Case Study: Build and deploy Web Applications in Private or Public Cloud

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Structured Abstract

This case study explores processes and challenges of deploying Web Applications in Private or Public Cloud. It also includes Installation procedures of Private Cloud “NextCloud” on Linux Ubuntu Server. As Installation and Running Private Cloud is important, monitoring of web service or private cloud is also of paramount importance to have continuous availability for users. During Software Engineering Research & Development course we learned process to Install Linux OS, LAMP Stack Installation using the available instructions in “Recipe”. NextCloud is open source private cloud, End to End encrypted solution, which user can customize it according to their need. NextCloud Web Service, Disk Usage and NextCloud Database is monitored using Nagios, which is open source monitoring tool for computer systems. Nagios Core is used as the version for monitoring services on Local Host and Remote Host.

Nagios Monitoring Tool monitors different services on localhost as well as other hosts. It allows remote monitoring using Nagios Remote Plugin Executer (NRPE) that has to be installed on each host that is being monitored. NextCloud performance such as Disk Usage, availability and database performance is monitored using Nagios. User can select services and update the configuration files. To achieve Private Cloud Installation and monitoring using Monitoring Tool various aspects are considered such as version of Scripting Language (PHP for this case study), Database Server Libraries (MySQL for this Case Study) and available services for a Monitoring tool version (Nagios Core for this case study)

Introduction

Cloud computing is defined as providing services over the internet such as servers, database, analytics and software. It helps organizations and individual to avoid managing or maintaining their own data centers or servers. Private Cloud resides on organizations own data centers where data is protected using organizations own security solutions. Though it brings responsibility of managing, maintaining and providing security to data centers which is not very cost effective in case of small organizations. Public cloud on other hand provides services over the internet where data is stored in provider's data center, thus making provider responsible for managing and maintaining the data center, which allows organizations to deploy Web Applications faster. One drawback of Public cloud is that organizations don't have control over security of data, though there are no major security breaches of Public Cloud yet. This case study will look in to Private and Public Cloud Build and deployment processes for Web Applications along with understanding when it becomes cost effective to move to Public Cloud. This case study also looked in to installation of Private Cloud and monitor it with Nagios Monitoring Tool.

CRUD Application was installed on Regis Private Cloud Server 02 and virtual host was configured. Used Apache2 as webserver, PHP as scripting language and MySQL as database. Database was created followed by Tables, then configuration file was updated to have MySQL login credentials and database name. Web Application was run on Server 02 on Regis Private Cloud.

For Public Cloud – Google cloud's process to deploy Web Application was researched using authoritative resources. Best practices such as first running the app on local environment and then moving to App Engine was observed. Process of deploying multiple services and how build images are managed was reviewed. It also consisted of testing on App Engine before receiving any user traffic.

Nagios Monitoring Tool was configured on Server 07 for monitoring services on localhost and Remote Host. Nagios Remote Plugin Executer (nrpe) is used to monitor remote hosts. NRPE Plugins were installed on both Localhost and Remote Host. Server Configuration file was updated on Localhost (Server 07) to have IP of Remote Host (Server 02), Remote Server Host Name and Alias. Services such as NextCloud Web Service availability and NextCloud Database monitoring was configured. Commands are then configured to get data for service checks, host checks, database checks etc. It allowed to monitor services both on Server 02 and Server 07. Specifically for Private Cloud "NextCloud" on Server 02.

Private Cloud "NextCloud" Installation was done on Server 02 that required creating mysql user and PHP Installation. Followed by Virtual host configuration and updating of config.php file to include local IP to browse NextCloud Instance. Nagios Monitoring Tool and MySQL Workbench was used to monitor performance of NextCloud by storing files.

Hypotheses

Research questions with interest in learning about Private Cloud, Public Cloud and Monitoring are basis of investigation. Below research questions paved the way for research

- How to Install, configure and deploy Web Application on Private Cloud?
- How to Install, configure and deploy Web Application on Public Cloud?
- How to Install, configure and deploy NextCloud?
- How to Monitor NextCloud using Nagios Monitoring Tool?
- Compare Private Cloud and Public Cloud?

Above research questions helped to start with Installation and Configuration of Server. Followed by Security hardening and Installation of LAMP Stack CRUD Application. Regis Private Cloud gave unique opportunity to access servers on private cloud to further progress the research. Nagios Monitoring Tool Installation on Server allowed to understand how monitoring works and the role it plays in keeping systems up and running with the help of notification and alerts. NextCloud was the private cloud service used to understand the installation process along with monitoring it using Nagios Monitoring Tool. Most of the research was done using servers on Regis Private Cloud and LAMP installation was done on both personal as well as Regis Cloud Servers.

Installation of Database driven Web Application on server in the form of CRUD Application and configuration of MySQL as database successfully, helped in understanding the process,

challenges and best practices. Research on Public Cloud (Google Cloud) gives information about services offered and allows to differentiate between private and public cloud for better understanding of which service to be used in different scenarios.

Using Nagios Monitoring Tool different services including Private Cloud “NextCloud” can be monitored for availability and performance. It solidifies the hypotheses that multiple hosts can be monitored at the same time with live alerts and notifications.

NextCloud Installation and configuration served as web based service and Private Cloud which is also end to end encrypted and open source. NextCloud Performance Monitoring using Nagios and MySQL Workbench helped in gauging the non-functional attributes of web application. MySQL database connection was made over VPN using Standard TCP/IP over SSH. Nagios is used to monitor Disk Usage and other services such as HTTP, Load and Number of Users connected to Server. Self-signed SSL (Secure Socket Layer) Certificate was installed on Server 02 where NextCloud Service is running to provide encryption for data being transferred.

Results and analysis section has more details for case study. Methodology will cover the step by step procedures.

Methodology

How to deploy CRUD App on LAMP stack on Regis Private Cloud Server.

This was part of assignment for this course but helped with understanding the step by step procedures to deploy CRUD App on LAMP Stack on Regis Private Cloud. It also helped in exploring best practice and how to mitigate issues by troubleshooting. Steps to deploy CRUD App on LAMP stack are presented in summary below along with pre-installation steps that must be completed before actual deployment of CRUD App.

Below are the system requirements to start with deployment

- Linux Server running Ubuntu version 18.04
- Access to Regis Private Cloud via VPN
- Non-root user with sudo privileges

First LAMP (Linux, Apache2, MySQL and PHP) stack was installed on server running Ubuntu Version 18.04. “LAMP is collection of software technology that is packed together to form a platform” (Stackify, 2020). Recipe for LAMP stack provided by Professor was used as reference guide. Apache2 Webserver was installed and tested by typing localhost in browser that it’s running. Status of uncomplicated firewall (ufw) was checked and Apache was allowed access on port. MySQL database is installed which is an open source database to store application data. MySQL password was created to access the database securely. Database ‘restfulcrud’ was then

created and Table ‘people’ was created under that database. PHP was then installed which is scripting language that works with Apache2 to deliver dynamic web pages to users. Virtual Host was created for hosting CRUD App.

Below Screenshot shows versions of Apache2, MySQL and PHP Installed on Ubuntu Server 18.04

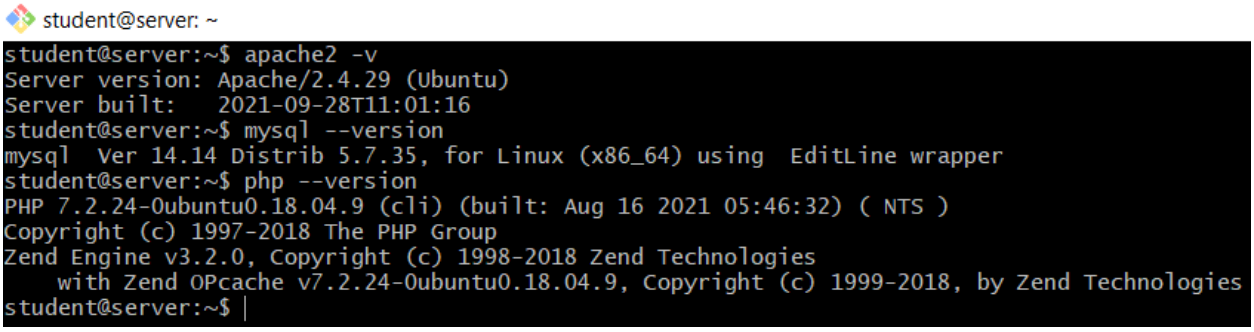

Fig. 1.1 Apache2, MySQL and PHP Versions on Ubuntu 18.04 Server after Installation

