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Enhancing Data Storage and Access in CSN Labs with Raspberry Pi 3B+ and Open Media Vault NAS

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Abstract: The purpose of this study was to devise a more efficient system for data storage and exchange in the Computer System and Network (CSN) Laboratory at Ibn Khaldun Bogor University. Open Media Vault (OMV) software and Raspberry Pi 3B+ were employed to establish a Network Attached Storage (NAS) system. The performance and file transfer speeds of the Raspberry Pi were evaluated in the context of this implementation. The implementation of the NAS system was intended to offer students of the CSN laboratory swifter and more efficient access to data, thereby reducing dependence on USB media. The findings of this study could hold substantial implications for enhancing the efficiency and effectiveness of data storage and exchange in educational environments.

Keywords: Network Attached Storage (NAS); Open Media Vault (OMV); Raspberry Pi 3B+

1 Introduction

The limited and inefficient data storage and exchange in the Computer System and Network (CSN) Laboratory at Ibn Khaldun University of Bogor has necessitated a more cost-effective and efficient solution [1].

In light of these issues, a solution was formulated to develop an additional storage service. One of the most viable alternatives was selecting hardware capable of supporting data storage services. Network Attached Storage (NAS) addresses the issues of expensive storage devices and ineffective USB usage for data exchange. NAS does not require substantial hardware resources to exchange files. NAS refers to a server with an operating system specifically designed to meet data file needs. NAS is accessible over a local area network via the TCP/IP protocol. NAS can be conceptualized as a computer system primarily built to perform file storage server functions. Compared to file storage servers, NAS offers faster and more efficient data access, simpler and easier management, and configuration.

NAS allows access through selectable protocols such as Network File System (NFS) or Common Internet File System (CIFS). The NAS in this study utilized the Server Message Block (SMB) protocol, selected as the access protocol, which operates on the Windows Operating System [2]. Developing a server specifically designed to handle data file needs and utilizing Network Attached Storage (NAS) could resolve file distribution problems. The advantages of NAS as a network storage, media processing, and data exchange server are well suited to replacing USB usage so that it becomes effective. The resources available in the CSN laboratory would be helpful in developing NAS for storing and accessing files [3–7]. Open Media Vault is a program used to create NAS servers based on Debian Linux. OMV is a NAS system that offers Secure Shell (SSH), FTP, CIFS/SMB, Digital Audio Access Protocol (DAAP) audio server, Remote Sync (RSync), BitTorrent client, and other services [8, 9]. The Raspberry Pi 3B+ was used as a cost-effective alternative device for NAS implementation [10, 11]. The Raspberry Pi 3B+ enables NAS operation [12]. Using existing components and network resources backed by the Informatics Engineering Study Program CSN Laboratory environment at Ibn Khaldun University Bogor.

Switches, routers, and access points were required as internet media devices on the local network utilizing Wireless Local Area Network (WLAN) for CSN laboratory users to easily access data using technological means such as smartphones or laptops on the same network [13–15]. The Raspberry Pi mainboard was used as the NAS data storage media implementation target.

A study was conducted on using the Raspberry Pi 3B+ as an NAS data storage medium target. The study included upload and download tests from client to server and server to client, as well as NAS performance tests. NAS using a Raspberry Pi 3B+ could be developed, which this study aimed to do: determining if the Raspberry Pi 3B+ could operate NAS services; parameters testing NAS access rights from client to server and server to client; accessing various platforms; ascertaining upload and download file transfer rates from client to server and server to client; and testing NAS performance on the Raspberry Pi 3B+ using an HDD as a data storage medium [16]. Successfully creating an NAS service using a Raspberry Pi in the CSN laboratory offers an alternative for choosing NAS devices and software in operating NAS services, given the difficulty in studying file servers and expensive license availability, increasing data exchange process efficiency replacing the inefficient role of USB and purchasing expensive PC computers, providing ease of NAS management operation in a small space. The outcomes of this study could have significant implications for data exchange and storage effectiveness and efficiency in educational settings.

