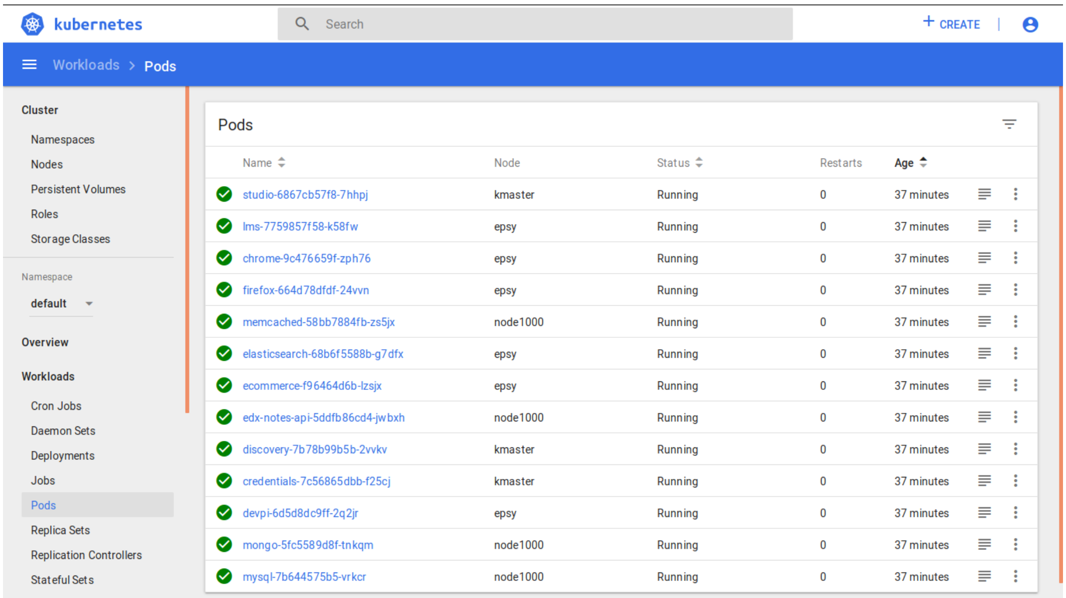


Figure 5.6: Pods running before deleting a node

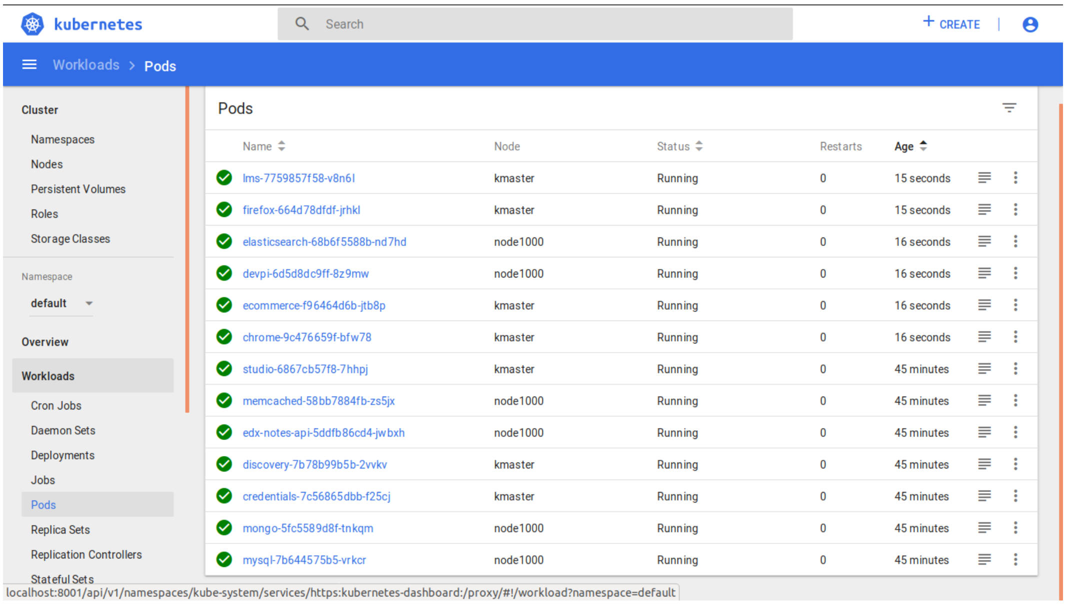


Figure 5.7: Pods running after deleting the node

5.1.6 Provisioning

The file provision.sh in the devstack directory has the commands and links to the files that are to be executed for provisioning and migration of databases. Those are simply docker commands. Since, our containers are running on a Kubernetes cluster, we used the **kubectl exec** in place of **docker exec** to run commands inside the containers. But we faced an internet connectivity issue for the pods:

The containers running inside the Kubernetes cluster were not able to connect to the internet

Commands those were to be executed inside a container and required internet access failed, as containers were not able to connect to the internet.

Suggested resolutions:

These are some methods that may solve this issue (due to lack of time, we were not able to try them properly and anyone taking up this project from here on can try these methods):

- On further research, we found out that the internet connectivity problem of the containers was probably due to some issue in the DNS resolution. This can be further looked up using this link: https://blog.yaakov.online/kubernetes-getting-pods-to-talk-to-the-internet/[20]
- We can mention the commands that are to be executed inside a containere inside its deployment file itself. This is probably a better way than the above one as here the commands will be executed inside any new container that is created through that deployment file. This can be done by using **command** and **args** fields in the deployment file.
- If we have an already running instance of Open edX devstack version on a machine, then we can use the command **docker commit** to create a new image that reflects the changes made on the container while provisioning and then use the new image for deployment purpose in our Kubernetes cluster.

Chapter 6

Performance Testing Open edX Ironwood Release

Given a certain load, Performance Testing allows us to determine and examine non-functional parameters like speed and stability of an application.

6.1 Tools used for Performance Testing

JMeter is a popular tool used for performance testing. Apart from being an open-source software, JMeter is purely written in Java and hence, is platform independent. Also, it provides a GUI to easily set up a test plan. This, combined with the support for a full multithreading framework and the ability to test a wide range of protocols and applications, makes it a very good tool for performance testing.

One can install JMeter by downloading the required binaries from `https://jmeter.apache.org/download_jmeter.cgi`.

6.2 JMeter Test Scripts

A JMeter test script is a collection of user activities that have been pre-recorded using a proxy. These scripts are stored in the XML format with *.jmx* extension.

The test script can be recorded as follows:[21]

1. Firstly, create a new test plan. A test plan describes what JMeter should do when we run a test script.
2. Next, right-click on the newly created test plan and add a thread group. (Add->Threads (Users)->Thread Group) A thread group is used to simulate users for testing an application.
3. Add an instance of the HTTP(S) Test Script Recorder via the add sub-menu accessed by right-clicking on the test plan. (Add->Non-Test Elements->HTTP(S) Test Script Recorder)
4. In the recorder instance created in the previous step, set the Target Controller field to the newly created Thread Group. This field can be accessed in the Test Plan Creation tab.

5. Thereafter, configure the port field to an unused port on your system.

6. We must instruct the recorder to bypass recording the loading of static elements like images. To do this, go to the request tab in the recorder instance created earlier, and click on the Add Suggested Excludes button to add default static files' extensions. This can be modified as per convenience.

7. Since a user may pause for a while between successive requests, the need to add think time to our test script is evident. JMeter provides various timers. We will use a Uniform Random Timer here, which can be added to the HTTP(S) Test Script Recorder instance. With each timer, we associate some parameters. For a Uniform Random Timer, these are Random Delay Maximum and Constant Delay Offset. This timer samples a point from a Uniform Probability Distribution such that it lies between 0 and the Random Delay Maximum value. Thereafter, it adds the Constant Delay Offset to it. To modify the Constant Delay Offset value, use ${T} in the corresponding field.

8. JMeter would now act as an HTTP proxy and would listen to all the incoming and outgoing requests on the configured port.

9. Now, we configure the proxy settings in the browser to send requests to the JMeter proxy.

10. Click on the Start button available in the State tab in the recorder instance to start the recording.

11. Note that the JMeter Root CA certificate must be installed in the web browser to record encrypted web requests.

12. To do this, go to the bin directory in the JMeter directory to locate the file named ApacheJMeterTemporaryRootCA, and install it in the system as well as the browser being used for recording the test script. In Firefox, for example, one needs to go to the options page, move to the Privacy and Security tab, click on the View Certificates button, and then click on the Import button to add the JMeter's self-signed certificate.

13. Once the recording starts, execute the test scenario.

14. Thereafter, click on the Stop button in the Transaction Controller to stop the recording.

6.3 Viewing JMeter Test Results using Listeners

JMeter listeners enable us to view and analyze the test results in graphical or tabular form. Some of these are:

- View Result Tree: This listener allows us to view a tree of samples' responses with their response codes. Furthermore, the response of each sample is shown separately.