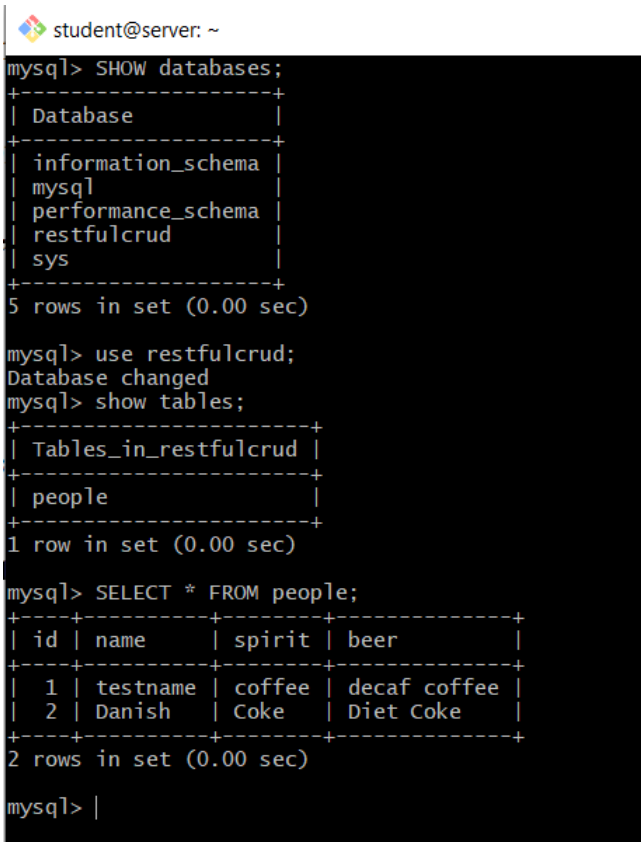

Fig. 1.2 MySQL Database and Table for CRUD Application

CRUD application was then run successfully on localhost and CRUD functionalities were tested to ensure deployment of application was successful.

How to Install, configure and deploy Web Application on Public Cloud?

For Public Cloud available research documents were investigated and compared with Private Cloud activities. Deployment on Public cloud requires companies to opt for cloud services such as Platform as a service (PaaS) or Software as a Service (SaaS). As mentioned in (Weinmann, 2016) “Cloud

Migration" can be referred as moving legacy applications to cloud architecture and it can also be referred as moving cloud architecture ready application to either private cloud or public cloud. Google Cloud was researched that has solutions based on need of the organizations.

Below are some steps that were mentioned in (Google Cloud, 2021) for Node.js web service on App Engine.

Setting Up

Setting up Development Environment which includes installing required software for development. Then Cloud project for App Engine is Setup that has App Engine application and other Google Cloud resources. Labeling App Engine resources are done to have associated resources in groups.

Designing App

Structuring of Web Services is done in App engine and then communication between App Engine services with other services is established. Handling and routing of requests is done by App Engine**.**

Securing App

App security is achieved then by implementing access controls. User managed service account is required to access other Google Cloud services.

Defining Configuration Files

Defining runtime settings and specifying dependencies is another task that is done. Custom build setup is done for running preprocessing tasks.

Testing and Deploying Application

It is recommended to run application locally first before deploying. Application is deployed in App engine followed by deploying versions of applications service and configuration files.

How to Install, configure and deploy NextCloud?

NextCloud is open source private cloud, End to End encrypted solution, which user can customize it according to their need. Installation of Private Cloud “NextCloud” on Ubuntu 18.04 Server was done to understand the process and to document challenges and best practices. Instructions from website (Techguide, 2021) were followed to Install NextCloud version 22.2.0. First step is to install MySQL and PHP that is covered in CRUD application deployment section in document above. For MySQL user ‘nextcloud@localhost’ was created with all permissions to ‘nextcloud’ database. Next step is to download file from NextCloud website which didn’t work on server. As a workaround we downloaded file to personal laptop and transferred it to server using “scp” command on VPN. Then ownership of NextCloud folder was transferred to Apache2. Virtual host entry was done as below and apache2 was restarted.

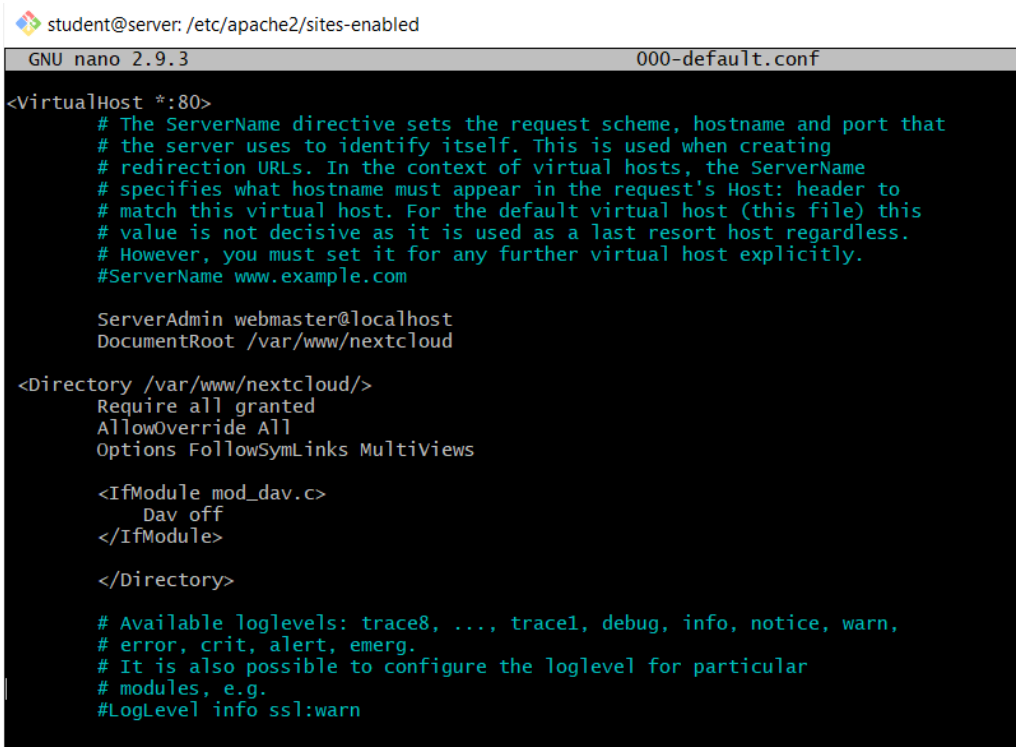

Fig 2.1. Virtual Host Configuration

Another challenge faced was PHP version NextCloud 22.2.0 supports PHP 7.3 and above and by default PHP 7.2 was installed, so NextCloud failed to run with error message to update PHP Version. PHP version was updated to 8.0 and another issue showed up. Internal server error was displayed and issue was fixed by increasing memory of MySQL DB “sort_buffer_size = 256000000” in “/etc/mysql/mysql.conf.d/mysql.d.cnf”.