2 Methodology

This study employed an action research approach, involving a systematic and iterative process of identifying a problem, developing and implementing a solution, and testing and evaluating the solution's effectiveness. The stages or framework of thought used in the research are shown in Figure 1:

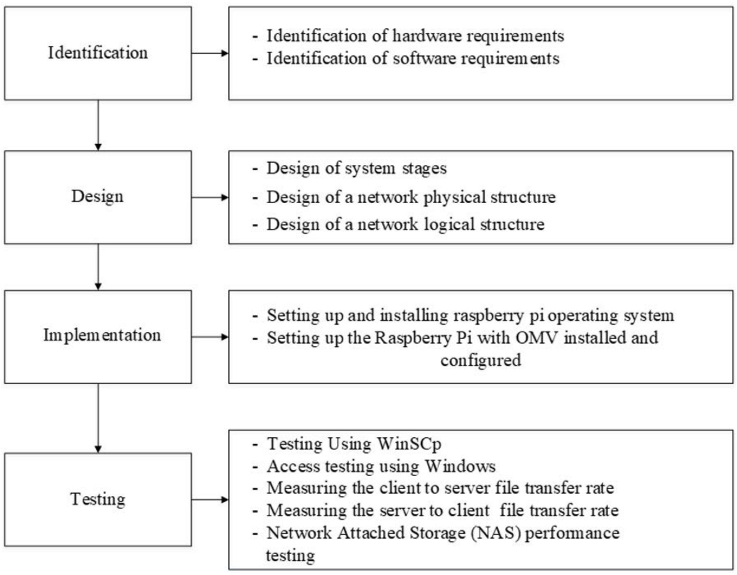

Figure 1. Research stages

A. Identification

At this initial stage, any requirements to design the system were identified. The identification steps were divided into two parts: identifying software requirements and hardware requirements.

B. Design

The system design and network topology used in this stage were based on those used in the CSN laboratory in the Rise-Center building of the Informatics Engineering study program, Faculty of Engineering, Ibn Khaldun University, Bogor, with the addition of the Raspberry Pi as a Network Attached Storage (NAS) feature.

C. Implementation

Implementing each step from planning to execution was necessary during this phase. Specifically, the Open Media Vault (OMV) program was installed and configured on the Raspberry Pi, along with the NAS.

D. Testing

Testing implemented in the previous stage was conducted at this stage:

(1) Testing WinSCP NAS access.

The WinSCP program for Windows 8 was used to test NAS and determine each client's access permissions to the NAS according to the configuration in the OMV software.

(2) Access testing using Windows, Ubuntu Linux, and a smartphone.

Multiple platforms, including Windows, Linux, and Android cellphones, were used for testing.

(3) Measuring client to server file transfer rate.

The DiskBoss program tested the speed of file transfers from client to server using one client and five different file sizes. The speed (s) formula, data (A) divided by transfer time (T), was manually calculated to determine whether the received speed value was accurate.

(4) Measuring server to client file transfer rate.

To assess file download speed from the server to the client, the DiskBoss software test used one client and five different file sizes. The speed (s) formula, data (A) divided by transfer time (T), was manually calculated to determine whether the received speed value was accurate.

(5) Network Attached Storage (NAS) performance testing.

NAS performance testing on the Raspberry Pi 3B+ determined the speed stability of the NAS using the Raspberry Pi 3B+ by running the NAS on the Raspberry Pi 3B+ for 7 days. To determine the speed stability of the NAS, a file transfer scenario from client to server using the same file was performed each day by one client using one folder. The speed (s) formula, data (A) divided by transfer time (T), was manually calculated to determine whether the received speed value was accurate.

3 Results

The results of the research are explained in more detail based on the stages: identification of hardware requirements, identification of software requirements, design, and implementation. They are discussed as follows:

3.1 Identification

Based on the existing problem, assessing the use of the Raspberry Pi 3B+ as an Open Media Vault NAS server was required, as previously described. These needs included:

3.1.1 Identification of hardware requirements

To enable using the Raspberry Pi 3B+ as an Open Media Vault (OMV) NAS server for Network Attached Storage (NAS) services, the hardware in Table 1 was required:

Table 1. Identification of hardware requirements

Hardware Name	Function
Raspberry pi	Serving as the NAS system motherboard
Micro SD	To serve as storage for the Open Media Vault repository and Raspbian operating system software
Docking station	As a connector from the hard disk to the Raspberry Pi
Hard disk	File storing apparatus
Personal Computer (PC)	As a client
Smartphone android	As a client
UTP Cable Category (5e)	As a means of communication between the switch and router, and the Raspberry Pi and router
RJ 45	Plug for an Ethernet wire
Monitor PC	Showing Raspbian
Keyboard	On a Raspberry Pi, typing in the Command Line Interface (CLI)

3.1.2 Identification of software requirements

To enable using the Raspberry Pi 3B+ as an Open Media Vault NAS server for Network Attached Storage (NAS) services, the software in Table 2 was required:

3.2 Design

The design stage was based on the topology already used in the CSN laboratory of the Informatics Engineering study program, Faculty of Engineering, Ibn Khaldun University of Bogor, with the addition of Network Attached Storage (NAS) using a Raspberry Pi.

