

PAPER • OPEN ACCESS

## Open Source network boot server for low-cost computer network learning

To cite this article: G Aryotejo and M Mufadhol 2021 *J. Phys.: Conf. Ser.* **1943** 012101

View the [article online](#) for updates and enhancements.

### You may also like

- [Nuclear forward scattering by the 68.7 keV state of  \$^{73}\text{Ge}\$  in  \$\text{CaGeO}\_3\$  and  \$\text{GeO}\_2\$](#)   
R. E. Simon, I. Sergueev, J. Persson et al.
- [Field control of single x-ray photons in nuclear forward scattering](#)  
Xiangjin Kong, Wen-Te Liao and Adriana Pálffy
- [New Focal Plane Array Controller for the Instruments of the Subaru Telescope](#)  
Hidehiko Nakaya, Yutaka Komiyama, Satoshi Miyazaki et al.



*Benefit from connecting  
with your community*

## ECS Membership = Connection

### ECS membership connects you to the electrochemical community:

- Facilitate your research and discovery through ECS meetings which convene scientists from around the world;
- Access professional support through your lifetime career;
- Open up mentorship opportunities across the stages of your career;
- Build relationships that nurture partnership, teamwork—and success!

**Join ECS!**

**Visit [electrochem.org/join](https://electrochem.org/join)**



# Open Source network boot server for low-cost computer network learning

G Aryotejo<sup>1</sup>, M Mufadhol<sup>1</sup>

<sup>1</sup>Department of Informatics Engineering, STEKOM University, Majapahit 605, 50192, Semarang, Indonesia

Corresponding author: guruh2000@yahoo.com

**Abstract.** Universities in developing countries must have innovative ways of educating students to anticipate higher education costs. Computer network courses require server and client computers that are not cheap in terms of hardware and software. The most vulnerable computer hardware is the Hard Disk Drive (HDD), while the very expensive operating system license cost often forces universities to keep using outdated operating systems. This study aims to build open source network boot server by using PXE, DNSMASQ, TFTP, Casper and NFS. The PXE, DNSMASQ, TFTP, Casper and NFS will work together to become Open Source Network Boot Server (OSNBS). We conducted a simulation to measure the client boot speed from the network by using five clients and two versions of the uBuntu operating system image that have the capability of being a tool for computer networking courses. In addition, the processor server and hard disk server will be further monitored and analyzed. The simulation were carried out using virtualization on a desktop computer. We found that all clients successfully booted from the network. The latest uBuntu operating system image can efficiently improve the use of server resources for the processor and hard drive. In addition, the use of open source operating systems and existing hardware have also significantly reduced IT expenditure. This finding reinforces that OSNBS is suitable for low-cost computer network learning.

## 1. Introduction

Information and Communication Technology (ICT) are evolving really fast [1], [2]. This very rapid growth, especially in the field of education, is difficult for developing countries to adopt. Implementation of ICT in education requires high costs and is difficult to implement [3]. High quality human resource shortages such as Network Administrators that has the ability to analyze computer network systems [4] and the high cost of software licenses are the causes of very slow ICT adoption in developing countries. Software is one of the reasons why ICT implementation costs are high, ranging from thousands to hundreds of thousands of dollars [5], [6]. The high cost of licensing software has resulted in educational institutions searching for cheaper alternatives to create a successful learning atmosphere [7]. Furthermore, computer hardware also doesn't come cheap. One component that is sometimes destroyed is the Hard Disk Drive (HDD), which causes many machines not to be used because they are not replaced by educational institutions [8]. This study aims to reduce software licensing costs and the use of Hard Disk Drive (HDD) by utilizing the Open Source system. PXE, DHCP, and TFTP will work together with Casper and NFS to become the Open Source Network Boot Server. Simulations are carried out using a virtual machine. We conducted the analysis of