Then on local IP I was able to access NextCloud

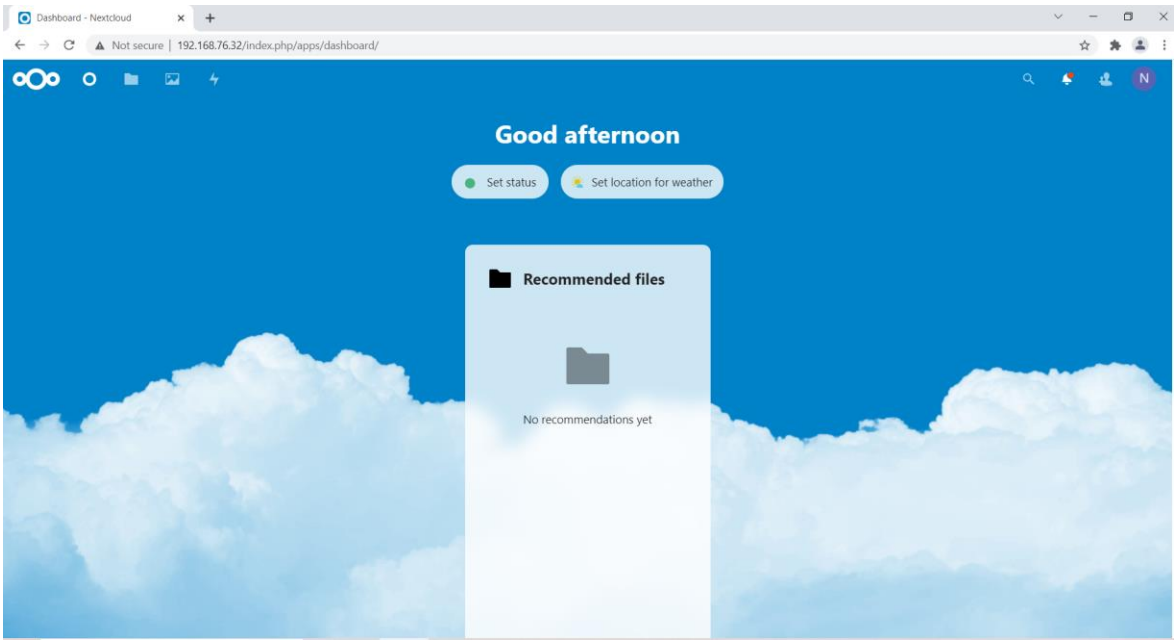

Fig 2.2. NextCloud running on Ubuntu Server (Server 02)

SSL (Secure Socket Layer) Certificate Installation

Self-signed SSL (Secure Socket Layer) Certificate was installed on Server 02 where NextCloud Service is running. SSL Certificate enables encrypted connection thus ensuring data is transferred over as secured Network. SSL Certificate installation Recipe is available in **Appendix B.**

After Installation of Self-signed SSL Certificate NextCloud can be accessed using HTTPS as shown in Fig 2.3.

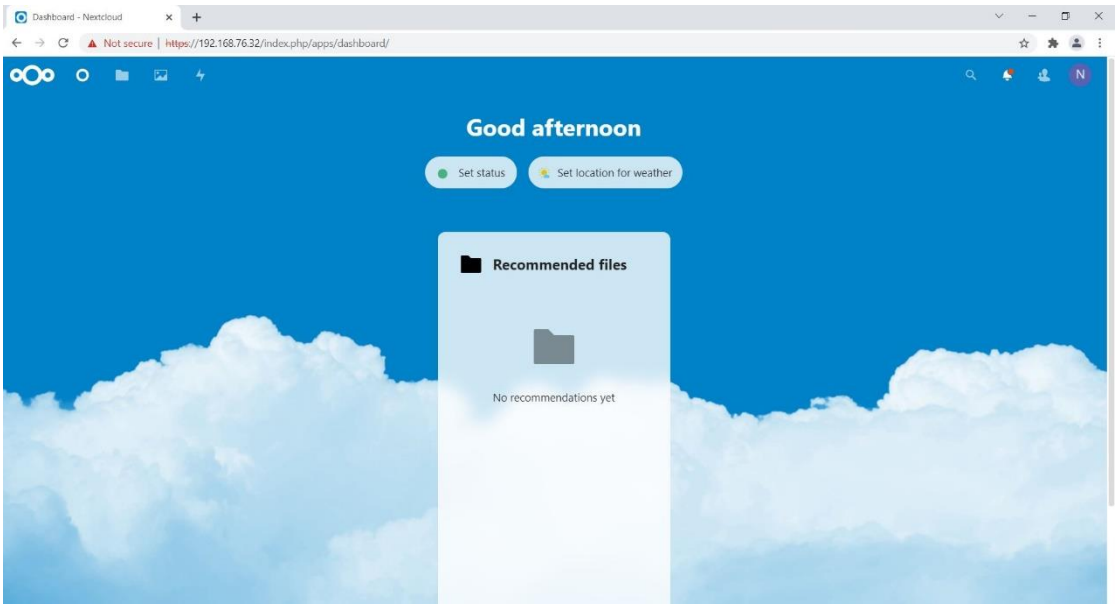

Fig 2.3 Accessing NextCloud through https after SSL Certificate Installation

How to Monitor NextCloud using Nagios Monitoring Tool?

Nagios is open source monitoring tool for computer systems. Nagios helps in ensuring that web applications, services and systems are running as expected. Nagios Core was used as the version for monitoring NextCloud web service and database. Nagios was also used to monitor Disk Usage and Load. Nagios was installed on Server 07 which served as local host where Nagios is running.

For End to End Nagios system we have two Regis Cloud Servers running Ubuntu 18.04. Server 07 is local host where Nagios is running and Server 02 is Host Server where NextCloud is installed and running. Nagios requires Apache Webserver and PHP but doesn't required MySQL.

MySQL can be installed to for monitoring databases. Apache2 and PHP was installed. Apache2 service was then tested by opening a browser and entering http://<ip of server> or http://localhost. Allowed Apache2 Server access to ports and then Apache2 server was restarted. Pre-requisites for Installing Nagios was completed.

For Nagios Installation SSH in to Server 07 and update currently installed packages. Nagios Installation package was downloaded and unzipped. Nagios is then configured to pair Nagios config files with Apache2 config files followed by user creation and restarting of Apache2.

Nagios Plugin package is then downloaded and configured. “Plugins process command line arguments, perform a specific check and then return the results to Nagios Core” (Nagios, 2021). Nagios Remote Plugin Executer (nrpe) is downloaded and installed that helps in monitoring remote hosts.

Nagios Configuration is required as it specifies which hosts are monitored and commands that are going to get executed.