3.2.1 Design of old structure

The CSN laboratory students' prior data interchange procedure was ineffective because it relied on USB media. To slow data interchange speed, students had to physically connect USB media devices to computer equipment. Figure 2 shows the design of the old structure.

Table 2. Identification of software requirements

Hardware Name	Function
RaspiOS buster armhf lite.img	The Open Media Vault (OMV) program management operating system.
Open Media Vault (OMV) versi 5.6.26-1 (Usul)	The administration operating system for NAS.
Balena Etcher	To put the RaspiOS operating system into the SD card as a storage medium, the SD card must be flashed.
PuTTY	To connect a raspberry pi remotely.
Chrome	To view the Open Media Vault Web Graphical User Interface (GUI), configure it, and keep track of it (OMV).
OS Linux Ubuntu 20.04.4 LTS	On a Personal Computer as a customer PC.
Easy FTP	Using a client software on an Android phone.
WinSCP	Application for universal Windows HDD access.
Windows	A host operating system.

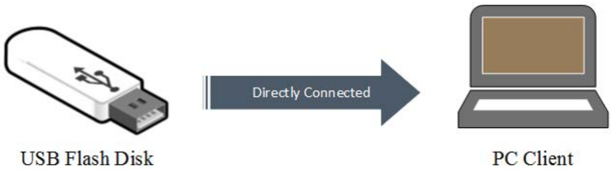

Figure 2. Design dated structure

3.2.2 Design of proposed structure

The proposed design structure creates an NAS service as a more effective and faster solution for the data exchange process because the NAS system is accessed via the IP address assigned to the Raspberry Pi NAS device connected to the local network. Users only need to create an account and know the NAS IP address, eliminating the need to directly connect USB media devices to computers and making the data exchange process more effective and faster. Figure 3 shows the proposed design structure.

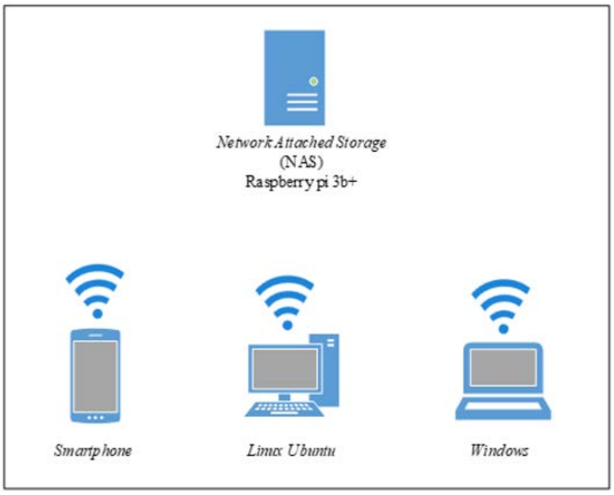

Figure 3. Design structure that is being proposed

3.2.3 Design of system stage

The installation process of the required application requirements, the format of the SD card used to store RaspiOS, the installation of RaspiOS buster armhf.img, and the installation of Open Media Vault were the first in the system stages describing the work process flow to build Network Attached Storage (NAS) on the Raspberry Pi. If the OMV application was configured correctly, the client could effectively upload and download files to the server. If not, the OMV application needed to be reconfigured. Figure 4 shows the design of the system stages.