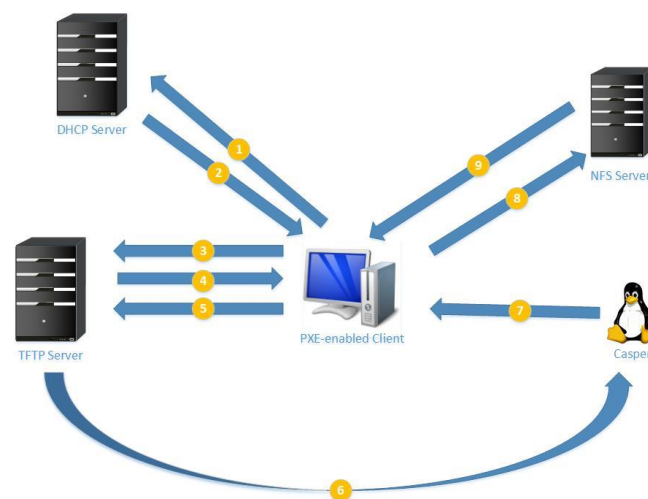


client boot times. Server performance is also measured by monitoring processor and hard drive usage during client boot. Furthermore, we also compared the server operating system licenses between Windows and Linux uBuntu.

## 2. Research method

### 2.1. Open source network boot system

The Open Source Network Boot System consists of five (5) protocols, namely Preboot Execution Environment (PXE), Dynamic Host Configuration Protocol (DHCP), Trivial File Transfer Protocol (TFTP), Casper, and NFS (Network File System). All these protocols are based on Open Source and must be installed on the server. The working concept is similar to the research conducted by G Aryotejo and Mufadhol [8]. PXE will search for the IP Address where the TFTP server is located. The TFTP server will send the operating system selection menu to the PXE client. Once the operating system is selected, the TFTP server will send a boot-loader file that matches the selected operating system via the Casper protocol. Casper will load the boot image from NFS into memory, after which the operating system will continue the boot process using NFS protocol.



**Figure 1.** The architecture of Open Source Network Boot System; (1) Request Network Information, (2) Receive Network Information, (3) Request Boot-Options Menu, (4) Receive Boot-Options Menu, (5) Request Operating System, (6) Request Boot Loader, (7) Receive Boot Loader, (8) Request file for Operating System, (9) Receiving file for Operating System

### 2.2. Development tools

**2.2.1. Syslinux, pxelinux, dnsmasq.** Syslinux is an open source boot loader that uses MS-DOS / FAT and has a function of running the Linux operating system. PxeLinux is a derivative of syslinux, which has the function to perform network boot and refers to the specifications of Intel PXE. Dnsmasq has a role as a DHCP Server and TFTP Server. Furthermore, the initial mechanism of OSNBS is begun by client computers with the PXE protocol will search for IP addresses on the network. The DHCP Server responds by sending

the necessary network configuration. Based on the network configuration information, the client computer then loads syslinux and pxelinux using TFTP protocol to carry out the initial stages of the boot process.

**2.2.2. Casper.** Casper acts as a hook so that initrams can mount the root file systems. Initramfs is a set of script files commonly found when booting a Debian-based Linux Live image. At boot time, the boot loader loads the kernel and the initrams into memory and runs the kernel. The kernel and Casper will search for initrams which mount the root and starts /init. The /init is a set of shell scripts that automatically run commands to continue booting the operating system. The above processes are executed after the initial boot process using syslinux and pxelinux.

### 2.2.3. NFS

Network File System is a file system protocol that has the ability to mount both remote and local directories. After Casper finishes running /init, it will mount the operating system image. After the image is mounted, the loading process for the operating system is switched from Casper to the kernel and continues loading the entire operating system into memory using the NFS protocol.