- Summary and Aggregate Report: These listeners give an abridged view of information like Request Count, Average, Median, Min, Max, 90% Line, Error Rate, Throughput, Requests/second, and KB/sec for each uniquely named sample in the test plan. For low memory consumption, the Summary Report listener can be a good alternative.

Due to insufficient Java Heap Space, a test plan execution may result in JMeter giving an Out of Memory error. To resolve this, edit the jmeter.bat (for Windows) or jmeter.sh (for Linux) files and update the JVM_ARGS parameter accordingly.

6.4 Test Scenario

Our test scenario is as follows:

1. The user registers on the website.
2. The user views a list of available courses.
3. The user chooses a test course.
4. The user enrolls in the chosen course.
5. The user views the chosen course's dashboard.
6. The user chooses the quiz modules.
7. The user attempts the quiz.
8. The user submits the quiz responses for evaluation.

We had used this scenario since it involves all the activities that can be performed by a user on a course page.

6.5 Testing Open edX Native Installation

6.5.1 System Configurations

Here are the details of the hardware and software configuration of the application under test and the client machine that has been used to generate load.

6.5.2 Load Generator System Details

- Operating System: Windows 10 Home 64-bit
- RAM: 8GB
- Processor: Intel(R) Core(TM) i5-7200U CPU @ 2.50GHz x 2 Cores

6.5.3 Server Configuration

- Operating System: Ubuntu 16.04.6 LTS
- RAM: 7.61 GB
- Processor: Intel Common KVM Processor @ 2.095 MHz x 2

6.5.4 Test Details

- Duration: 1 Hour
- Virtual Connections: 100

6.5.5 Test Results

The application under test could handle 100 users for the specified server configuration under the current test setup. Furthermore, the test fails for around 120-130 users.

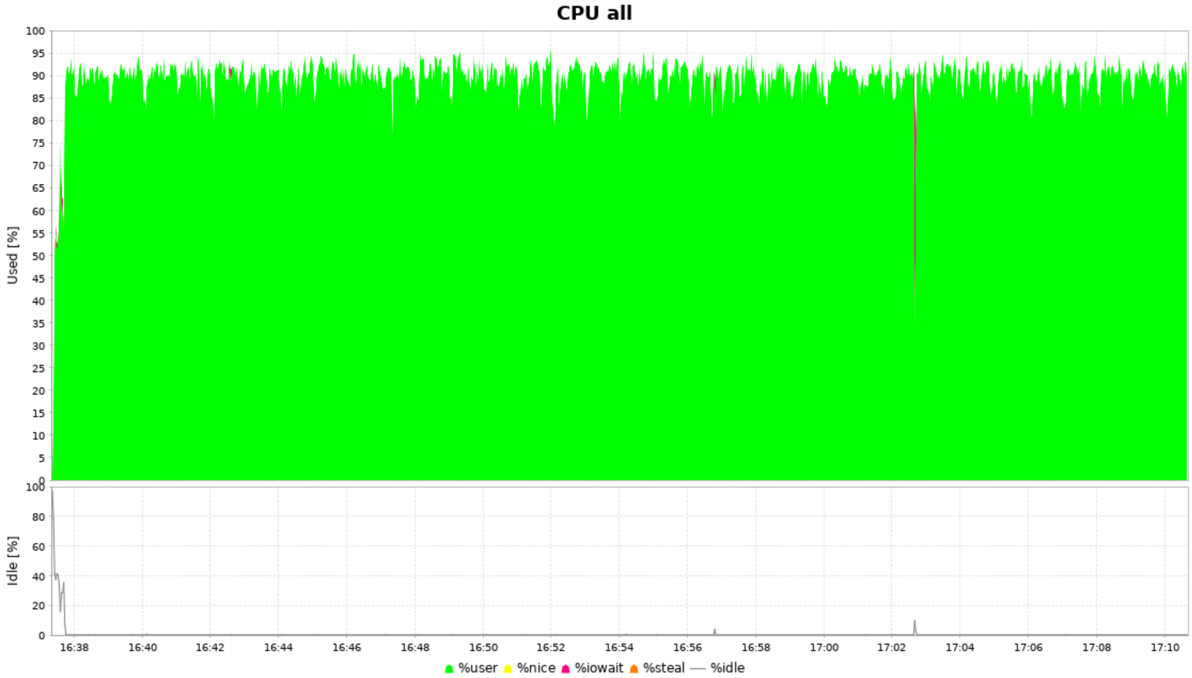


Figure 6.1: SAR CPU Metrics

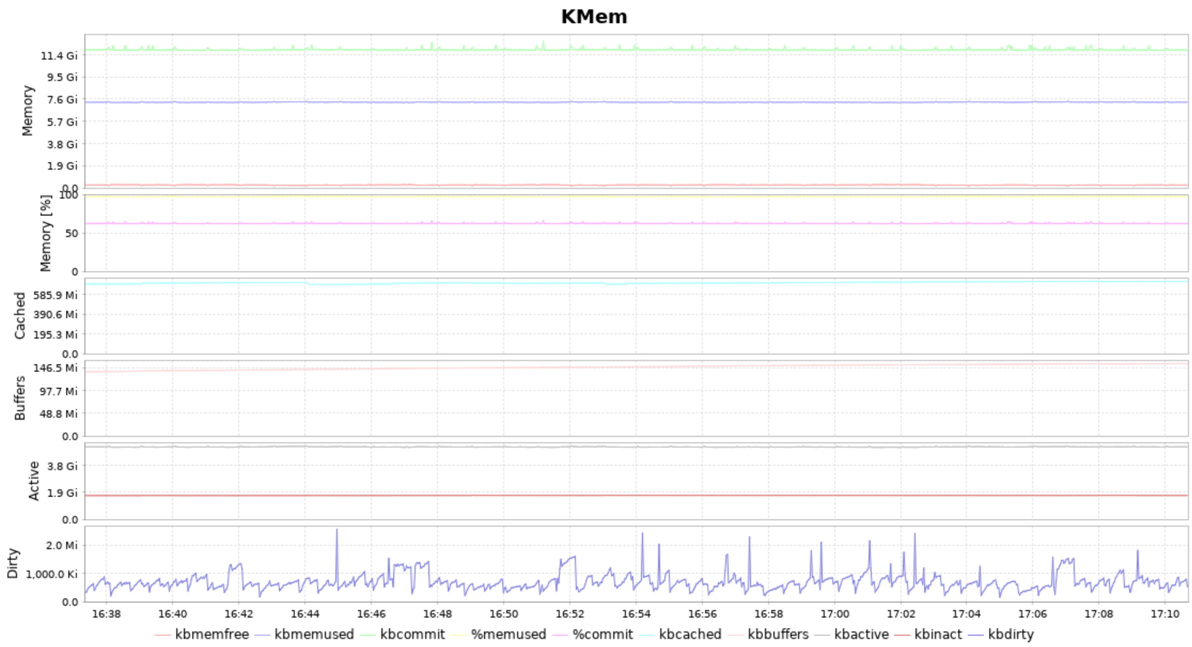
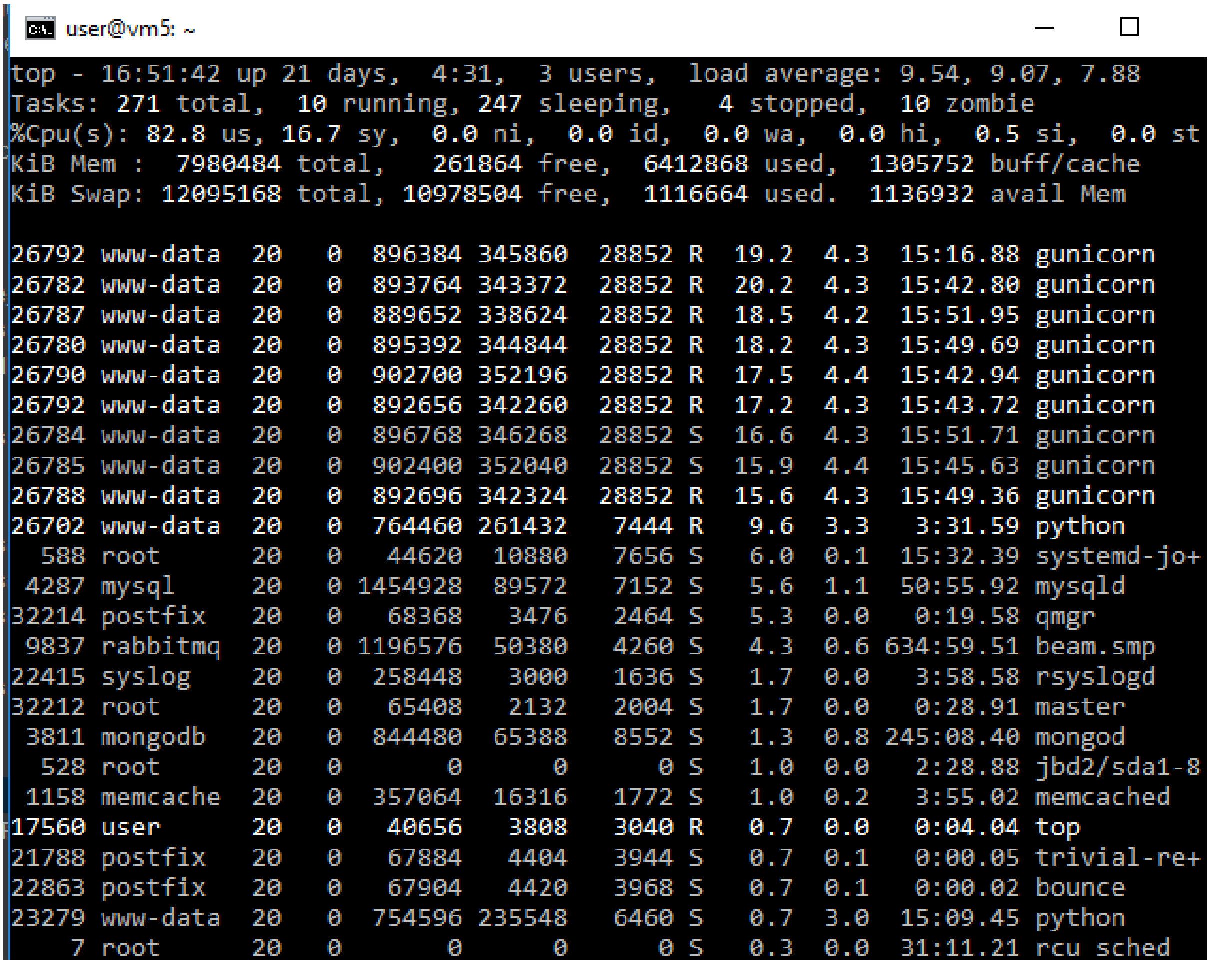