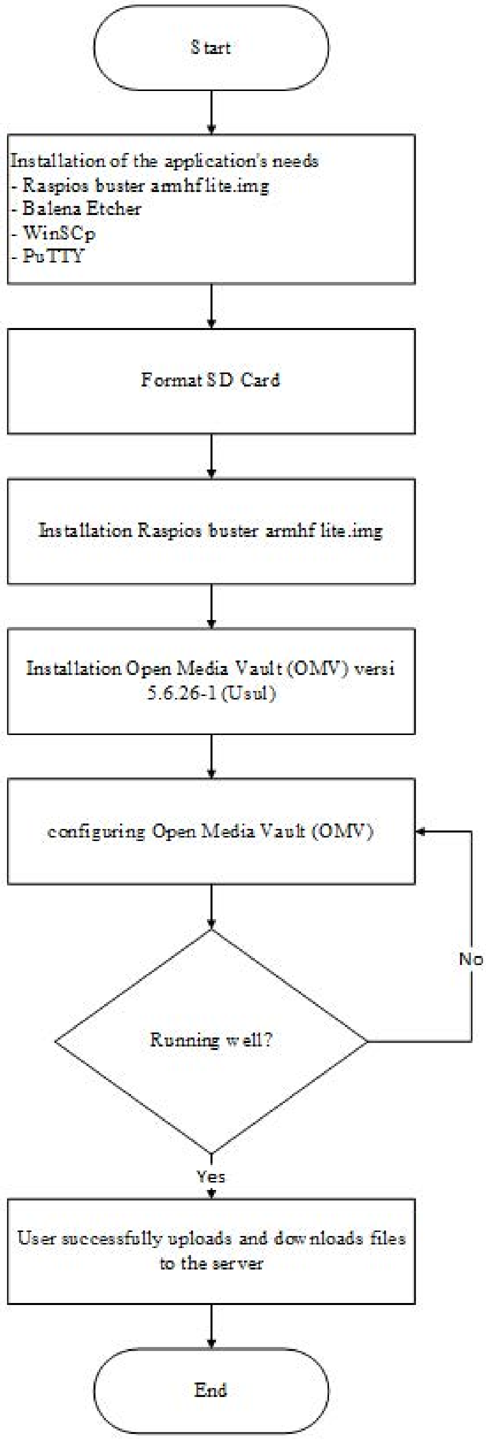

Figure 4. Design of system stages

3.2.4 Design of physical network structure

The design of the physical network structure shows that the ISP using Indotrans was connected to the RB 951UI-2nd router from the Faculty of Engineering server room, Ibn Khaldun University of Bogor, to the CSN lab server rack via FO cable through a media converter. The physical network topology shows the CSN Laboratory network structure design of the Informatics Engineering study program. Switch 01 (Penelitian NCC) of the Cisco SF90-24 was linked to the router and Raspberry Pi NAS server. The client could access the NAS running on the Raspberry Pi 3B+ in the CSN lab room using Category 5e UTP cable connected to the D-link DIR-612 access point. The internal IP was accessed for SMB/CIFS services and the public IP from the router for the OMV GUI manager. The CSN Laboratory of the Informatics Engineering study program, Faculty of Engineering, Ibn Khaldun University, Bogor, had all the installed devices [17]. Figure 5 shows the physical network structure design.

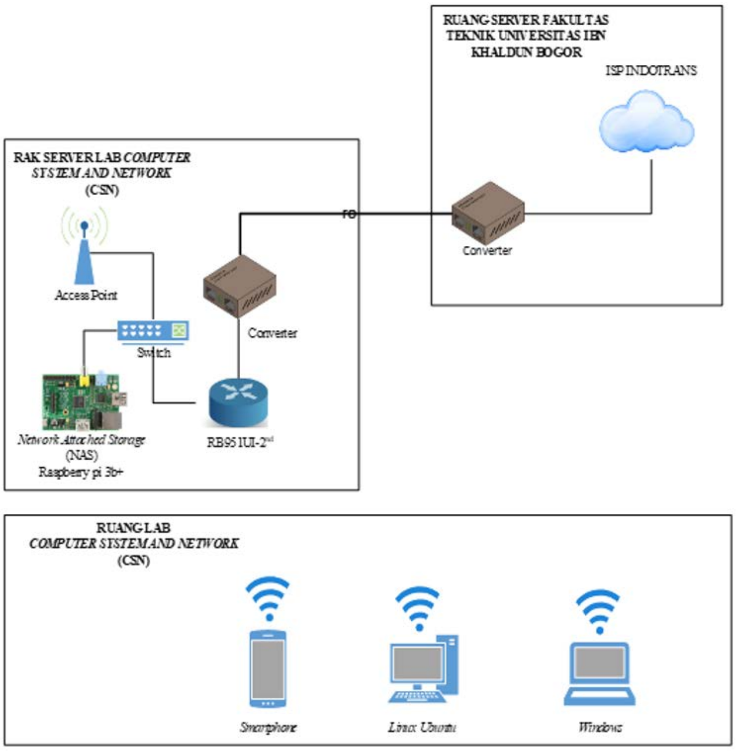

Figure 5. Design of a network physical structure

3.2.5 Design of logical network structure

The logical network structure design in the CSN Laboratory shows that the logic network topology explains the IP addressing of the computer network structure. The Laboratory server room server rack was connected to the router at the address where the internet source was received from ISP Indotrans via Fiber Optic (FO) cable and a media converter. A Category 5e UTP cable then linked the router and Raspberry Pi NAS server to Switch 01 (NCC Research) of the Cisco SF90-24. It had a local IP of 192.168.x.xxx for clients to access the NAS on Raspberry Pi 3B+ in the CSN laboratory area and a public IP of 103.3.xx.x to access the Open Media Vault (OMV) software [18]. Figure 6 shows the logical network structure design.