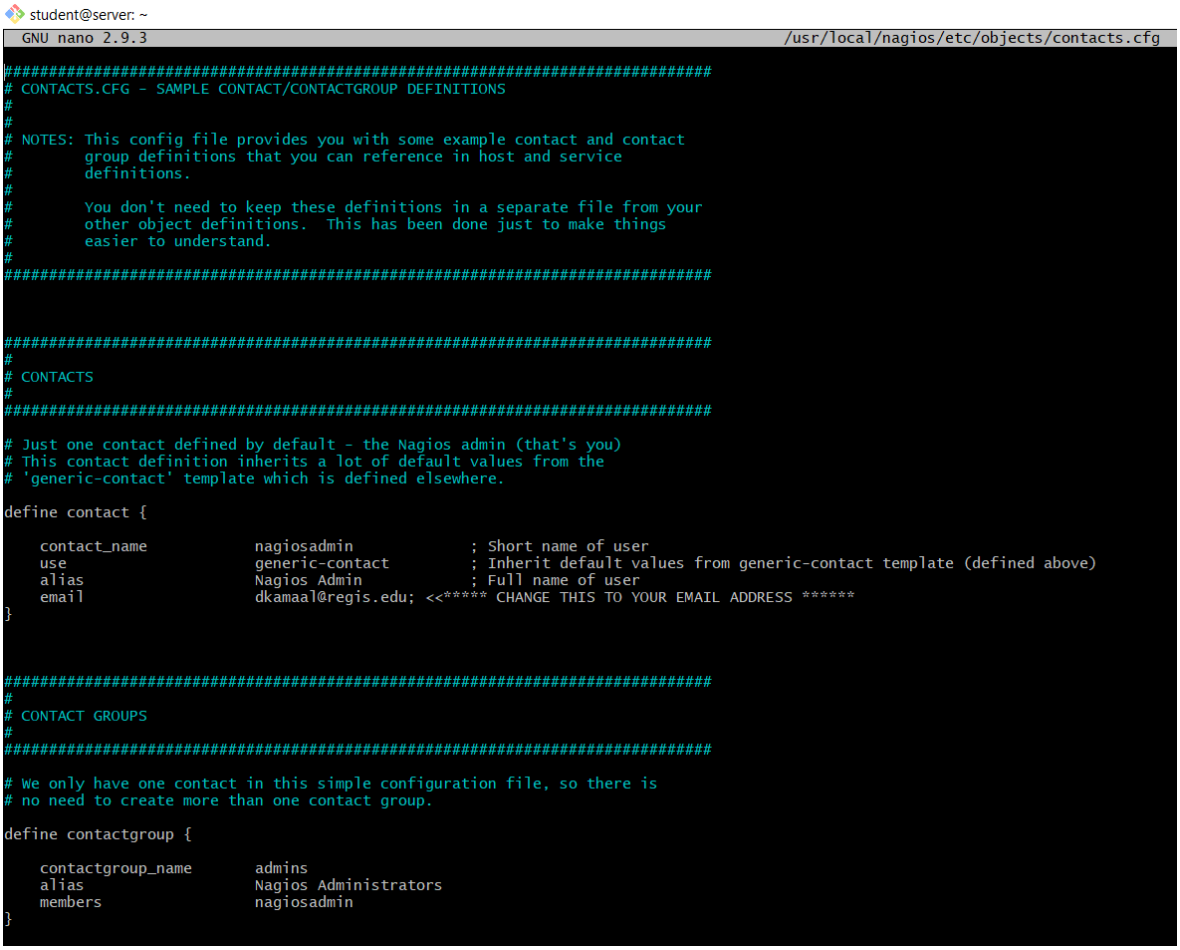

Fig 3.1. Contacts.cfg file

Command Configuration file is updated by adding check_nrpe

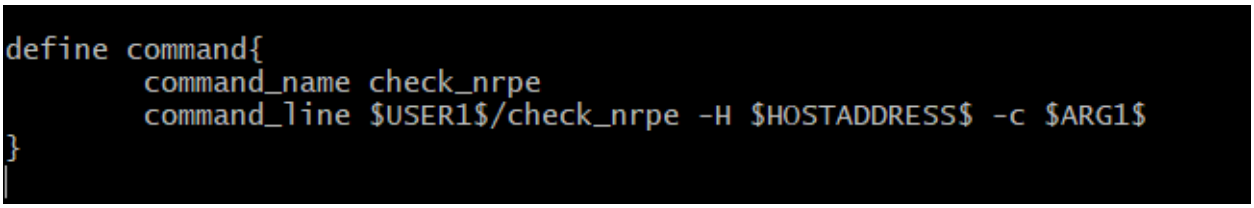

Fig 3.2. Command.cfg file

Nagios is then started using below command.

sudo systemctl start Nagios

Access Nagios Web Interface using below link for Server 07

http://192.168.76.37/nagios

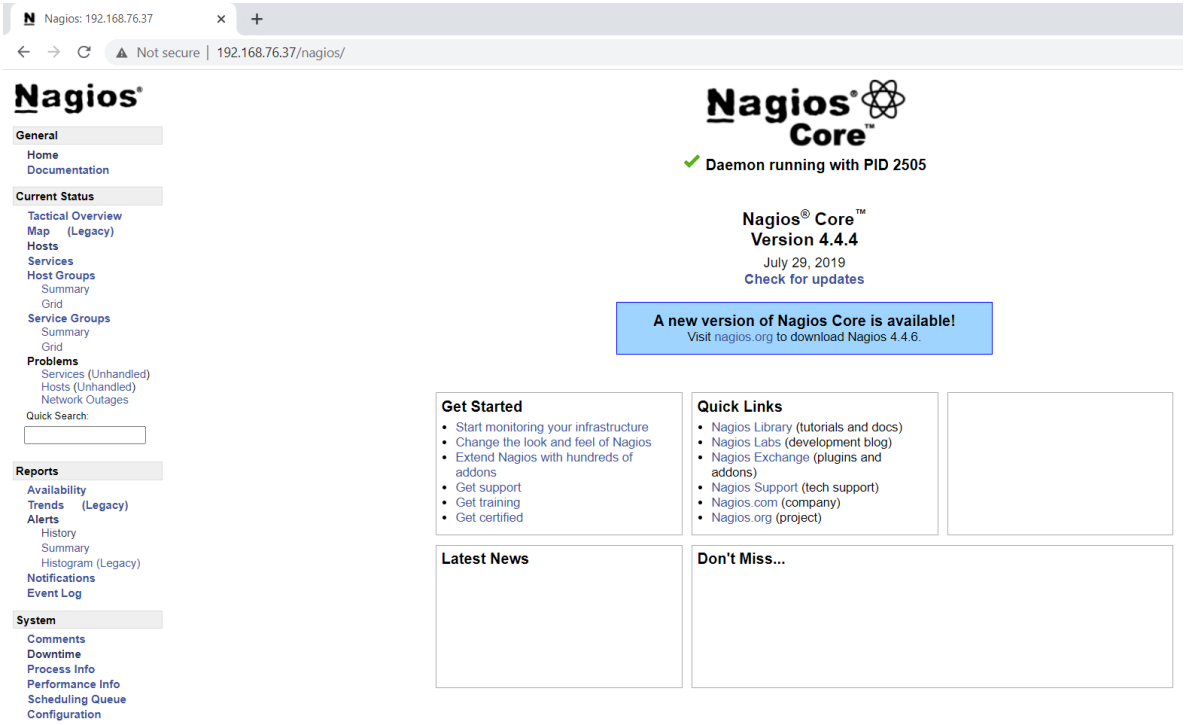

Fig 3.3. Nagios Web Interface

To monitor Host which is Server 02 Nagios Plugins and NRPE Daemon is installed on Server 02. First “nagios” user is added then plugins are installed and configured.

“nrpe.cfg” file is then updated with server address (Server 02) and allowed hosts IP (Server 07) and commands to check services are added.

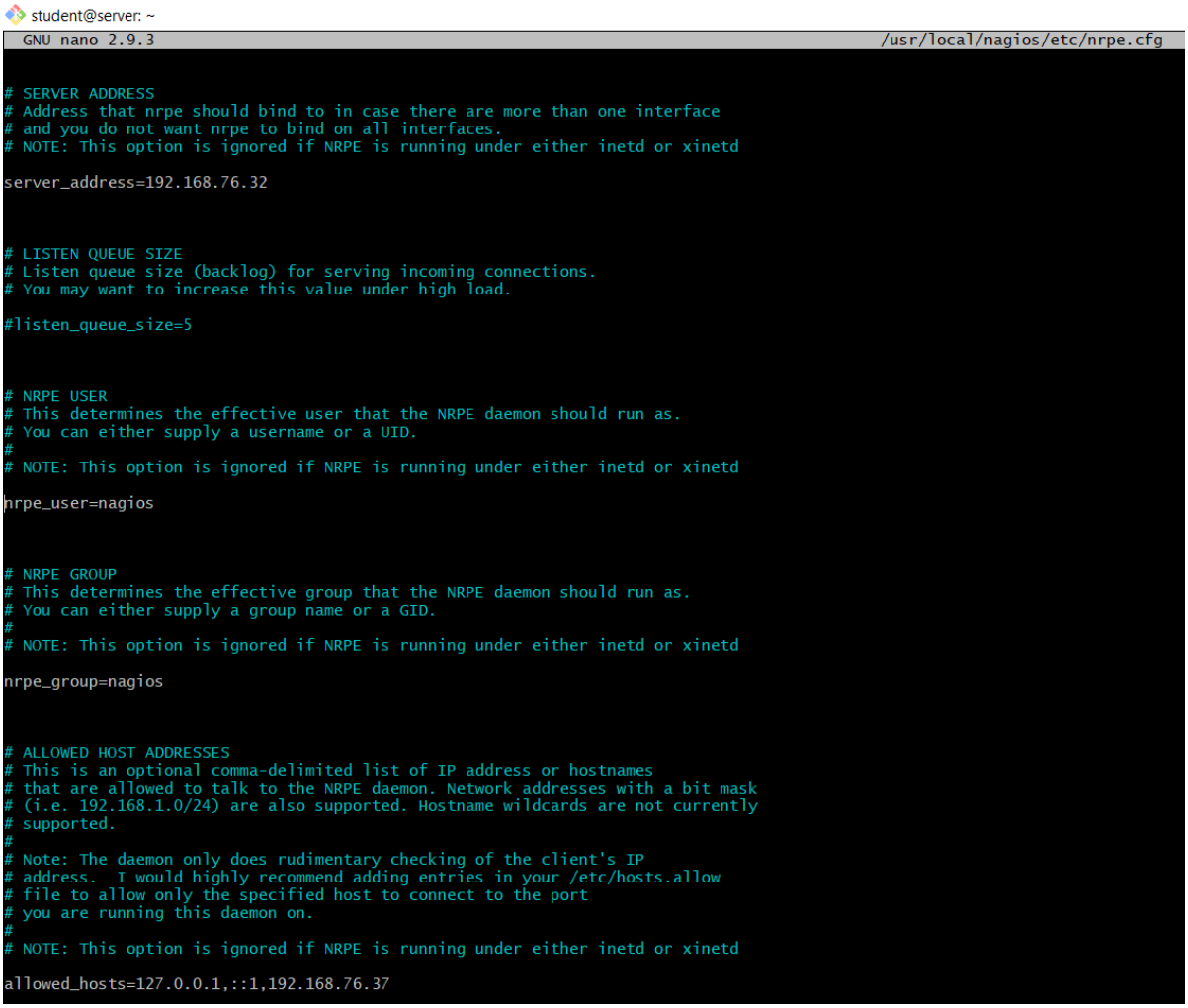

Fig 3.4. Server Address and Allowed Hosts in nrpe.cfg file

Fig 3.5 shows commands that are used to monitor different services. Commands are configured in command.cfg file on LocalHost (Server 07). “check_http” is used to monitor NextCloud service on Server 02 and “check_mysql” is used for monitoring NextCloud database.