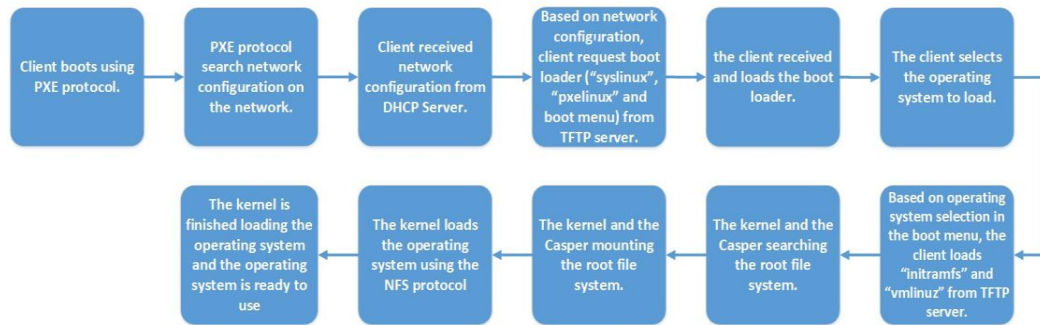
**2.2.4. Operating system.** OSNBS operating system using uBuntu Server 20.04.1 LTS. The operating system for clients is using the image of uBuntu Desktop 18.04.3 LTS and uBuntu Desktop 20.04.1 LTS. uBuntu is a Linux-based operating system that is known as a network operating system behind a mission-critical environment [9]. This proves that uBuntu can be used as a learning computer network.

**2.2.5. Virtual machine.** The simulation for this research was carried out using a virtual machine with the VMWare application. The host has an Intel Core i7 2.6 GHz processor, 8 GB of system memory, and 1TB SATA 3 SSD.

## 3. Methods

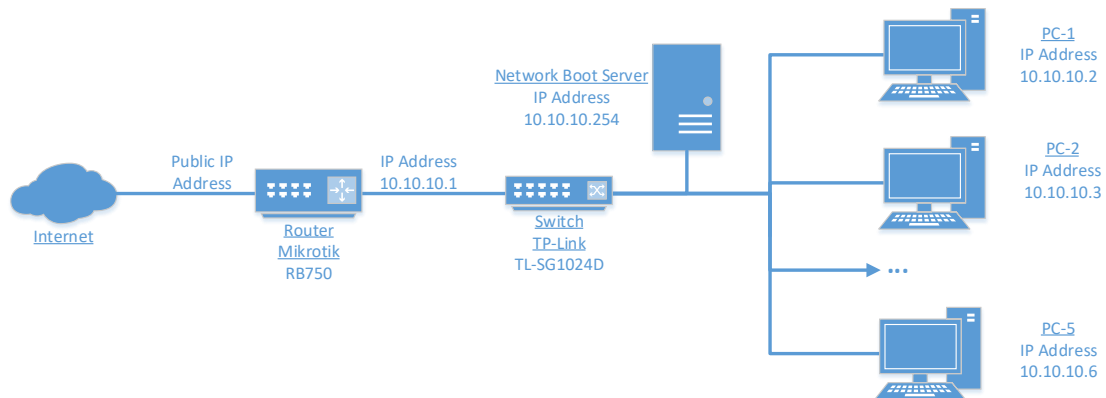
### 3.1. Open Source Network Boot System (OSNBS) and hardware setup

The server must be configured first, and the protocols required to build an Open Source Network Boot System (OSNBS) must be installed on the server. The OSNBS operating system uses uBuntu 20.04 LTS (Long-Term Support). uBuntu is an open source operating system based on Debian and is very popular among Desktop and Server users [2]. This Operating System must be updated to the latest version to patch existing security holes. The next step is that the server must have a fixed IP address. This is to prevent IP addresses from being assigned by the router and complicate IP address management. After that, the dnsmasq application is installed to provide DHCP and TFTP services to PXE clients. Before dnsmasq can be enabled, it must be configured with the network information to be used, including the network card interface, IP address range, and the PXE menu for clients. The TFTP server can be configured by simply creating a directory for tftp-root on the server. The next step is to install the NFS, so that the server has the capability to mount the image. The mount feature must be configured first to match the operating system specifications to be mounted. The next phase is installing and configuring the bootloader required to boot via PXE. The syslinux and pxelinux applications are installed first followed by copying the files ldlinux.c32, libcom32.c32, libutil.c32, vesamenu.c32 and pxelinux.0 to the tftp-root directory. The boot menu is also configured for the selection of the operating system to load into the PXE client. The final step is to extract the operating system image to the NFS server, as shown in Figure 2.



**Figure 2.** OSNBS method.

Building a stable network system requires basic knowledge of computer networks and monitoring systems [10]. The computer network must be configured in advance so that OSNBS can work properly. The network topology for OSNBS can be seen in Figure 3.