3.3 Implementation

All design findings were implemented on a functioning system during the implementation phase. The completed implementation steps are listed below:

3.3.1 Setting up and installing the Raspberry Pi operating system

a. The stages of setting up the Raspberry Pi 3B+ SSH and installing Raspbian operating system were [19, 20]:

- Obtain the necessary programs: Raspbian Buster Lite Armhf.img, Balena Etcher, WinSCP, and PuTTY.
- Format the SD card after inserting it into the card reader.
- Open Balena Etcher to install Raspbian Buster Lite Armhf.img.
- Insert the micro SD into the Raspberry Pi SD card slot after the micro SD flash procedure completes.
- Connect the Category 5e UTP wire attached to the CSN laboratory RB 951UI-2nd router to the Raspberry Pi Ethernet interface.
- Power on the Raspberry Pi. Installation of Raspbian Buster Lite Armhf.img is complete if the Raspbian Command Line Interface (CLI) is accessed.
- After completing the Raspbian installation procedure, the Raspberry Pi connects to the accessible internet network in the CSN laboratory using DHCP IP.
- Select Format after inserting the SD card into the card reader.
- To remotely connect to the Raspberry Pi with DHCP-assigned IP, enable SSH as follows:
- Log in as the superuser and enter the command in Figure 7.
- After logging in as the superuser, enter the command in Figure 8.
- Change permitRootLogin yes as shown below in Figure 9.

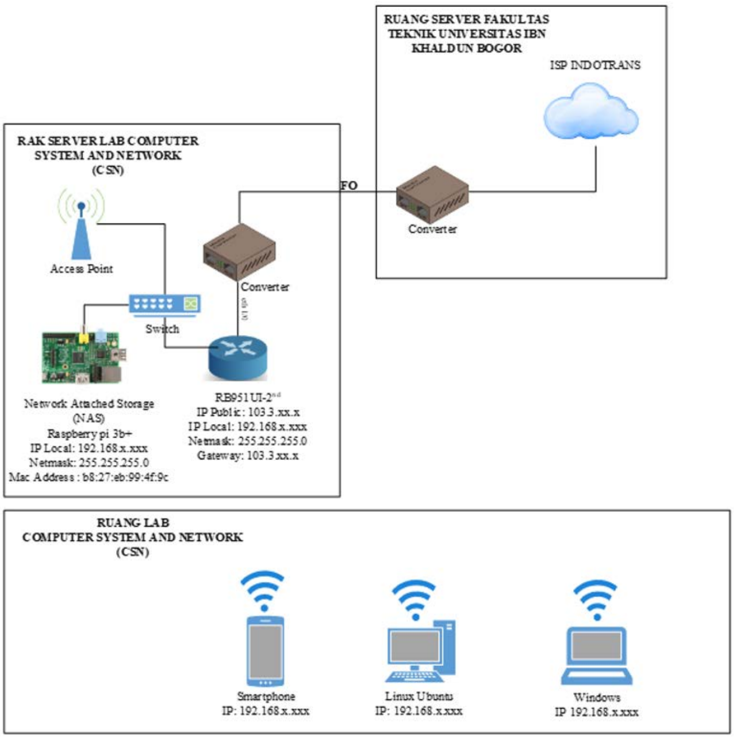

Figure 6. Design of a network logical structure

```
pi@raspberrypi :~ $ sudo su
```

Figure 7. Command super user

```
root@raspberrypi :/home/pi# nano    /etc/ssh/sshd_config
```

Figure 8. Command masuk sshd_config

```
#ListenAddress:

#HostKey /etc/ssh/ssh_host_rsa_key
#HostKey /etc/ssh/ssh_host_ecdsa_key
#HostKey /etc/ssh/ssh_host_ed25519_key

# Ciphere and keying
#RekeyLimit default none

# Logging
#SyslogFacility AUTH
```

Figure 9. Command sshd_config

- Enter the code in Figure 10 to access the SSH configuration.
- To activate the command in the SSH configuration, remove the # from PasswordAuthentication yes as shown below in Figure 11.
- If the PuTTY application successfully enters the DHCP IP, the SSH activation procedure was successful.