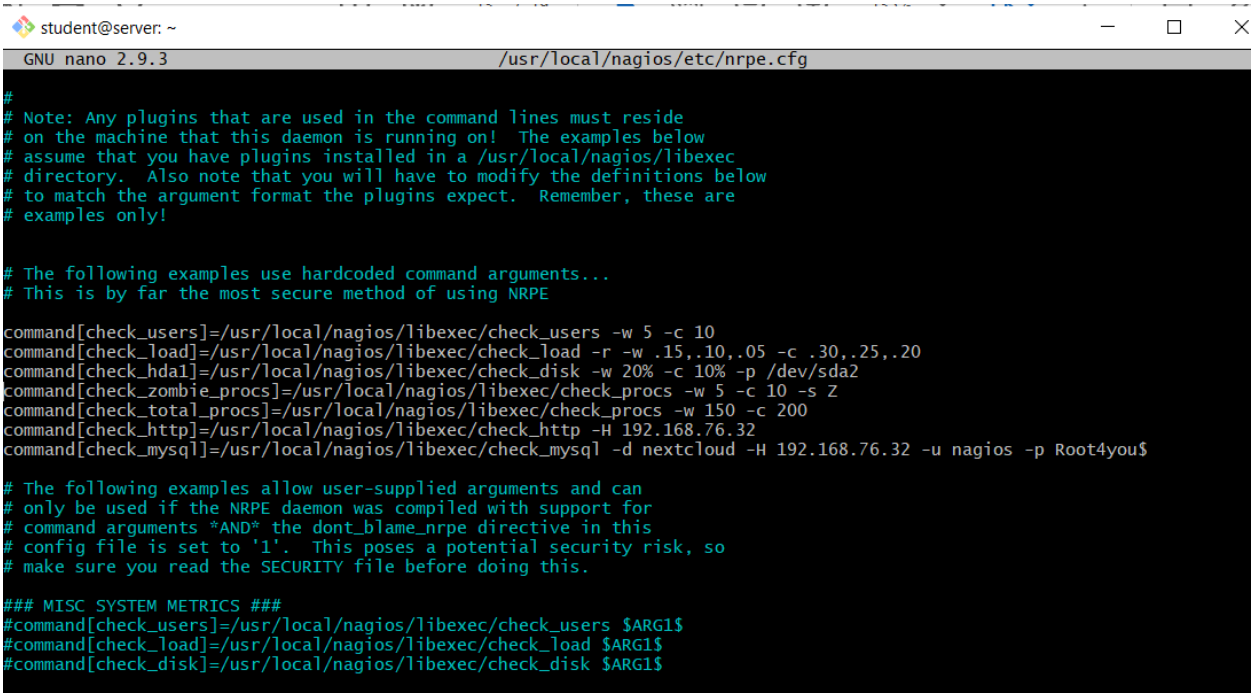

Fig 3.5. Commands in nrpe.cfg file

To check connection with host i.e. Server 02. Command is run on Server 07 as shown in Fig 3.6.

Version of Plugin is returned based on Plugin version installed on Server 02.

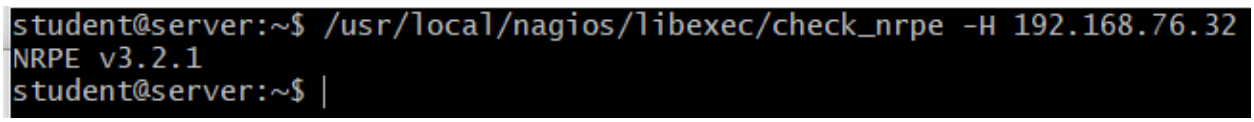

Fig 3.6 Checking connection of Server 02 with Server 07

Nagios Installation and configuration Recipe is available in **Appendix A.**

Monitoring Host (Server 02) with Nagios

Configurations files are added for each host which will have service details that are monitored on Host (Server 02). For each host separate configuration file is created. Fig 3.7 shows the configuration file example.

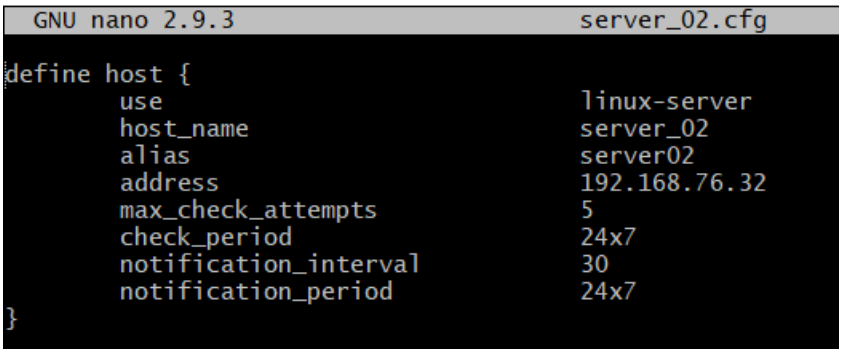

Fig 3.7. Host Configuration File on Server 07

Monitored services are then added to configuration files. Fig 3.8 and Fig3.9 shows NextCloud services that are monitored using Nagios on Server 02.

```
define service {
        use                             generic-service
        host_name                       server_02
        service_description             Load average
        check_command                   check_nrpe!check_load
}

define service {
        use                             generic-service
        host_name                       server_02
        service_description             /dev/sda2 free space
        check_command                   check_nrpe!check_hda1
}

define service {
        use                             generic-service
        host_name                       server_02
        service_description             NextCloud Web Service
        check_command                   check_nrpe!check_http
}

define service {
        use                             generic-service
        host_name                       server_02
        service_description             NextCloud Database Status
        check_command                   check_nrpe!check_mysql
}
```

Fig 3.8. Host (Server 02) Services that are being monitored.

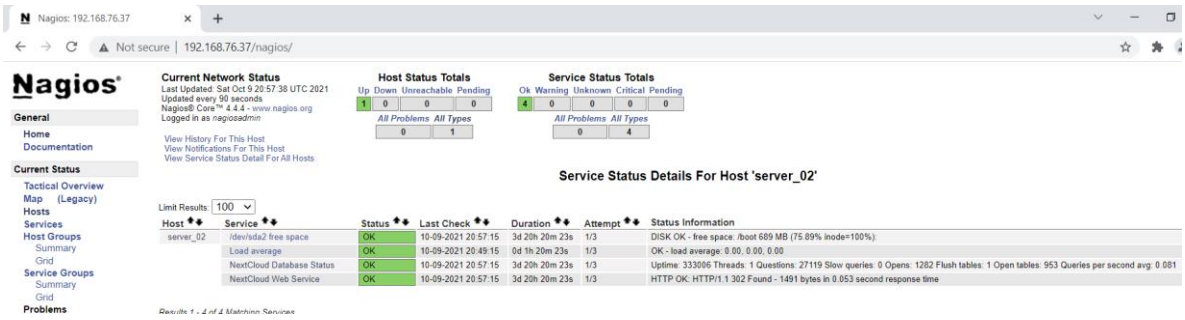

Fig 3.9 Nagios showing Serviced in OK status for Server 02 including NextCloud

System Architecture

System Architecture of NextCloud Monitoring using Nagios Monitoring Tool is shown in Fig 3.10