**Figure 3.** Steps to building an OSNBS server.

The configuration of the Network Topology of the OSNBS is shown in **Table 1**.

**Table 1.** The network configuration of the OSNBS network.

Hardware	IP Address	Gateway	DNS Server
Router Mikrotik RB750	10.10.10.1	Public IP Address	8.8.8.8
Switch TP-Link SF1024D	-	-	-
Network Boot Server	10.10.10.254	10.10.10.1	8.8.8.8
PC-1	10.10.10.2	10.10.10.1	8.8.8.8
PC-2	10.10.10.3	10.10.10.1	8.8.8.8

PC-5	...	...	...	...
		10.10.10.6	10.10.10.1	8.8.8.8

The hardware configuration for the virtual machines (VM) used for ONSBS and clients can be seen in table 2. The router we used was the Mikrotik RB-750. Mikrotik is a router manufacturer capable of turning an ordinary computer into an enterprise-class router, as well as the ability to create custom scripts on its router for different situations. This has resulted in Mikrotik being a router that is widely used in developing countries [11]. The clients for the simulation consist of 5 virtual computers that have the same hardware configuration. The virtual servers for ONSBS use different hardware configurations than the clients.

**Table 2.** Virtual machine configuration

Hardware	Purpose	CPU Cores	RAM (GB)	SSD Quantity	SSD (GB)	Ethernet (Gbit)
ONSBS VM	Network Boot Server	1	2	1	20	1
Clients VM	Clients (PC-1 ~ PC-5)	1	1	0	0	1

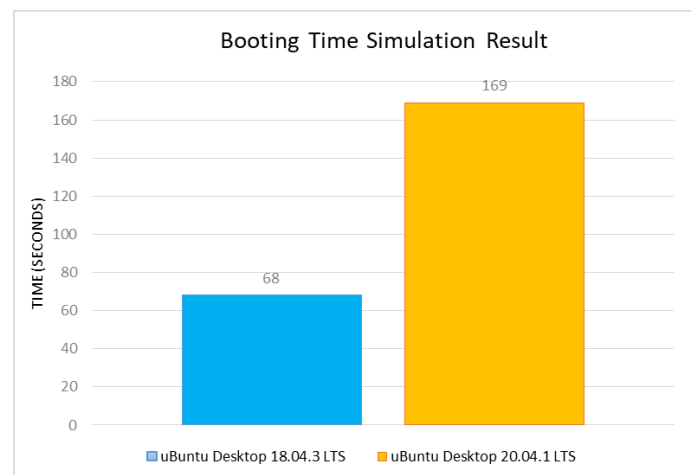
### 3.2. Simulation

We use two (2) open source operating system images for simulation, namely uBuntu 18.04.3 Desktop, which has a size of 1.93 GB, and uBuntu 20.04.1 Desktop which has a size of 2.59 GB. This simulation will measure the boot time of five clients simultaneously using the two operating system images above. Measuring boot time is done by installing the SnagIt Capture application on the host of the virtual machine and using the Desktop Capture feature with the final result is a video. The boot time is obtained by calculating the video time frame starting from the operating system selection menu until entering the uBuntu Desktop. This calculation is performed for each client to obtain boot time data for each client. These data will be averaged to obtain boot times for five clients. The shutdown time is obtained by the same method as the boot time. The difference is that data retrieval starts from pressing the shutdown button on uBuntu Desktop until the client shuts down. The measurements for maximum data transfer during client boot are performed using an application called iostat on the server. This application will display the input and output transactions for the processor and hard disk drive every second. Measurement to determine processor usage during client boot is done using the htop application on the server. This application calculates the average processor usage in 1, 5 and 15 minutes. We recorded average processor usage during client boot at 1 minute intervals and took the highest numbers as data.