Setting up the Raspberry Pi with installed and configured OMV.

```
root@raspberrypi:/home/pi#
```

Figure 10. Command ssh_config

```
# Configuration data is parsed as follows:
#       1. command line options
#       2. user-specific file
#       3. System-wide file
# Any configuration value is only changed the first time it is set.
# Thus, host-specific definitions should be at the beginning of
the
# configuration file, and defaults at the end.
# Site-Wide defaults for some commonly used options. For a
comprehensive
# list of available options, their meanings and defaults
# ssh_config (5) man page.
Host   *
#       ForwardAgent no
#       ForwardX11 no
#       ForwardXTrusted yes
            PasswordAuthentication yes
#       HostbasedAuthentication no
#       GSSAPIAuthentication no
#       GSSAPIDelegateCredentials no
#       GSSAPIKeyExchange no
#       GSSAPITrustDNS no
#       BatchMode no
```

Figure 11. Ssh_config

b. The stages of installing and setting up Open Media Vault (OMV) were:

- Application installation stage on RaspiOS is the second step in creating a Network Attached Storage (NAS) using a Raspberry Pi. The steps can be completed as follows:
- Download OMV by running the commands in Figure 12 after reviewing the GitHub script.

```
pi@raspberrypi :~ $ wget -O
https://raw.githubusercontent.com/OpenMediaVault-Plugin-Developers/installScript/master/install | sudo bash
```

Figure 12. Command download OMV

- Search for ”OMV NAS server IP 103.3.x.xx” as shown in Figure 13.

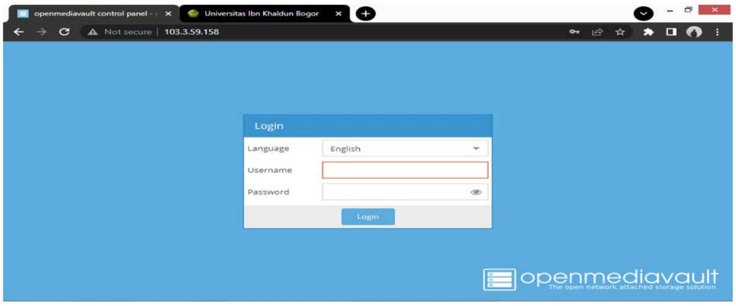

Figure 13. Log in Open Media Vault (OMV)

- Log into the webGUI to set up storage, RAID, services, and users.
- To view available disks, select Storage Physical Disks and then Scan.
- Click Create then Disk Management.
- RAID configurations, or Redundant Array of Independent Disks, can achieve improved disk speed and performance. One partition of multiple hard disks is created using the technique of creating a system of multiple hard disks. Data reliability requires RAID data storage protection. Combining several physical hard drives into one logical storage unit with specialized software or hardware is known as RAID [21–23].
- Enter ”RAID1” in the name field, select Level 1, select all devices, and then create.
- Select the file system before creating.
- Populate the RAID software created on the device, label it ”RAID 1,” and mount using EXT4 file system [9, 10] as shown in Figure 14.

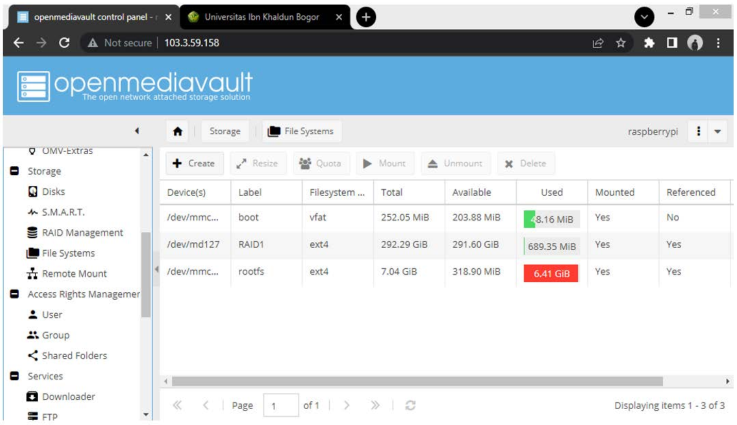

Figure 14. File system

- Click Users under Access Rights Management, then create a user by providing a name and password as shown in Figure 15.
- SMB/CIFS shared folders are Windows file sharing and Samba folders. Data is streamed every second to the graphical interface for visualization, and historical data can be stored [18].
- Next, select Shared Folders, add, enter the share name, select the previously created file system, and save.
- Select SMB/CIFS from Services, then click Allow.
- Next, in Share Folder Share Settings, select the previously created share, enter the name ”ResearchRAID1,” and then save as shown in Figure 16.
- After creating a user, select Users and Organizations Access, and then sign up the user by providing a name and password.

4 Testing

Following identification, design, and configuration, the system was tested according to the previously set configuration.