Figure 6.2: SAR Memory Metrics



```
user@vm5: ~
top - 16:51:42 up 21 days,  4:31,  3 users,  load average: 9.54, 9.07, 7.88
Tasks: 271 total,  10 running, 247 sleeping,   4 stopped,  10 zombie
%Cpu(s): 82.8 us, 16.7 sy,  0.0 ni,  0.0 id,  0.0 wa,  0.0 hi,  0.5 si,  0.0 st
KiB Mem :  7980484 total,   261864 free,  6412868 used,  1305752 buff/cache
KiB Swap: 12095168 total, 10978504 free,  1116664 used.  1136932 avail Mem

26792 www-data  20   0  896384 345860  28852 R  19.2  4.3  15:16.88 gunicorn
26782 www-data  20   0  893764 343372  28852 R  20.2  4.3  15:42.80 gunicorn
26787 www-data  20   0  889652 338624  28852 R  18.5  4.2  15:51.95 gunicorn
26780 www-data  20   0  895392 344844  28852 R  18.2  4.3  15:49.69 gunicorn
26790 www-data  20   0  902700 352196  28852 R  17.5  4.4  15:42.94 gunicorn
26792 www-data  20   0  892656 342260  28852 R  17.2  4.3  15:43.72 gunicorn
26784 www-data  20   0  896768 346268  28852 S  16.6  4.3  15:51.71 gunicorn
26785 www-data  20   0  902400 352040  28852 S  15.9  4.4  15:45.63 gunicorn
26788 www-data  20   0  892696 342324  28852 R  15.6  4.3  15:49.36 gunicorn
26702 www-data  20   0  764460 261432   7444 R   9.6  3.3   3:31.59 python
  588 root      20   0   44620  10880   7656 S   6.0  0.1  15:32.39 systemd-jo+
 4287 mysql     20   0 1454928  89572   7152 S   5.6  1.1  50:55.92 mysqld
32214 postfix   20   0   68368   3476   2464 S   5.3  0.0   0:19.58 qmgr
 9837 rabbitmq  20   0 1196576  50380   4260 S   4.3  0.6 634:59.51 beam.smp
22415 syslog    20   0  258448   3000   1636 S   1.7  0.0   3:58.58 rsyslogd
32212 root      20   0   65408   2132   2004 S   1.7  0.0   0:28.91 master
 3811 mongodb   20   0  844480  65388   8552 S   1.3  0.8 245:08.40 mongod
  528 root      20   0       0      0      0 S   1.0  0.0   2:28.88 jbd2/sda1-8
 1158 memcache  20   0  357064  16316   1772 S   1.0  0.2   3:55.02 memcached
17560 user      20   0   40656   3808   3040 R   0.7  0.0   0:04.04 top
21788 postfix   20   0   67884   4404   3944 S   0.7  0.1   0:00.05 trivial-re+
22863 postfix   20   0   67904   4420   3968 S   0.7  0.1   0:00.02 bounce
23279 www-data  20   0  754596 235548   6460 S   0.7  3.0  15:09.45 python
    7 root      20   0       0      0      0 S   0.3  0.0  31:11.21 rcu_sched
```

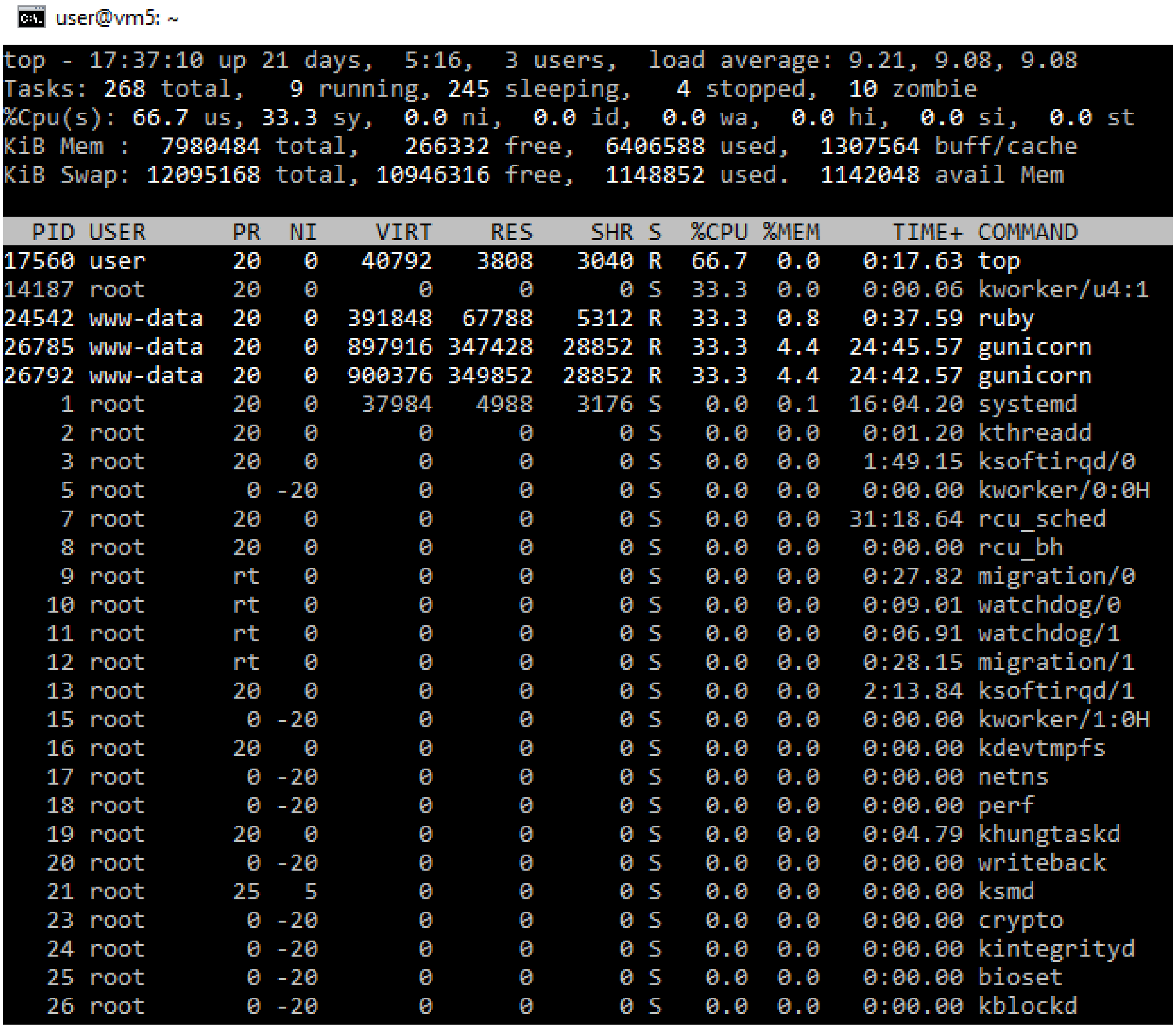
Figure 6.3: A look at the top command, 15 minutes into the test. Guincorn, which is a Python Web Server Gateway Interface HTTP Server, takes up most of the CPU resources.

```
user@vm5: ~
 - 17:07:25 up 21 days,  4:46,  3 users,  load average: 9.82, 9.39, 8.78
(s: 265 total,  11 running, 240 sleeping,   4 stopped,  10 zombie
u(s): 91.6 us,  7.6 sy,  0.0 ni,  0.0 id,  0.0 wa,  0.0 hi,  0.8 si,  0.0 st
 Mem :  7980484 total,   248276 free,  6400176 used,  1332032 buff/cache
 Swap: 12095168 total, 10973708 free,  1121460 used.  1145236 avail Mem

ID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
37 www-data  20   0  888308 337612  28852 R  20.8  4.2  18:58.67 gunicorn
32 www-data  20   0  897240 346720  28852 R  20.1  4.3  18:48.76 gunicorn
02 www-data  20   0  900888 350140  28852 R  20.1  4.4  18:50.32 gunicorn
35 www-data  20   0  892708 342348  28852 R  19.8  4.3  18:51.86 gunicorn
38 www-data  20   0  890700 340120  28852 R  19.8  4.3  18:54.76 gunicorn
34 www-data  20   0  899836 349336  28852 R  19.5  4.4  18:57.57 gunicorn
00 www-data  20   0  897292 346788  28852 R  19.5  4.3  18:49.71 gunicorn
30 www-data  20   0  893088 342588  28852 R  19.1  4.3  18:56.01 gunicorn
02 www-data  20   0  764460 261432   7444 S  15.5  3.3   4:27.98 python
37 mysql     20   0 1454928  92788   7152 S   7.3  1.2  52:18.81 mysqld
37 rabbitmq  20   0 1201712  50420   4260 S   5.0  0.6 635:36.14 beam.smp
58 memcache  20   0  357064  16316   1772 S   1.7  0.2   4:12.86 memcached
11 mongodb   20   0  844480  65396   8552 R   1.3  0.8 245:23.31 mongod
18 www-data  20   0   35244   6140   2924 S   1.3  0.1   0:25.32 nginx
38 root      20   0   44620  12200   8976 S   0.7  0.2  15:42.19 systemd-journal
17 www-data  20   0   35144   6172   2944 S   0.7  0.1   0:19.52 nginx
50 user      20   0   40792   3808   3040 R   0.7  0.0   0:08.93 top
78 www-data  20   0  754504 233680   5932 S   0.7  2.9  14:49.98 python
79 www-data  20   0  754596 235532   6460 S   0.7  3.0  15:14.53 python
15 www-data  20   0  391748  67632   5312 S   0.7  0.8   0:29.19 ruby
13 root      20   0       0      0      0 S   0.3  0.0   2:12.82 ksoftirqd/1
16 www-data  20   0   34840   5496   2912 S   0.3  0.1   0:29.50 nginx
39 www-data  20   0   60888  10224   4084 S   0.3  0.1  21:41.01 supervisord
31 elastic+  20   0 3054468 267640   8800 S   0.3  3.4 133:13.75 java
18 user      20   0    9712   1120   1028 S   0.3  0.0   0:01.16 sadc
19 user      20   0    9712   1076    984 S   0.3  0.0   0:01.22 sadc
73 www-data  20   0  332616  46388   8700 S   0.3  0.6   0:23.85 python
```