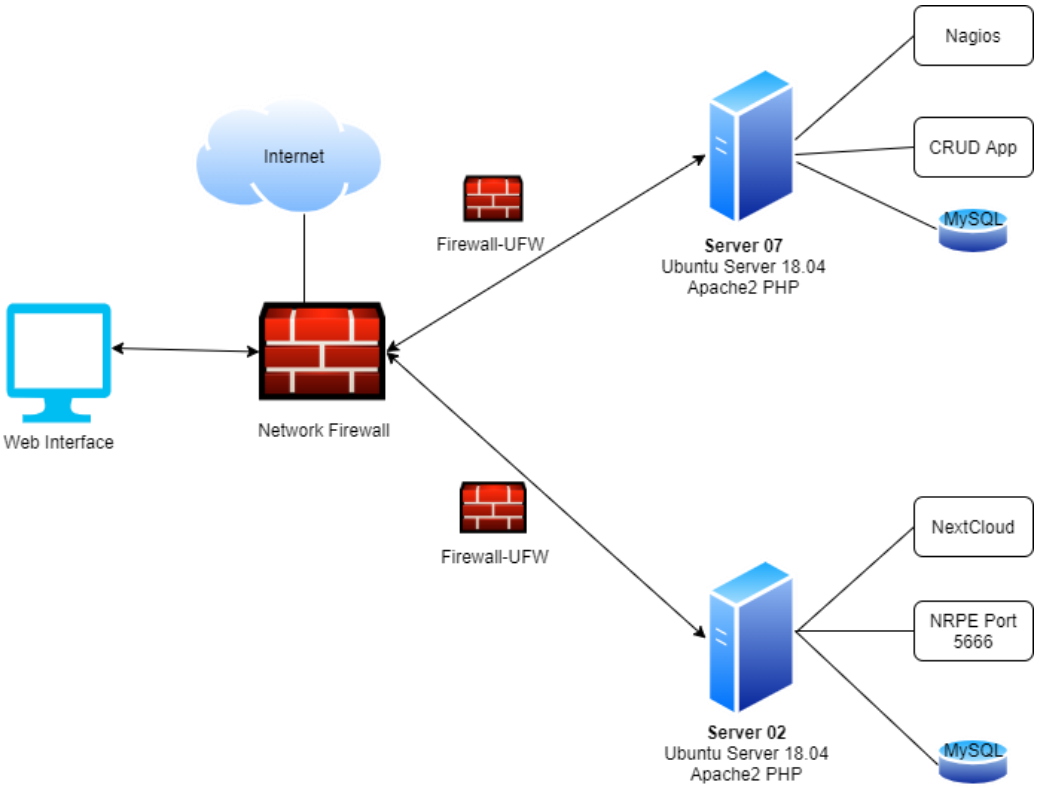

Fig 3.10 System Architecture

Compare Private and Public Cloud

	Private Cloud	**Public Cloud**
Definition	It is a cloud service provided over the internet or intranet to selected users for one organization.	It is a cloud service that is provided by third party provided and is shared among organizations over public internet.
Infrastructure	It is hosted on privately owned organization's Data Center. They are responsible to manage it.	It is hosted by public cloud providers such as Amazon (AWS), Google and Microsoft (Azure).
Security	Organization that owns data center is responsible for physical and cyber security.	It is considered more secure as they have latest security solutions, can easily attract talent and due to more hacking attempts security is hardened.
Cost Effectiveness	Private Cloud is considered more cost effective in most cases. Example of Evernote given in (Weinmann, 2016).	Upfront cost to house data in public cloud is low but organizations has to pay to access that data. If Public cloud is used as primary storage it can become expensive.

Results

Getting result is objective of study “The overall objective of a study is a statement of what the researcher, and perhaps the industrial participants, expects to achieve as a result of undertaking that study” (Runeson et al, 2012).

Data Collection

Data was collected using First-Degree, Second-Degree and Third-Degree methods. For deploying Web Application on LAMP Stack process was followed using Recipe and once Web Application was successfully deployed lesson learnt and best practices were documented. For NextCloud Installation online resources were referred along with working as team and observing the process, lesson learnt and best practices is documented in FieldBook **(Appendix C).** For Nagios Monitoring Installation we worked as a team and Installation process was observed and then documented as “Recipe” along with lesson learnt and best practices.

For NextCloud Service and Database Monitoring Data was collected by setting up services and adding commands in configuration files to get output of specific service. Tests were also performed by uploading and accessing data and getting results live for Load, Web Service availability and Database Performance. MySQL workbench was also used to see impact on MySQL Database when performing above tests.

Validity Procedures

Triangulation was used to increase the validity of research. “The need for triangulation is Obvious when relying primarily on qualitative data, which is broader and richer, but less precise than quantitative data” (Runeson et al, 2012). This case study encompasses topic that has both quantitative and qualitative data sources, triangulation played important role in getting different perspective and most of the study was done as a part of team. “Construct Validity” aspect of validity was used to make sure correct process is followed for research question under study. “Internal Validity” aspect was examines for Nagios Monitoring of NextCloud when uploading large amount of data increases load on the system. Considering the time limitation of this course case study was not done for prolonged time which is another aspect of adding validity to case study.

Analyses

Collected Data is summarized for analysis. Analysis of data started during data collection to make sure if more data is required. Analysis was done base on Case Study questions and data from Field Book **(Appendix C)** and is synthesized.

Private Cloud “NextCloud” Installation

NextCloud Installation started with issue where file was not getting downloaded directly using terminal on Server 02. Workaround to download file on personal laptop with internet connection and then transfer file using “scp” to Server 07 was used which allowed to continue with the Installation. Another important thing to remember is to install supported version of PHP which was 7.3 and above in the case of NextCloud V 22.2.0. Setting up database in MySQL was

straightforward with creation of "nextcloud" user to access the database with all privileges. NextCloud was tested by uploading files up to 500 MB and then accessing it. It turned out to be robust private cloud solution with no issues in accessing nextcloud database for read, write or update queries. NextCloud was also monitored using Nagios Monitoring Tool which is described in next sections.

Nagios Monitoring Tool Installation

Nagios Monitoring Tool Installation was little challenging as it requires multiple steps and setting of Server configuration files to access services on servers. Setting of Contact Configuration and Commands configuration is required on Nagios Server (Server 07). Nagios Remote Plugin Executer (NRPE) to monitor remote host was installed.

Configuring services for NextCloud was challenging as it requires creating MySQL user that has all privileges and can access it from Nagios Server (Server 07). After all configuration Nagios was restarted and Nagios Web Interface was launched using address http:192.168.76.37/Nagios. Web Interface showing Servers are shown in Fig 5.1.

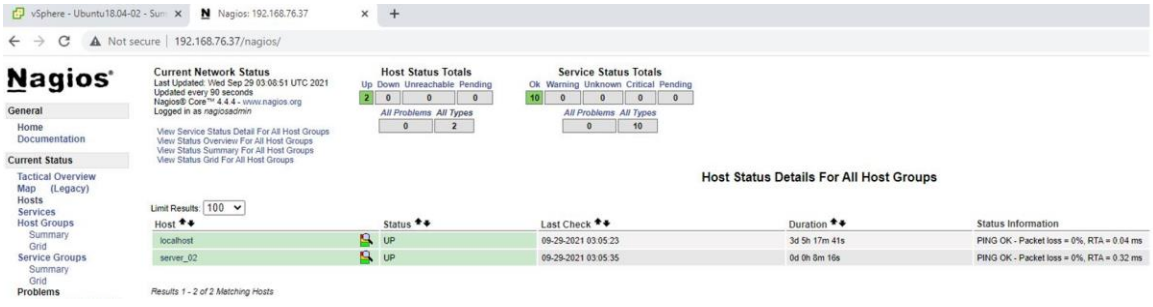

Fig 5.1. Nagios Web Interface showing localhost (Server 07) and server_02

NextCloud Private Cloud is installed on Server 02 and services to check database and web services were configured as shown below in Fig 5.2.