After successfully creating the NAS, data exchange became more effective and faster because the NAS system was accessed via the IP address of the Raspberry Pi NAS device connected to the local network. Users only needed to

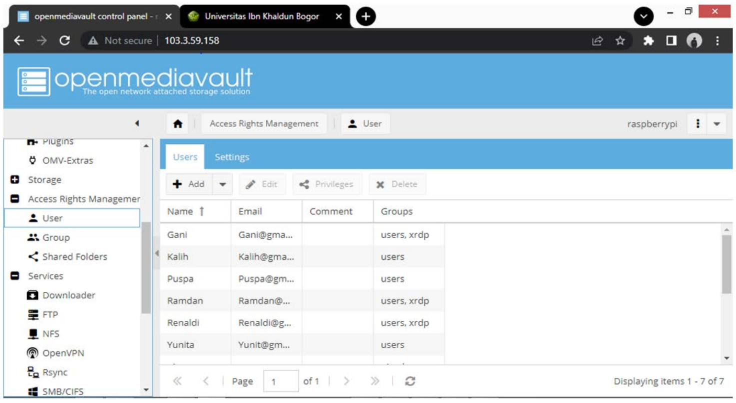

Figure 15. Create user

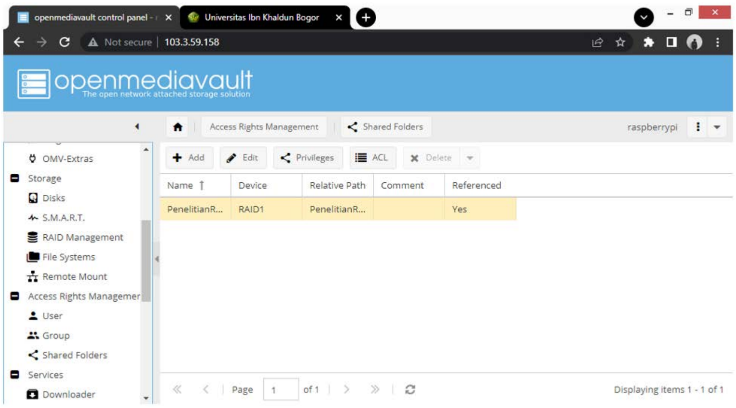

Figure 16. Device shared folder

create an account and know the IP address. The prior system still used USB media, so the CSN laboratory students' data exchange process was inefficient. The system had the following characteristics:

4.1 Network Attached Storage

NAS centralized data storage despite many users accessing it. The four layers of NAS are Storage, File System, Network, and Application. The NAS application layer is software that makes NAS easy for users to access. NAS allows users to avoid directly connecting storage devices like USB media to computers. NAS connects via TCP/IP network protocols, allowing users to access the same storage from multiple devices and minimizing redundancy. Figure 17 shows the Network Attached Storage layers.

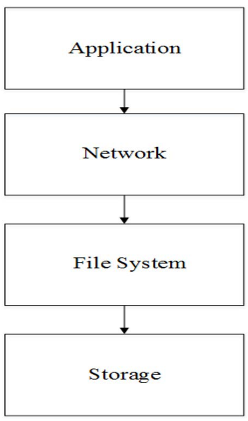

Figure 17. Network attached storage layer

4.2 A Network Storage Device

There are two types of network storage systems:

a. Host system

The host system is a PC client that connects to the NAS server via a local network.

b. Storage system

Its primary role is to serve as storage for the NAS itself, housing both primary and backup data. RAID (Redundant Array of Independent Disks) is a type of storage device that combines multiple storage devices into one.

4.3 NAS Testing Using WinSCp

As shown in Table 3, this test used WinSCP, an open-source FTP, SFTP, SCP, and WebDAV client for Windows. WinSCP's primary use is file transfers between a remote computer (Raspberry Pi 3B+) and a local computer (server). WinSCP also has scripting options and file manager functionality to check NAS access rights matched the OMV configuration [24, 25].

Table 3. NAS testing using WinSCp

Name	Group 1	Group 2	Group 3
Gani	According to Access rights	According to Access rights	According to Access rights
Kalih	According to Access rights	According to Access rights	According to Access rights
Puspa	According to Access rights	According to Access rights	According to Access rights
Renaldi	According to Access rights	According to Access rights	According to Access rights
Yunita	According to Access rights	According to Access rights	According to Access rights
Ramdan	According to Access rights	According to Access rights	According to Access rights

4.4 Access Testing Using Windows, Ubuntu Linux, and Smartphone

This test used three different platforms—Windows, Linux, and Ubuntu—to determine whether NAS access was available, as shown in Table 4.