Figure 6.4: A look at the top command, 30 minutes into the test. Guincorn, which is a Python Web Server Gateway Interface HTTP Server, takes up most of the CPU resources.

```
user@vm5: ~
top - 17:22:23 up 21 days,  5:01,  3 users,  load average: 9.78, 9.25, 9.02
Tasks: 248 total,   8 running, 226 sleeping,   4 stopped,  10 zombie
%Cpu(s): 84.6 us, 15.1 sy,  0.0 ni,  0.0 id,  0.0 wa,  0.0 hi,  0.3 si,  0.0 st
KiB Mem :  7980484 total,   276760 free,  6393076 used,  1310648 buff/cache
KiB Swap: 12095168 total, 10966484 free,  1128684 used.  1152376 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
26788 www-data  20   0  890904 340532  28852 S  21.9  4.3  21:53.62 gunicorn
26787 www-data  20   0  901084 350580  28852 R  21.2  4.4  21:57.39 gunicorn
26780 www-data  20   0  894624 343908  28852 R  19.9  4.3  21:54.26 gunicorn
26782 www-data  20   0  901024 350504  28852 R  19.9  4.4  21:47.64 gunicorn
26784 www-data  20   0  892348 341976  28852 S  19.9  4.3  21:54.85 gunicorn
26790 www-data  20   0  895296 344792  28852 R  19.9  4.3  21:48.39 gunicorn
26785 www-data  20   0  898688 348328  28852 S  19.2  4.4  21:49.21 gunicorn
26792 www-data  20   0  896384 345860  28852 R  17.5  4.3  21:48.21 gunicorn
26702 www-data  20   0  764460 261432   7444 S   8.9  3.3   5:19.16 python
 4287 mysql     20   0 1454928  96752   7148 S   5.3  1.2  53:38.56 mysqld
 9837 rabbitmq  20   0 1194008  50508   4260 S   2.3  0.6 636:10.45 beam.smp
 1158 memcache  20   0  357064  16316   1772 S   1.3  0.2   4:30.18 memcached
  588 root      20   0   44620   5868   2644 S   1.0  0.1  15:51.57 systemd-journal
 3811 mongodb   20   0  844480  65656   8544 S   1.0  0.8 245:37.50 mongod
    3 root      20   0       0      0      0 S   0.3  0.0   1:48.67 ksoftirqd/0
    7 root      20   0       0      0      0 S   0.3  0.0  31:16.28 rcu_sched
10517 www-data  20   0   35144   6172   2944 S   0.3  0.1   0:22.28 nginx
10518 www-data  20   0   34508   5256   2924 S   0.3  0.1   0:28.58 nginx
12139 www-data  20   0   60888  10224   4084 R   0.3  0.1  21:45.01 supervisord
16781 elastic+  20   0 3054468 267976   8892 S   0.3  3.4 133:19.38 java
17560 user      20   0   40792   3808   3040 R   0.3  0.0   0:13.29 top
23267 www-data  20   0  744380 221024   6004 S   0.3  2.8  14:56.83 python
23279 www-data  20   0  754596 235440   6460 S   0.3  3.0  15:19.25 python
23359 www-data  20   0  204836  28576   3244 S   0.3  0.4   1:37.23 gunicorn
    1 root      20   0   37984   4988   3176 S   0.0  0.1  16:03.67 systemd
    2 root      20   0       0      0      0 S   0.0  0.0   0:01.20 kthreadd
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
```

Figure 6.5: A look at the top command, 45 minutes into the test. Guincorn, which is a Python Web Server Gateway Interface HTTP Server, takes up most of the CPU resources.



```
user@vm5: ~
top - 17:37:10 up 21 days,  5:16,  3 users,  load average: 9.21, 9.08, 9.08
Tasks: 268 total,   9 running, 245 sleeping,   4 stopped,  10 zombie
%Cpu(s): 66.7 us, 33.3 sy,  0.0 ni,  0.0 id,  0.0 wa,  0.0 hi,  0.0 si,  0.0 st
KiB Mem :  7980484 total,   266332 free,  6406588 used,  1307564 buff/cache
KiB Swap: 12095168 total, 10946316 free,  1148852 used.  1142048 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
17560 user      20   0   40792   3808   3040 R  66.7  0.0   0:17.63 top
14187 root      20   0       0      0      0 S  33.3  0.0   0:00.06 kworker/u4:1
24542 www-data  20   0  391848  67788   5312 R  33.3  0.8   0:37.59 ruby
26785 www-data  20   0  897916 347428  28852 R  33.3  4.4  24:45.57 gunicorn
26792 www-data  20   0  900376 349852  28852 R  33.3  4.4  24:42.57 gunicorn
    1 root      20   0   37984   4988   3176 S   0.0  0.1  16:04.20 systemd
    2 root      20   0       0      0      0 S   0.0  0.0   0:01.20 kthreadd
    3 root      20   0       0      0      0 S   0.0  0.0   1:49.15 ksoftirqd/0
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
    7 root      20   0       0      0      0 S   0.0  0.0  31:18.64 rcu_sched
    8 root      20   0       0      0      0 S   0.0  0.0   0:00.00 rcu_bh
    9 root      rt   0       0      0      0 S   0.0  0.0   0:27.82 migration/0
   10 root      rt   0       0      0      0 S   0.0  0.0   0:09.01 watchdog/0
   11 root      rt   0       0      0      0 S   0.0  0.0   0:06.91 watchdog/1
   12 root      rt   0       0      0      0 S   0.0  0.0   0:28.15 migration/1
   13 root      20   0       0      0      0 S   0.0  0.0   2:13.84 ksoftirqd/1
   15 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/1:0H
   16 root      20   0       0      0      0 S   0.0  0.0   0:00.00 kdevtmpfs
   17 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 netns
   18 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 perf
   19 root      20   0       0      0      0 S   0.0  0.0   0:04.79 khungtaskd
   20 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 writeback
   21 root      25   5       0      0      0 S   0.0  0.0   0:00.00 ksmd
   23 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 crypto
   24 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kintegrityd
   25 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 bioset
   26 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kblockd
```

Figure 6.6: A look at the top command, 60 minutes into the test. Guincorn, which is a Python Web Server Gateway Interface HTTP Server, takes up most of the CPU resources.