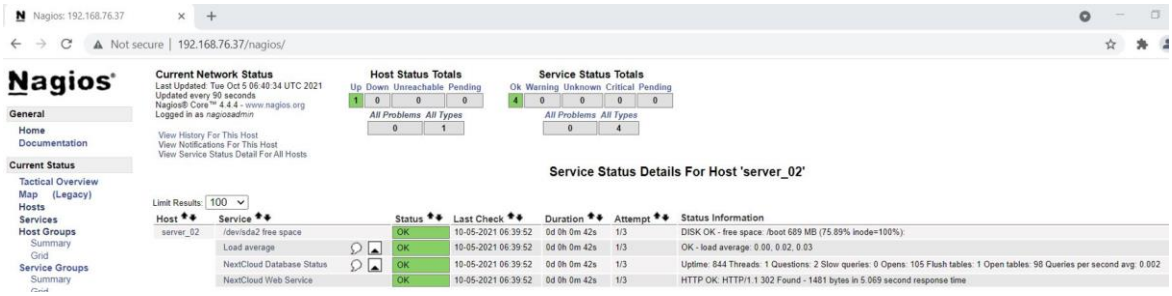

Fig 5.2. Services Monitored on Server 02 that includes NextCloud Web Service and Database.

Performance Testing

Testing was done to check the load on system when uploading files to NextCloud. Files were uploaded starting from 2 MBs to 500 MB and load was monitored using Nagios.

- Uploading 2-3 MB Files.

Load Status was OK in Nagios Web Interface and there was no latency observed accessing other services such as running commands on Terminal.

- Uploading 50 MB Files simultaneously on Multiple NextCloud Instances.

Nagios Monitoring tool warning threshold exceeded and it started reporting warning in web interface as showing in Fig 5.3.

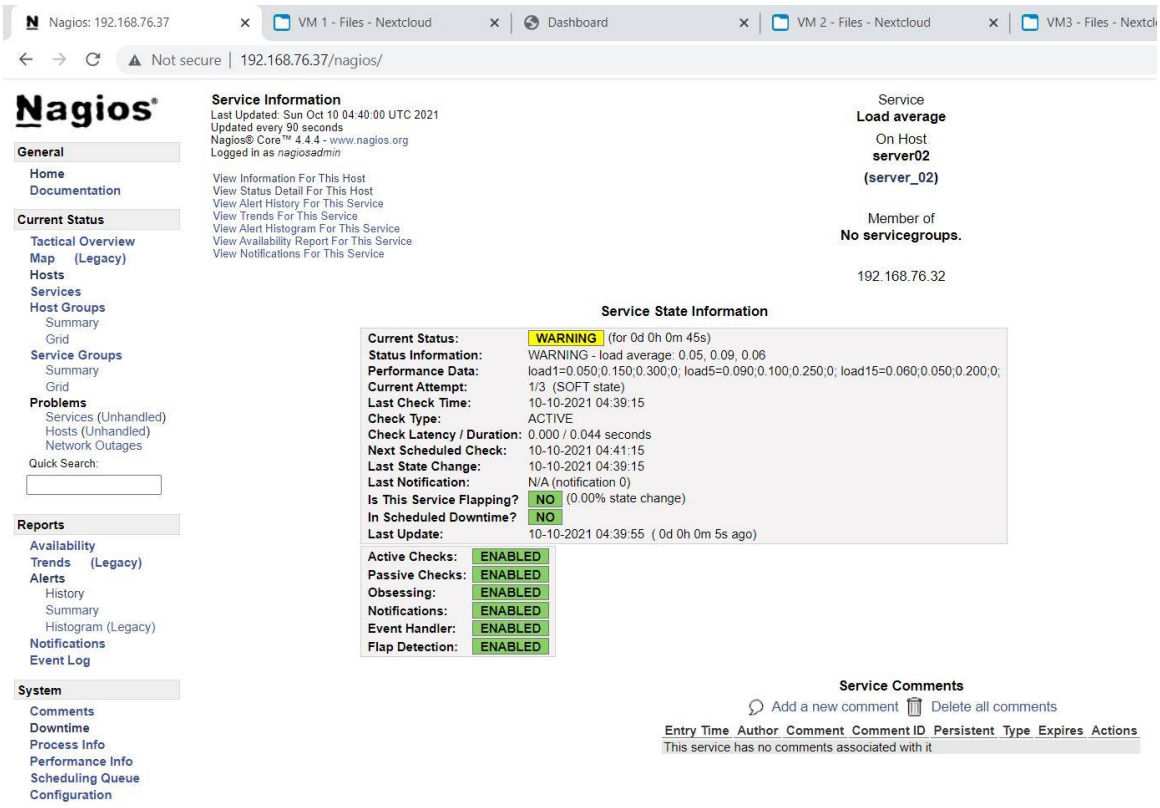

Fig 5.3. Load Warning in Nagios Web Interface.

- Uploading 500 MB Files and simultaneously accessing images on NextCloud.

When uploading large files and simultaneously accessing images on NextCloud made system load in Critical status and it was reported in Nagios Monitoring Tool as shown in **Fig 5.4**

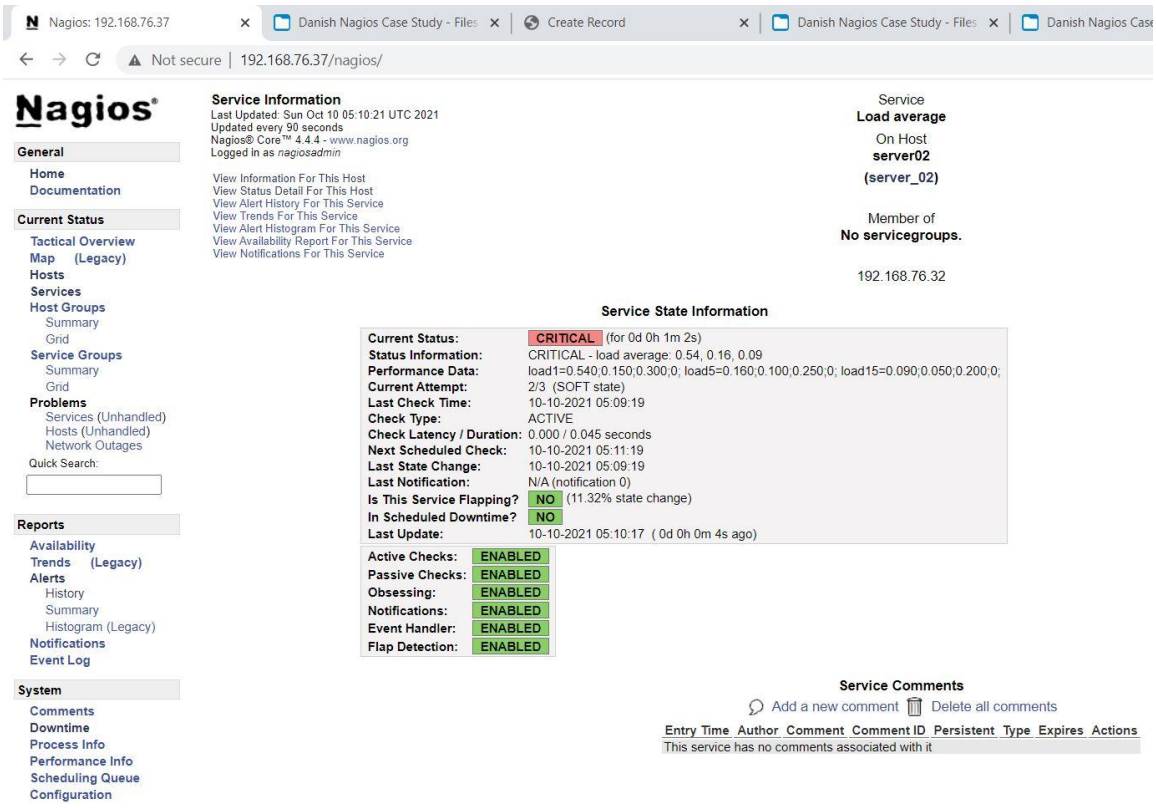

Fig 5.4. Nagios Web Interface showing Load in CRITICAL status

- NextCloud Web Service availability

NextCloud service was available all time during testing and was showing OK status in Nagios Monitoring Tool as shown in Fig 5.5.