Table 4. Access testing using Windows, Ubuntu Linux, and Smartphone

Operating System	Access NAS
Windows	Success
Linux	Success
Smartphone	Success

4.5 Measuring Client to Server and Server to Client File Transfer Rate

DiskBoss software tests measured the speed of file transfers from clients to servers and servers to client [26]. The results were computed using Eq. (1).

$$Speed(s) = \frac{\text{Put the data } (A)}{\text{Transfer time } (T)} \tag{1}$$

Afterwards, the outcome is attained as shown in the following Table 5 and Table 6:

Table 5. Measuring the client to server file transfer rate

Client	Size File			
	0.00018 MB	4.28 MB	65.90 MB	502.70 MB
Windows	0 Mbps	2.2 Mbps	1,4 Mbps	1.7 Mbps
Average		**1.66 Mbps**		

4.6 Network Attached Storage (NAS) Performance

NAS performance testing on the Raspberry Pi 3B+ determined the speed stability of the NAS using the Raspberry Pi 3B+ by running the NAS for 7 days while performing file transfer operations from client to server. The formula used to calculate the test results is shown in Eq. (1). The results are shown in Table 7.

Table 6. Measuring the server to client file transfer rate

Client	Size file			
	0.00018 MB	4.28 MB	65.90 MB	502.70 MB
Windows	0 Mbps	0.922 Mbps	2.471mbps	3.542 Mbps
Average		**2.01 Mbps**		

Table 7. Network Attached Storage (NAS) performance

Day of the experiment	Date/time of transfer	Put the data (A)	Transfer time (T)	Speed (Mbps)
1	08-30-2022 / 07:51	786.52 MB	254 s	3.097 Mbps
2	08-31-2022 / 02:30	786.52 MB	353 s	2.228 Mbps
3	09-01-2022 / 09:56	786.52 MB	252 s	3.212 Mbps
4	09-02-2022 / 10:24	786.52 MB	315 s	2.496 Mbps
5	09-03-2022 / 08:50	786.52 MB	312 s	2.520 Mbps
6	09-05-2022 / 10:08	786.52 MB	749 s	1.050 Mbps
7	09-06-2022 / 10:08	786.52 MB	398 s	1.976 Mbps
Average			376.14 s	2.368 Mbps

4.7 Overall Tool Test Result

This test described the state of the Network Attached Storage (NAS) device using a Raspberry Pi 3B+. The NAS server was on the CSN Laboratory shelf, displaying the DHCP IP [27]. Information from the RB 951UI-2nd router OLED was helpful for users accessing NAS storage in real time [28]. CPU utilization was expressed as a percentage so the Raspberry Pi temperature could be regulated to avoid overheating [29, 30]. The CSN Laboratory implemented all network devices by booting the Raspberry Pi micro SD operating system data traffic and booting the entire micro SD disk embedded in the Raspberry Pi SD card port. Figure 18 shows the overall tool test results.

Figure 18. Overall tool test results

5 Conclusion

This study led to several conclusions:

Successfully creating a Network Attached Storage service using a Raspberry Pi in the CSN laboratory offered an alternative NAS device and software selection for operating NAS services, considering the difficulty of studying file servers and the availability of expensive licenses. It increased the data exchange process efficiency, replacing the inefficient role of USB and purchasing expensive PC computers. The aim was faster and more effective data access for CSN lab students, eliminating reliance on USB media while enabling ease of operation in controlling NAS on small and large scales. The results could significantly impact the effectiveness and efficiency of data storage and exchange in a learning environment. The available NAS services allowed CSN laboratory students to improve the data exchange process efficiency and reduce dependence on USB media.

Given the availability of expensive licenses, using NAS with OMV software could be selected as one of the free (open source) software choices for building a NAS server. The Raspberry Pi 3B+ could be an alternative device selection to reduce costs in building a NAS server.

Based on the test results, accessing NAS files on the Raspberry Pi 3B+ corresponded to the access permissions carried out according to the OMV software user management settings. Different cross-platform systems, including Windows, Linux, and Android, accessed the NAS.

The average NAS performance speed stability on the Raspberry Pi 3B+ was 2.37 Mbps, with an average download speed from server to client of 2.01 Mbps and an average file upload transfer speed from client to server of 1.66 Mbps under various file size test scenarios. The speed results could change depending on the file size tested, the choice of Ethernet port connected to the switch, and MicroTik router. The average test results achieved were obviously faster than the results analyzed if using hardware with higher speeds, such as 1 Gbps routers and switches.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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