6.6 Testing Open edX Developer Stack (Devstack)

6.6.1 System Configurations

Here are the details of the hardware and software configuration of the application under test and the client machine that has been used to generate load.

6.6.2 Load Generator System Details

- Operating System: Windows 10 Home 64-bit
- RAM: 8GB
- Processor: Intel(R) Core(TM) i5-7200U CPU @ 2.50GHz x 2 Cores

6.6.3 Server Configuration

- Operating System: Ubuntu 16.04.4 LTS
- RAM: 7.61 GB
- Processor: Intel Common KVM Processor @ 2.095 MHz x 2

6.6.4 Test Details

- Duration: 1 Hour
- Virtual Connections: 10

6.6.5 Test Results

The application under test could handle 10 users for the specified server configuration under the current test setup. Furthermore, the test fails for around 15-20 users.

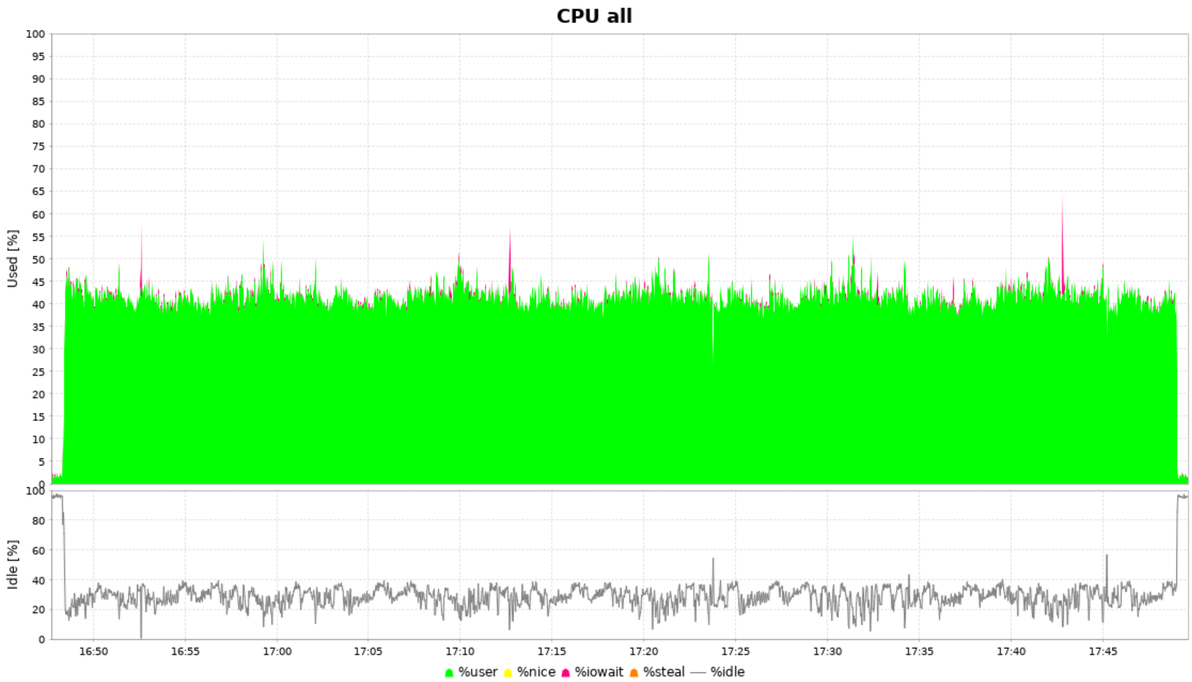


Figure 6.7: SAR CPU Metrics

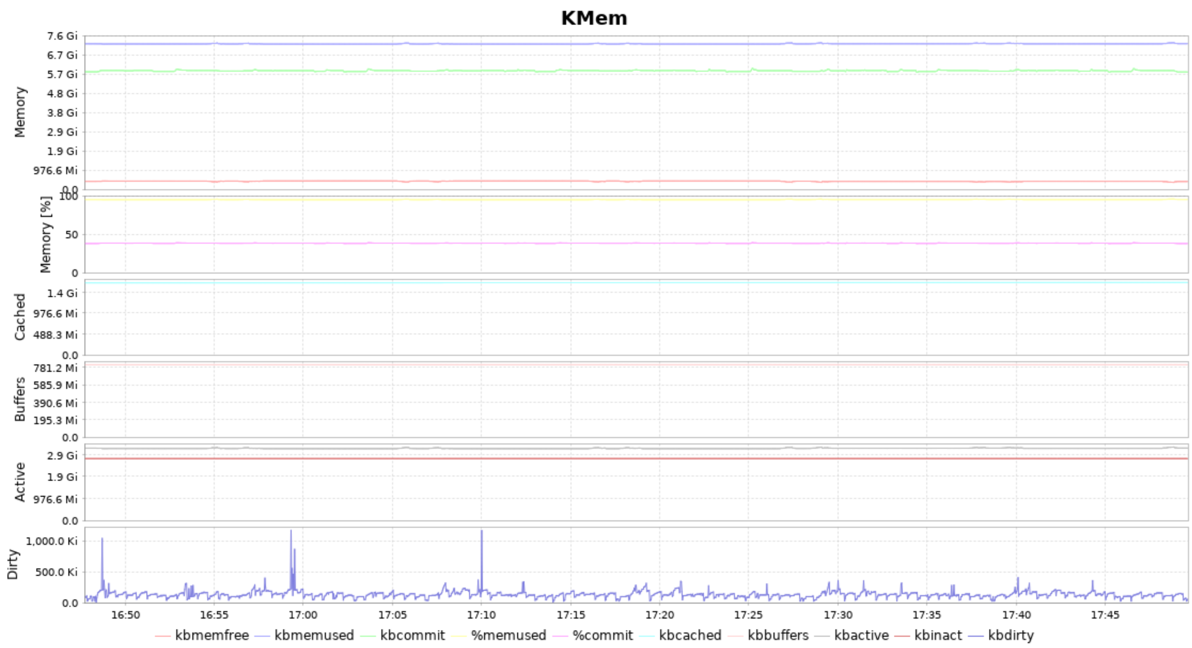


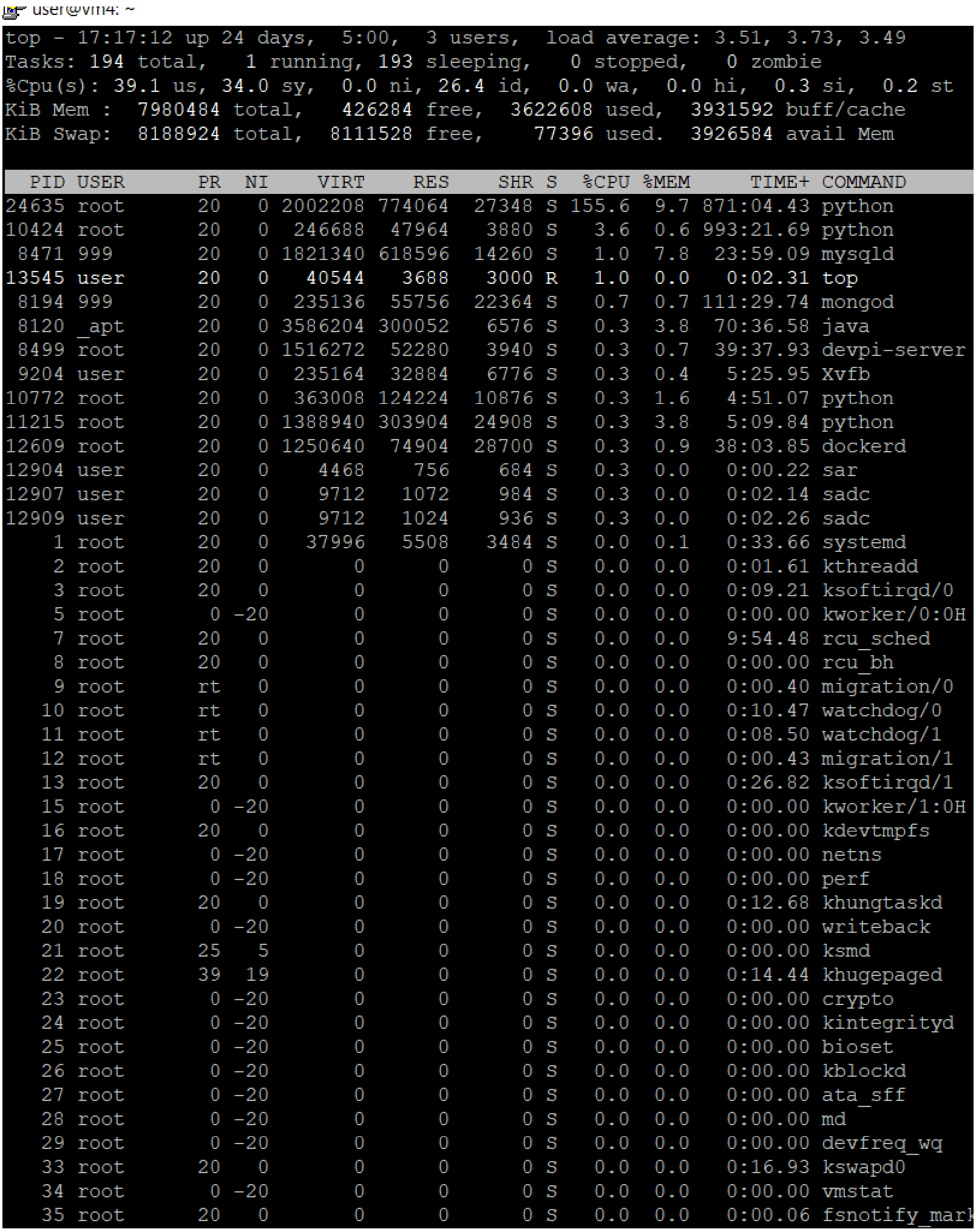
Figure 6.8: SAR Memory Metrics

```
top - 17:39:10 up 24 days,  5:22,  3 users,  load average: 2.46, 3.31, 3.70
Tasks: 193 total,   1 running, 192 sleeping,   0 stopped,   0 zombie
%Cpu(s): 38.9 us, 28.6 sy,  0.0 ni, 31.9 id,  0.0 wa,  0.0 hi,  0.5 si,  0.0 st
KiB Mem :  7980484 total,   405856 free,  3641224 used,  3933404 buff/cache
KiB Swap:  8188924 total,  8111528 free,    77396 used.  3908028 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
24635 root      20   0 2002208 792816  27348 S 144.2  9.9 903:21.15 python
10424 root      20   0  246688  47964   3880 S   5.6  0.6 994:33.08 python
 8471 999       20   0 1821340 618596  14260 S   0.7  7.8  24:14.04 mysqld
13545 user      20   0   40544   3688   3000 R   0.7  0.0   0:07.95 top
 8194 999       20   0  235136  55756  22364 S   0.3  0.7 111:37.82 mongod
 9297 user      20   0  113380   8156   1016 S   0.3  0.1  17:06.17 x11vnc
12907 user      20   0    9712   1072    984 S   0.3  0.0   0:03.64 sadc
12908 user      20   0    9712   1040    948 S   0.3  0.0   0:03.55 sadc
14291 root      20   0       0      0      0 S   0.3  0.0   0:00.18 kworker/u4:2
23800 root      20   0  582060  80820   8736 S   0.3  1.0   5:21.01 ruby
    1 root      20   0   37996   5508   3484 S   0.0  0.1   0:33.67 systemd
    2 root      20   0       0      0      0 S   0.0  0.0   0:01.61 kthreadd