## 4. Result and Discussion

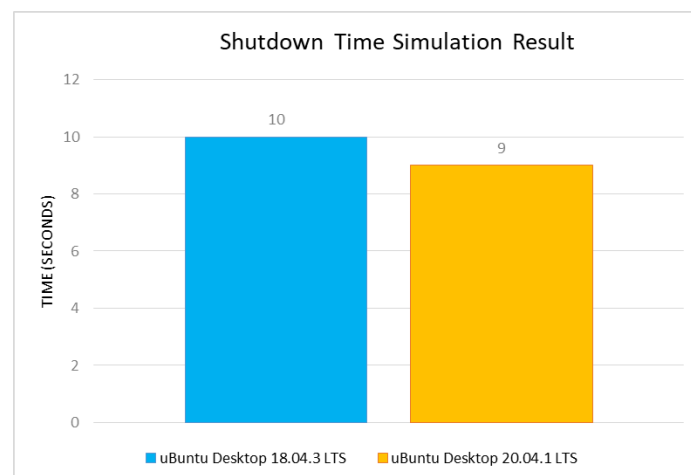
Each version of the uBuntu operating system has its own configuration for the ONSBS's protocols. Even though the protocols configuration has been adjusted to the version of the operating system, if there is a hardware difference on the client, it can make the PXE client unable to boot. The best way to know whether the operating system can be used is by trial and error. The selected operating system image is tested directly with the PXE client. Problems generally occur in the Casper protocol. If there is a misconfiguration or the client system memory is insufficient, the client boot process will stop at the Casper protocol. If there are no problems in the Casper protocol, then the next problem is in the NFS protocol. In most cases, the problem with the NFS protocol is a misconfiguration in the operating system image directory information. This information error causes the client to display a directory not found error message.

The first simulation is to compare the boot times for uBuntu 18.04.3 Desktop and uBuntu 20.04.1 Desktop image. The results in figure 4 shows that the uBuntu 18.04.3 Desktop image took 1 minutes 08 seconds (68 seconds), while the uBuntu 20.04.1 Desktop image took 2 minutes 49 seconds (169 seconds).



**Figure 4.** Booting Simulation Result; uBuntu Desktop 18.04.3 LTS had a faster boot time (68 seconds) than uBuntu Desktop 20.04.1 LTS (169 seconds)

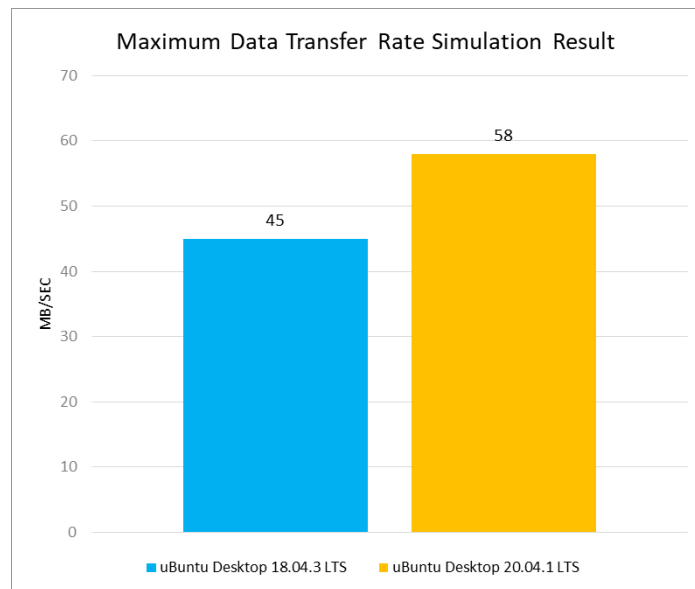
The second simulation is to compare the shutdown time with the same operating system image. uBuntu 18.04.1 Desktop takes 10 seconds to shutdown, while ubuntu 20.04.3 Desktop takes 9 seconds, as depicted in figure 5.