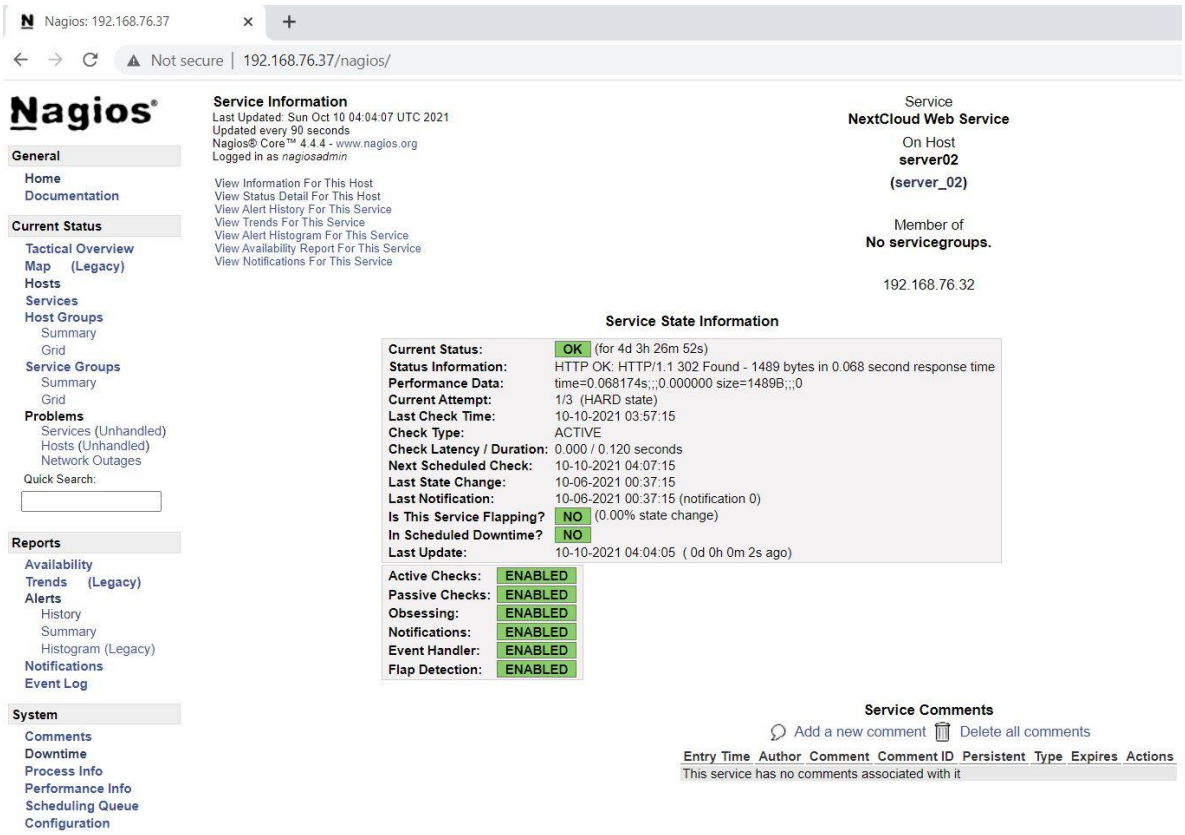

Fig 5.5. NextCloud Web Service running on Server 02 Local Host.

Database Status and MySQL Workbench

NextCloud database was also monitored and below variables were documented

- Queries per Second Average
- Queries (Statements run in stored procedures)
- Questions (Statements sent by server to the clients)

File Size	Queries per Sec Avg	Queries	Questions
85 MB Upload	0.165	59766	59765
500 MB Upload	0.17	61729	61728
500 MB Upload and Download Images	0.181	65668	65667

MySQL Workbench showed that performance of Database increased with more data getting uploaded in to it. It was at **95%** efficiency when I started uploading files, when 500 MB file was uploaded along with accessing images it became **98%** as shown in Fig 5.6.

Fig 5.6 MySQL WorkBench

Web Application on LAMP Stack on Regis Cloud

Web Application deployment was done on Regis Cloud Server 07. LAMP stack was used for it. Installing Apache2, PHP and MySQL was done using LAMP Recipe provided by Professor. All Installations were completed successfully without any issues. CRUD application was then downloaded to Server 07 and files were extracted at directory location /var/www/html. Virtual Host Configuration was done. Config.php file was updated with database credentials and then CRUD app ran successfully at localhost. CRUD functionalities were tested to ensure it works as expected. MySQL Workbench was used to monitor database efficiency and available memory as shown in Fig.6.1.

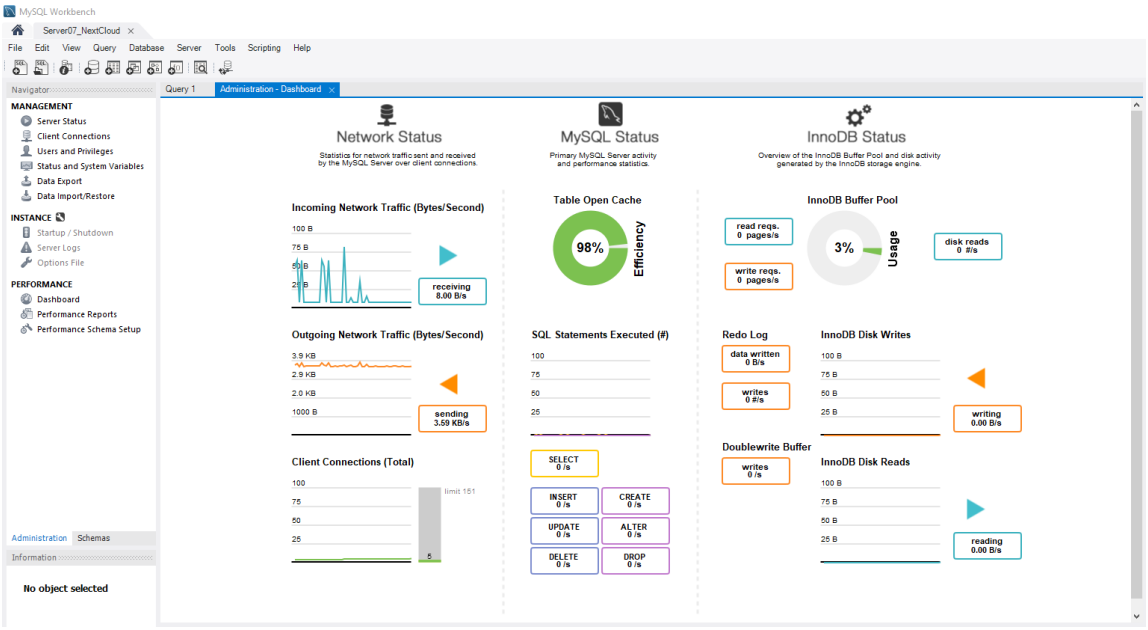

Fig 6.1. Monitoring Database using MySQL Workbench for Server 07.

Conclusions

As a team we were able to successfully Install Nagios Monitoring tool on Server 07 of Regis Cloud. At the same time we were able to Install NRPE (Nagios Remote Plugin Executer) on Server 02. We were able to prove that we can monitor services on Nagios Server (Server 07) and Remote Server (Server 02) with correct configurations in place along with commands defined to access those services data. To take it further we Installed Private Cloud “NextCloud” on Server 02 and proved that we can monitor Private Cloud running on remote server (Server 02) as well. To prove the Hypotheses Database and NextCloud Web Service were monitored and data was collected by uploading and downloading data to NextCloud.

CRUD app was installed successfully on Regis Cloud server and ran to prove that Web Application can be deployed after installing required technologies such as Apache2, MySQL and PHP. All the required configurations were done such as setting up database and configuring virtual host. All steps were documented. Comparison between Private and Public cloud was done which proved that each solution has its advantages and disadvantages. Organizations has to do assessment well in advance to make sure that they are opting for right cloud solution as mentioned in article by (Weinmann, 2016), it gives really good examples of organizations that are completely on Private Cloud or Public Cloud and in some cases using Hybrid Cloud Solutions. It was good to understand difference between Migrating application to cloud architecture and Migrating Cloud ready application to actual Private/Public Cloud.

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Appendix A

Research Project Recipe-Nagios

Research Project Recipe-Nagios.zip

Appendix B

Self-Signed SSL Certificate Recipe

Self Signed SSL Certificate Installation-Recipe.zip

Appendix C

Field-Book

MSSE 695 Fieldbook.zip