    3 root      20   0       0      0      0 S   0.0  0.0   0:09.30 ksoftirqd/0
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
    7 root      20   0       0      0      0 S   0.0  0.0   9:55.34 rcu_sched
    8 root      20   0       0      0      0 S   0.0  0.0   0:00.00 rcu_bh
    9 root      rt   0       0      0      0 S   0.0  0.0   0:00.40 migration/0
   10 root      rt   0       0      0      0 S   0.0  0.0   0:10.47 watchdog/0
   11 root      rt   0       0      0      0 S   0.0  0.0   0:08.50 watchdog/1
   12 root      rt   0       0      0      0 S   0.0  0.0   0:00.43 migration/1
   13 root      20   0       0      0      0 S   0.0  0.0   0:27.07 ksoftirqd/1
   15 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/1:0H
   16 root      20   0       0      0      0 S   0.0  0.0   0:00.00 kdevtmpfs
   17 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 netns
   18 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 perf
   19 root      20   0       0      0      0 S   0.0  0.0   0:12.68 khungtaskd
   20 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 writeback
   21 root      25   5       0      0      0 S   0.0  0.0   0:00.00 ksmd
   22 root      39  19       0      0      0 S   0.0  0.0   0:14.46 khugepaged
   23 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 crypto
   24 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kintegrityd
   25 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 bioset
   26 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kblockd
   27 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 ata_sff
   28 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 md
   29 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 devfreq_wq
   33 root      20   0       0      0      0 S   0.0  0.0   0:16.93 kswapd0
   34 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 vmstat
   35 root      20   0       0      0      0 S   0.0  0.0   0:00.06 fsnotify_mark
   36 root      20   0       0      0      0 S   0.0  0.0   0:00.00 ecryptfs-kthr
   52 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kthrotld
   53 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 acpi_thermal_
   54 root      20   0       0      0      0 S   0.0  0.0   9:12.81 vballoon
```

Figure 6.9: A look at the top command, 15 minutes into the test. Python takes up most of the CPU Resources.