**Figure 5.** Shutdown Time Simulation Result; uBuntu Desktop 18.04.3 LTS had a lower shutdown time (10 seconds) than uBuntu Desktop 20.04.1 LTS (9 seconds)

The third simulation is to measure the maximum data transfer on the server while the PXE client is booting. The results in figure 6 show that the maximum data transfer for the uBuntu 18.04.1 Desktop image

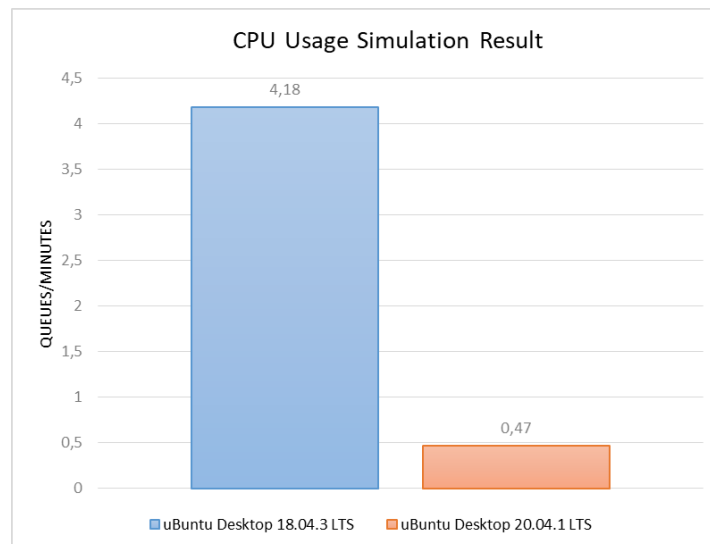
is 45 MB / sec, while the uBuntu 20.04.3 Desktop image is 58.25 MB / sec. This proves that the uBuntu 20.04.3 image is capable of maximizing server HDD resources.



**Figure 6.** Maximum Data Transfer Simulation Result; uBuntu Desktop 18.04.3 LTS had a lower transfer rate (45 seconds) than uBuntu Desktop 20.04.1 LTS (9 seconds)

The fourth simulation is to measure how many CPU resources are used during pxe booting. The results show that the CPU usage for the uBuntu 18.04.1 Desktop image was 4.18 queues/minute, while the uBuntu 20.04.3 Desktop image registered 0.47 queues/minute. These results indicate that the uBuntu 20.04.3 Desktop image is significantly more efficient at using server CPU resources.

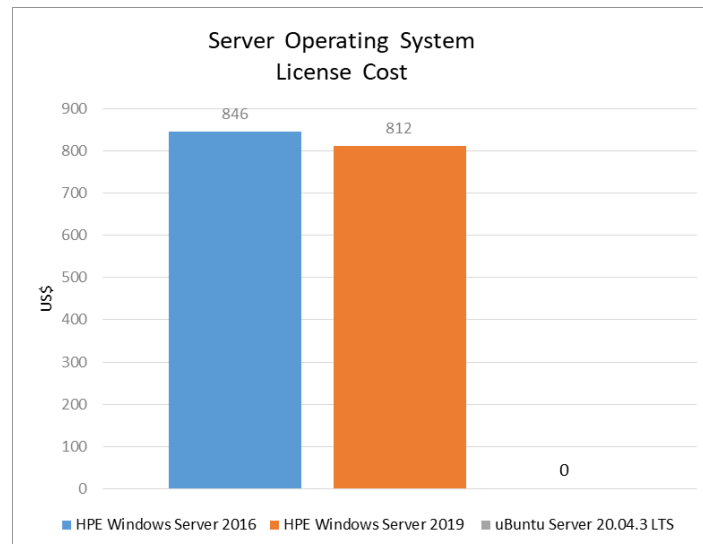




**Figure 7.** Maximum CPU Usage Simulation Result; uBuntu Desktop 18.04.3 LTS had a higher CPU usage (4.18) than uBuntu Desktop 20.04.1 LTS (9 seconds)

Previous researches to analyze boot network capabilities has been carried out by several authors. Galloway. *et al.*, 2018 [12] presents the comparison of Virtual Machines in a stationary state and a live migration state using the local hard disk and network boot system. The authors found that the network boot system reduces maintenance costs and electricity consumption but highly dependent on the network infrastructure. Davide B. *et al.*, 2015 [13] created a network boot application called BootTorrent based on peer-to-peer protocol. Unfortunately, both authors did not mention the name and version of the operating system used in the simulation.