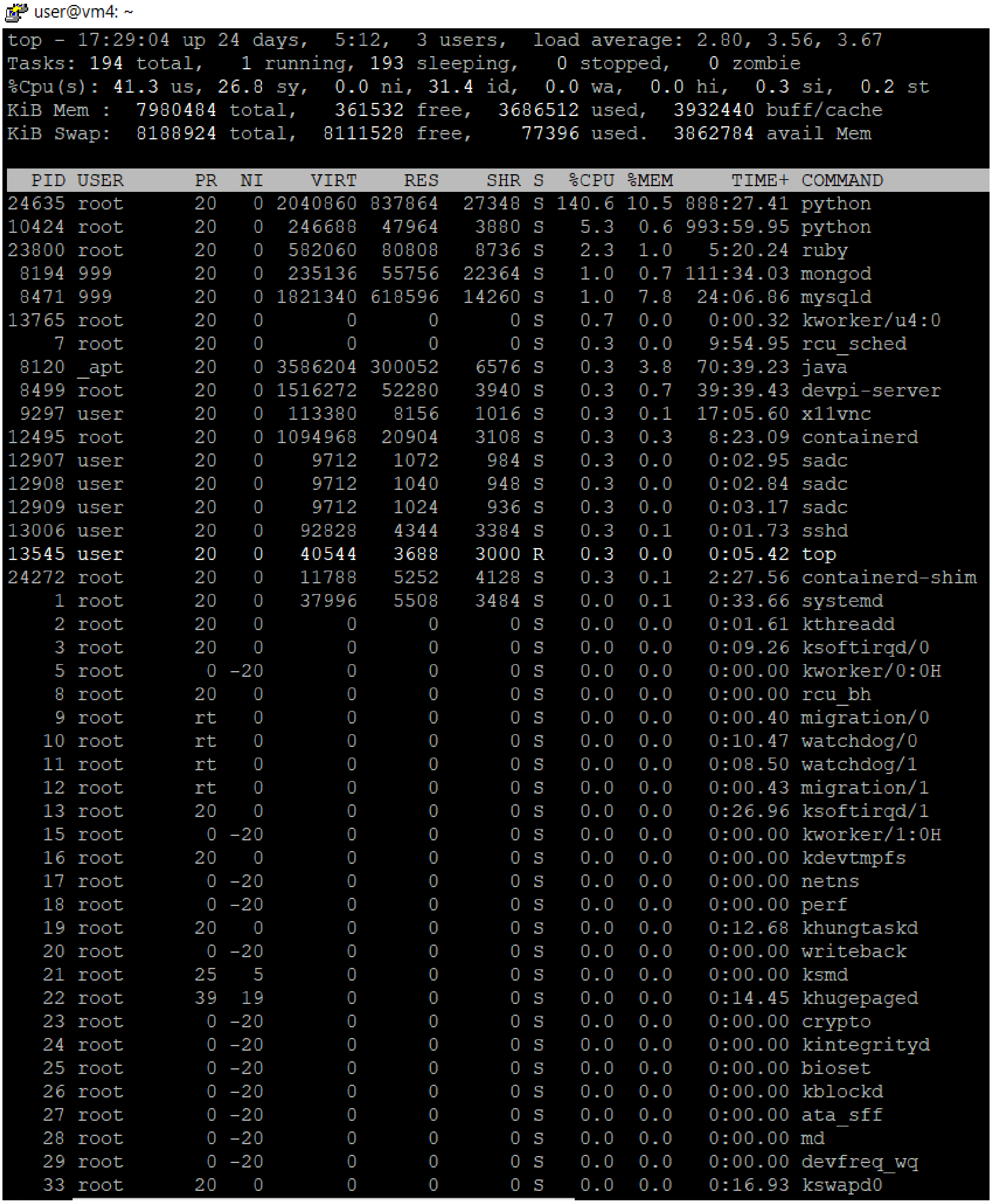
```
user@vm4: ~
top - 17:09:54 up 24 days,  4:52,  3 users,  load average: 2.94, 2.96, 3.17
Tasks: 194 total,   2 running, 192 sleeping,   0 stopped,   0 zombie
%Cpu(s): 46.2 us, 30.5 sy,  0.0 ni, 22.3 id,  0.3 wa,  0.0 hi,  0.5 si,  0.2 st
KiB Mem :  7980484 total,   426784 free,  3622320 used,  3931380 buff/cache
KiB Swap:  8188924 total,  8111528 free,    77396 used.  3926660 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
24635 root      20   0 2027308 774632  27348 S 154.5  9.7 860:16.23 python
10424 root      20   0  246688  47964   3880 S   5.3  0.6 992:58.04 python
 8471 999       20   0 1821340 618596  14260 S   1.3  7.8  23:54.23 mysqld
 8194 999       20   0  235136  55756  22364 S   1.0  0.7 111:27.16 mongod
23800 root      20   0  582060  80780   8736 S   1.0  1.0   5:19.02 ruby
12609 root      20   0 1250640  74704  28700 S   0.7  0.9  38:02.80 dockerd
 8120 _apt      20   0 3586204 300052   6576 S   0.3  3.8  70:34.91 java
 8499 root      20   0 1516272  52280   3940 S   0.3  0.7  39:36.97 devpi-server
 9297 user      20   0  113380   8156   1016 S   0.3  0.1  17:04.56 x11vnc
 9300 user      20   0 4507544  51996   8396 S   0.3  0.7  20:38.49 java
 9841 root      20   0   10732   4548   3708 S   0.3  0.1   1:04.46 containerd-shim
 9859 root      20   0    9324   4088   3328 S   0.3  0.1   1:00.17 containerd-shim
13006 user      20   0   92828   4344   3384 S   0.3  0.1   0:00.66 sshd
13466 root      20   0       0      0      0 S   0.3  0.0   0:00.06 kworker/u4:0
13545 user      20   0   40544   3688   3000 R   0.3  0.0   0:00.44 top
24272 root      20   0   11788   5284   4128 S   0.3  0.1   2:26.39 containerd-shim
    1 root      20   0   37996   5508   3484 S   0.0  0.1   0:33.65 systemd
    2 root      20   0       0      0      0 S   0.0  0.0   0:01.61 kthreadd
    3 root      20   0       0      0      0 S   0.0  0.0   0:09.18 ksoftirqd/0
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
    7 root      20   0       0      0      0 R   0.0  0.0   9:54.21 rcu_sched
    8 root      20   0       0      0      0 S   0.0  0.0   0:00.00 rcu_bh
    9 root      rt   0       0      0      0 S   0.0  0.0   0:00.40 migration/0
   10 root      rt   0       0      0      0 S   0.0  0.0   0:10.46 watchdog/0
   11 root      rt   0       0      0      0 S   0.0  0.0   0:08.50 watchdog/1
   12 root      rt   0       0      0      0 S   0.0  0.0   0:00.43 migration/1
   13 root      20   0       0      0      0 S   0.0  0.0   0:26.74 ksoftirqd/1
   15 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/1:0H
   16 root      20   0       0      0      0 S   0.0  0.0   0:00.00 kdevtmpfs
   17 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 netns
   18 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 perf
   19 root      20   0       0      0      0 S   0.0  0.0   0:12.68 khungtaskd
   20 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 writeback
   21 root      25   5       0      0      0 S   0.0  0.0   0:00.00 ksmd
   22 root      39  19       0      0      0 S   0.0  0.0   0:14.43 khugepaged
   23 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 crypto
   24 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kintegrityd
   25 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 bioset
   26 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kblockd
   27 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 ata_sff
   28 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 md
   29 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 devfreq_wq
   33 root      20   0       0      0      0 S   0.0  0.0   0:16.93 kswapd0
```

Figure 6.10: A look at the top command, 30 minutes into the test. Python takes up most of the CPU Resources.



```
user@vm4: ~
top - 17:17:12 up 24 days,  5:00,  3 users,  load average: 3.51, 3.73, 3.49
Tasks: 194 total,   1 running, 193 sleeping,   0 stopped,   0 zombie
%Cpu(s): 39.1 us, 34.0 sy,  0.0 ni, 26.4 id,  0.0 wa,  0.0 hi,  0.3 si,  0.2 st
KiB Mem :  7980484 total,   426284 free,  3622608 used,  3931592 buff/cache
KiB Swap:  8188924 total,  8111528 free,    77396 used.  3926584 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
24635 root      20   0 2002208 774064  27348 S 155.6  9.7 871:04.43 python
10424 root      20   0  246688  47964   3880 S   3.6  0.6 993:21.69 python
 8471 999       20   0 1821340 618596  14260 S   1.0  7.8  23:59.09 mysqld
13545 user      20   0   40544   3688   3000 R   1.0  0.0   0:02.31 top
 8194 999       20   0  235136  55756  22364 S   0.7  0.7 111:29.74 mongod
 8120 _apt      20   0 3586204 300052   6576 S   0.3  3.8  70:36.58 java
 8499 root      20   0 1516272  52280   3940 S   0.3  0.7  39:37.93 devpi-server
 9204 user      20   0  235164  32884   6776 S   0.3  0.4   5:25.95 Xvfb
10772 root      20   0  363008 124224  10876 S   0.3  1.6   4:51.07 python
11215 root      20   0 1388940 303904  24908 S   0.3  3.8   5:09.84 python
12609 root      20   0 1250640  74904  28700 S   0.3  0.9  38:03.85 dockerd
12904 user      20   0    4468    756    684 S   0.3  0.0   0:00.22 sar
12907 user      20   0    9712   1072    984 S   0.3  0.0   0:02.14 sadc
12909 user      20   0    9712   1024    936 S   0.3  0.0   0:02.26 sadc
    1 root      20   0   37996   5508   3484 S   0.0  0.1   0:33.66 systemd
    2 root      20   0       0      0      0 S   0.0  0.0   0:01.61 kthreadd
    3 root      20   0       0      0      0 S   0.0  0.0   0:09.21 ksoftirqd/0
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
    7 root      20   0       0      0      0 S   0.0  0.0   9:54.48 rcu_sched
    8 root      20   0       0      0      0 S   0.0  0.0   0:00.00 rcu_bh
    9 root      rt   0       0      0      0 S   0.0  0.0   0:00.40 migration/0
   10 root      rt   0       0      0      0 S   0.0  0.0   0:10.47 watchdog/0
   11 root      rt   0       0      0      0 S   0.0  0.0   0:08.50 watchdog/1
   12 root      rt   0       0      0      0 S   0.0  0.0   0:00.43 migration/1
   13 root      20   0       0      0      0 S   0.0  0.0   0:26.82 ksoftirqd/1
   15 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/1:0H
   16 root      20   0       0      0      0 S   0.0  0.0   0:00.00 kdevtmpfs
   17 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 netns
   18 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 perf
   19 root      20   0       0      0      0 S   0.0  0.0   0:12.68 khungtaskd
   20 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 writeback
   21 root      25   5       0      0      0 S   0.0  0.0   0:00.00 ksmd
   22 root      39  19       0      0      0 S   0.0  0.0   0:14.44 khugepaged
   23 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 crypto
   24 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kintegrityd
   25 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 bioset
   26 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kblockd
   27 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 ata_sff
   28 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 md
   29 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 devfreq_wq
   33 root      20   0       0      0      0 S   0.0  0.0   0:16.93 kswapd0
   34 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 vmstat
   35 root      20   0       0      0      0 S   0.0  0.0   0:00.06 fsnotify_mark
```

Figure 6.11: A look at the top command, 45 minutes into the test. Python takes up most of the CPU Resources.



```
user@vm4: ~
top - 17:29:04 up 24 days,  5:12,  3 users,  load average: 2.80, 3.56, 3.67
Tasks: 194 total,   1 running, 193 sleeping,   0 stopped,   0 zombie
%Cpu(s): 41.3 us, 26.8 sy,  0.0 ni, 31.4 id,  0.0 wa,  0.0 hi,  0.3 si,  0.2 st
KiB Mem :  7980484 total,   361532 free,  3686512 used,  3932440 buff/cache
KiB Swap:  8188924 total,  8111528 free,    77396 used.  3862784 avail Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
24635 root      20   0 2040860 837864  27348 S 140.6 10.5 888:27.41 python
10424 root      20   0  246688  47964   3880 S   5.3  0.6 993:59.95 python
23800 root      20   0  582060  80808   8736 S   2.3  1.0   5:20.24 ruby
 8194 999       20   0  235136  55756  22364 S   1.0  0.7 111:34.03 mongod
 8471 999       20   0 1821340 618596  14260 S   1.0  7.8  24:06.86 mysqld
13765 root      20   0       0      0      0 S   0.7  0.0   0:00.32 kworker/u4:0
    7 root      20   0       0      0      0 S   0.3  0.0   9:54.95 rcu_sched
 8120 _apt      20   0 3586204 300052   6576 S   0.3  3.8  70:39.23 java
 8499 root      20   0 1516272  52280   3940 S   0.3  0.7  39:39.43 devpi-server
 9297 user      20   0  113380   8156   1016 S   0.3  0.1  17:05.60 x11vnc
12495 root      20   0 1094968  20904   3108 S   0.3  0.3   8:23.09 containerd
12907 user      20   0    9712   1072    984 S   0.3  0.0   0:02.95 sadc
12908 user      20   0    9712   1040    948 S   0.3  0.0   0:02.84 sadc
12909 user      20   0    9712   1024    936 S   0.3  0.0   0:03.17 sadc
13006 user      20   0   92828   4344   3384 S   0.3  0.1   0:01.73 sshd
13545 user      20   0   40544   3688   3000 R   0.3  0.0   0:05.42 top
24272 root      20   0   11788   5252   4128 S   0.3  0.1   2:27.56 containerd-shim
    1 root      20   0   37996   5508   3484 S   0.0  0.1   0:33.66 systemd
    2 root      20   0       0      0      0 S   0.0  0.0   0:01.61 kthreadd
    3 root      20   0       0      0      0 S   0.0  0.0   0:09.26 ksoftirqd/0
    5 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/0:0H
    8 root      20   0       0      0      0 S   0.0  0.0   0:00.00 rcu_bh
    9 root      rt   0       0      0      0 S   0.0  0.0   0:00.40 migration/0
   10 root      rt   0       0      0      0 S   0.0  0.0   0:10.47 watchdog/0
   11 root      rt   0       0      0      0 S   0.0  0.0   0:08.50 watchdog/1
   12 root      rt   0       0      0      0 S   0.0  0.0   0:00.43 migration/1
   13 root      20   0       0      0      0 S   0.0  0.0   0:26.96 ksoftirqd/1
   15 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kworker/1:0H
   16 root      20   0       0      0      0 S   0.0  0.0   0:00.00 kdevtmpfs
   17 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 netns
   18 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 perf
   19 root      20   0       0      0      0 S   0.0  0.0   0:12.68 khungtaskd
   20 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 writeback
   21 root      25   5       0      0      0 S   0.0  0.0   0:00.00 ksmd
   22 root      39  19       0      0      0 S   0.0  0.0   0:14.45 khugepaged
   23 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 crypto
   24 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kintegrityd
   25 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 bioset
   26 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 kblockd
   27 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 ata_sff
   28 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 md
   29 root       0 -20       0      0      0 S   0.0  0.0   0:00.00 devfreq_wq
   33 root      20   0       0      0      0 S   0.0  0.0   0:16.93 kswapd0
```

Figure 6.12: A look at the top command, 60 minutes into the test. Python takes up most of the CPU Resources.

Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received	Sent	Avg. Bytes
309 /	467	31471	26	74382	17594.29	0.00%	0.23709	1.61	0.43	6940.9
313 /register	462	17669	105	44435	8535.64	0.00%	0.23664	2.72	0.24	11763.9
324 /user_api/v1/account/registrati	458	17503	264	44034	7988.56	0.00%	0.24067	0.33	0.32	1388.8
325 /	458	33225	204	78036	14456.6	0.00%	0.23193	1.49	0.56	6578.9
326 /dashboard	453	17476	164	44284	7792.17	0.00%	0.23172	1.35	0.27	5981.9
336 /courses	449	17407	120	43568	7644.5	0.00%	0.23766	1.17	0.28	5020.4
340 /search/course_discovery/	449	16704	56	41720	7587.38	0.00%	0.23471	0.51	0.32	2238.8
344 /courses/course-v1:edX+Dem	443	19313	402	45575	7937.03	0.00%	0.22953	1.42	0.28	6354.3
350 /change_enrollment	440	19322	142	44096	7636.84	0.00%	0.23375	0.1	0.32	419
351 /dashboard	440	19306	461	42813	7222.98	0.00%	0.23015	1.57	0.28	6966
353 /courses/course-v1:edX+Dem	440	22947	4222	49514	7467.51	0.00%	0.22494	2.35	0.27	10684.9
368 /event	440	21945	927	44781	8474.88	0.00%	0.22253	0.09	0.34	426
458 /event	440	23692	1978	44132	8519.23	0.00%	0.22127	0.09	0.39	426
459 /courses/course-v1:edX+Dem	435	58331	17509	92077	16739.07	0.00%	0.21711	17.52	0.6	82614.2
460 /courses/course-v1:edX+Dem	416	33240	12588	53849	8958.8	0.00%	0.21116	16.87	0.3	81815.5
498 /courses/course-v1:edX+Dem	387	24169	8809	44520	8902.71	0.00%	0.20016	0.16	0.3	811.3
501 /event	374	22862	8273	43750	8182.27	0.00%	0.19608	0.08	0.4	426
502 /courses/course-v1:edX+Dem	364	24479	11310	44928	9034.08	0.00%	0.19425	0.48	0.36	2523
503 /event	359	21414	10118	41553	7664.61	0.00%	0.19473	0.08	3.03	426
TOTAL	8174	24316	26	92077	13799.58	0.00%	4.01031	48.37	8.7	12350.4

Figure 6.13: JMeter Summary Report for Open edX Native.

Label	# Samples	Average	Min	Max	Std. Dev.	Error %	Throughput	Received	Sent	Avg. Bytes
505 /	60	45720	65	67966	21874.03	0.00%	0.01887	0.58	0.07	31202.7
572 /register	60	41969	315	54448	17739.53	0.00%	0.01859	0.7	0.11	38549.2
606 /user_api/v1/account/regist	60	12049	3183	16794	2432.88	0.00%	0.01849	0.05	0.04	2516.6
607 /	60	30228	27788	34045	1268.76	0.00%	0.01833	0.5	0.08	27842
608 /dashboard	60	30258	28003	33901	1294.17	0.00%	0.01834	0.49	0.04	27328.9
620 /courses	60	11264	3047	17583	3377.43	0.00%	0.01848	0.45	0.04	24769
623 /courses/course-v1:edX+D	60	39603	30718	49094	3607.05	0.00%	0.01828	0.52	0.04	29282.2
630 /change_enrollment	60	1884	750	3192	546.91	0.00%	0.01849	0.01	0.05	443
631 /dashboard	60	50971	35640	61853	6081.16	0.00%	0.01827	0.57	0.04	32168.1
634 /courses/course-v1:edX+D	60	80800	63578	95378	8477.24	0.00%	0.01809	1.54	0.04	86914.9
650 /event	60	647	247	1453	301.12	0.00%	0.01848	0.01	0.05	450
701 /event	60	676	222	1745	306.8	0.00%	0.01848	0.01	0.05	450
702 /courses/course-v1:edX+D	60	131800	126434	138025	2369.1	0.00%	0.01779	9.31	0.09	535781.9
739 /courses/course-v1:edX+D	50	100446	90343	115660	7293.53	0.00%	0.01845	9.64	0.05	535058.8
814 /courses/course-v1:edX+D	50	3417	1213	6092	1063.3	0.00%	0.01913	0.05	0.05	2721.9
817 /event	50	563	180	1147	230.95	0.00%	0.01916	0.01	0.06	450
818 /courses/course-v1:edX+D	50	7637	3211	12106	1912.21	0.00%	0.0191	0.21	0.06	11332
819 /event	50	776	277	1475	291	0.00%	0.01914	0.01	0.32	450
TOTAL	1030	33315	65	138025	37722.73	0.00%	0.28285	20.85	1.05	75497.6

Figure 6.14: JMeter Summary Report for Open edX Devstack.

6.7 Test Results

- Under the current test setup and server configurations, it is evident that Open edX Native can handle around 100 virtual connections, which is much better than 10, the number of virtual connections that could be handled by Open edX Devstack.
- In 1 hour, the total number of transation completed by Open edX Native was 8174, much more than that of Open edX Devstack, which amounted to 1030.
- Furthermore, the average response time of Open edX Native is 24.316 seconds, which outperforms Open edX Devstack, whose average response time is 33.313 seconds.
- Along with that, the throughput, which has been measured in requests/sec, for Open edX Native is 4.01, whereas it is 0.28 for Open edX Devstack.
- As for the CPU Utilization, Open edX Native consumes around 85-95% of CPU Resources, which is much more than the CPU Utilization of Open edX Devstack (40-50%).
- The memory consumption was close to 100% in both the setups.
- A closer look at the Summary Reports shows that the response time recorded corresponding to the case where the enrolled course's dashboard is accessed is very high, relative to other requests in a given test plan. Moreover, this response time is exceedingly high for Open edX Devstack.

The official Open edX documentation states that nginx and gunicorn have been disabled in Devstack. Hence, it uses Django's runserver as an alternative. This can be verified by the top command's result as shown in figures 14-17, 20-23.

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