The expenditure cost for a server operating system license is enormous. The price for the Windows-based server operating system, namely HPE Windows Server 2016, is IDR 12,500,000 or US\$ 846.02 [14], while the HPE Windows Server 2019 is IDR 11,990,000 or US\$ 811.50 [15] at an exchange rate of IDR 14,775. The license for Linux uBuntu 20.04.3 server is open source which is free of charge. The difference in license prices between Windows and Linux uBuntu is quite significant, and educational institutions in developing countries will tend to choose an open source operating system to reduce IT spending.



**Figure 8.** License Cost of Server Operating System; Windows servers have higher licensing fees than Linux uBuntu.

## 5. Conclusion

In this research, we designed and developed the OSNBS method. Expenditure costs can be greatly reduced because there are no software and hardware licensing costs using Open Source and utilizing existing hardware. We have done a simulation to evaluate the boot performance of the PXE Client from OSNBS using two (2) different operating systems, namely uBuntu Desktop 18.04.1 LTS and uBuntu Desktop 20.04.3 LTS. The first simulation shows that uBuntu Desktop 18.04.1 LTS has a faster boot time than uBuntu Desktop 20.04.3 LTS. In the second simulation, we measured the shutdown times for the two operating systems, and the results showed a difference of 1 second. The third simulation shows that ubuntu 20.04.3 Desktop image is able to maximize the performance of SSD on OSNBS and the last simulation shows that the ubuntu 20.04.3 image increases the efficiency of server CPU resource usage by 880%. The findings above indicate that OSNBS can be used in educational institutions in developing countries and become the foundation for the development of further research on the open source network boot system.

## Acknowledgment

This research is supported by the Department of Informatics Engineering, STEKOM University, Semarang, Indonesia, under the supervision of Research Institutions and Community Service of STEKOM University, Semarang, Indonesia.

## References

- [1] Avram M G 2014 *Procedia Tech.* **12** 529-534
- [2] Aryotejo G, Kristiyanto D Y and Mufadhol M 2018 *J. Phys.: Conf. Ser.* **1025** 1
- [3] Rekha V S and Adinarayanan V 2014 *7th Int. Conf. Contemp. Comput. IC3 2014* **2** 56–61
- [4] Mufadhol M, Aryotejo G and Wibowo A 2017 *Telecom. Comp. Elect. and Cont. (Telkomnika)* **15** 1 464-470
- [5] Lee G, Maryska M, Doucek P and Kunstova R 2012 *Int. Conf. Electron. Inf. Commun. Eng. (EICE*

- 2012) **55** 47–51
- [6] Pankaja N and Raj M 2013 *Am. J. Eng. Res* **02** 07 2320–847
  - [7] Akande A O and Belle V J P 2016 *ACM Int. Conf. Proceeding Ser* **1**
  - [8] Aryotejo G and Mufadhol M 2020 *J. Phys. Conf. Ser.*, **1524** 1012101
  - [9] Mishra M K and Goyal D 2014 *Int. Journ. of Enginee. Resea. & Techno. (IJERT)* **2** 8 1808–1812
  - [10] Mufadhol M, Aryotejo G and Kurniawan D E 2019 *Proc. 2019 2nd Int. Conf. Appl. Eng. ICAE* **1** p. 8–13
  - [11] Aryotejo G and Mufadhol M 2019 *J. Phys. Conf. Ser.* **1217** 1 012126
  - [12] Galloway M, Loewen G, Robinson J and Vrbsky S 2018 *IEEE Int. Conf. Cloud Comput. CLOUD* **1** 740–745
  - [13] Davide B and Trentini A 2015 *Proceed. of the 12th Interna. Conf. Appli. Computi.* **1** 73-79
  - [14] Bhinneka.com, “HPE Windows Server 2016.” [Online]. Available: <https://www.bhinneka.com/hpe-windows-server-2016-p00487-b21-sku3321591565>. [Accessed: 06-Sep-2020]
  - [15] Bhinneka.com, “HPE Windows Server 2019.” [Online]. Available: <https://www.bhinneka.com/hpe-windows-server-2019-p11058-b21-sku3326634983>. [Accessed: 06-Sep-2020]