2024 IEEE 4th International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering (MI-STA),Tripoli, Libya, 19-21 May 2024.

2024 IEEE 4th International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering (MI-STA) | 979-8-3503-7263-2/24/$31.00 ©2024 IEEE | DOI: 10.1109/MI-STA61267.2024.10599641

Building an Affordable Portable Storage Area Network (SAN) with Raspberry Pi: Design, Implementation, and Performance Evaluation

Muhammad Solihin bin Ahmad Nasser
Faculty of Information and Communication Technology, International Islamic University Malaysia, Selangor, Malaysia
solihin.solehin@gmail.com

Zainab S. Attarbashi
Faculty of Information and Communication Technology, International Islamic University Malaysia, Selangor, Malaysia
zainab_senan@iium.edu.my

Azana Hafizah Mohd Aman
Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Malaysia
azana@ukm.edu.my

Mustafa Ali Abuzaraida
Computer Science Department, Faculty of Information Technology, Misurata University, Libya
abuzaraida@it.misuratau.edu.ly

***Abstract*— In a digital landscape demanding cost-effective yet robust data storage solutions, Portable Storage Area Network (SAN) became an affordable alternative for data storage systems. A portable SAN system using the Raspberry Pi solution offers personal users the ability to easily expand their storage capacity, improve data organization and management, protect their data, and have a flexible and mobile solution. Users can share any sort of data. This project aims to address the increasing demand for efficient storage solutions by constructing a portable SAN system using the Raspberry Pi's compact size and budget-friendly hardware. The proposed SAN system enhances data organization, expands storage capacity, and offers secure, flexible data access. Targeting individual users and small to medium-sized enterprises, the project covers hardware specifications, intricate design elements, and the seamless integration of OpenMediaVault, Raspberry Pi OS, and the iSCSI protocol. Performance, stability, and practicality of the SAN solution are visually presented through extensive testing, to prove its potential benefits for diverse storage needs.**

Keywords—Storage Area Network, Raspberry Pi, OpenMediaVault, iSCSI protocol

I. Introduction

Today's world, people heavily rely on technology for communication, entertainment, and work. With the increasing use of mobile devices, apps have become an integral part of our daily lives. The increasing demand for efficiency and affordability data storage as the volume data keeps increasing dramatically. Storage Area Network (SAN) [1] are reliable and scalable data storage options that typically use adaption technology. A portable SAN system using the Raspberry Pi solution offers personal users the ability to easily expand their storage capacity, improve data organization and management, protect their data, and have a flexible and mobile solution. Users can share any sort of data, including files, with their family members and anyone they authorize. Due to the Raspberry Pi's small size, users can easily bring the SAN system wherever they go and set it up in minutes. For instance, this portable SAN system is ideal for remote workers who deal with various types and sizes of data on a daily basis, allowing them to ease their work from any location as long as there is a network connection.

Small and medium-sized businesses gain benefits such as the ability to easily expand their storage capacity, improved data management and organization, improved data protection, higher data transfer rates, flexibility, and scalability, streamlined data sharing and collaboration, and improved data privacy and security. Together, these organizations are better able to collaborate on projects, access and manage larger volumes of data more efficiently, and secure their data from unauthorized access. The SAN solution's portability also enables flexible deployment to meet evolving business needs.

However, SANs are expensive and need specialized infrastructure and technology. To develop a Storage Area Network (SAN) that allows users to have a large amount of storage with the help of Raspberry pi, since the average user only has 1-2 terabytes of storage, and their computer or device will eventually fill up. Consequently, this initiative will benefit them by providing them with personal storage that can be accessed via their local network without requiring them to upgrade the storage on their devices or computers. . As a SAN system, the Raspberry Pi is a compact, energy-efficient, and powerful small computer and it is affordable for this project and will benefits its user.

Raspberry Pi [2] is affordable and sufficiently powerful to run SAN without any problems. The majority of users upgrade their device's storage to increase its capacity. Nonetheless, this compact SAN system will make their lives simpler by allowing them to upgrade their storage by connecting their cables to an external SSD and updating to a web-based user interface. So they will skip the hustle of upgrading the storage on their devices. With this portable SAN system, they can bring it anywhere without worrying about storage issues. This SAN system is only accessible to local users, which means that no one else can gain access without permission; therefore, user data will be secured and protected. The aim of this project is to offer a solution by creating a portable Storage Area Network for storage system using Raspberry pi because of the compact size and low-cost hardware that can be applied on any system that needs storage solution. The goal of this project is an affordable data storage solution that is easy and simple to use in small to medium sized businesses or personal users. By using Raspberry Pi affordability and portability, the development of this project is not only cost effective but also easy to maintain and upgrade. This project is a low-cost budget, which means that anyone that doesn't want to spend more of their money can have an alternative to have this SAN system in their network architecture. In this proposal, the overview of the project will elaborate in depth and detail

979-8-3503-7263-2/24/$31.00 ©2024 IEEE

including the purposes, objective, methodology and expected outcomes..

II. Related Works

(Shrivastava, 2017) developed a home server and Network Attached Storage (NAS) with Raspberry Pi. The author emphasizes the expanding demand for increased storage capacity as a result of our reliance on the internet and the limitations of currently available NAS devices in terms of cost, flexibility, and power consumption. The project use Raspberry pi 3 as their central device to act as home server and Network Attach Storage (NAS). Combining NAS functionality with a Raspberry Pi web server is the proposed method. The project use Apache, MySQL and PHP to act as server and link with Owncloud which the software synchronizes the web server and the storage to act as NAS. The project bandwidth result of upload rate is 636 KB/sec while downloading 1.9MB/sec.

(Mythili et al., 2021) developed encrypted NAS using the Raspberry Pi 4 concentrates on existing network-attached storage (NAS) systems and technologies. NAS has been utilized by researchers for real-time systems, patient monitoring, AI-based scanning systems, and video data rendering. The project uses True NAS, an open-source solution as software for configuring NAS system. The project utilizes RC5 algorithm and SNAD security protocols for encryption protocol and method of secured. The researcher uses Raspberry Pi 4 8gb Ram version which provides significant performance for the project. The project yield bandwidth writes speed of 90MB/sec and read speed of 113.96 MB/sec in file size of 1gb.

(Prasath Kumar et al., 2021) developed Raspberry Pi based secured cloud data. The application software they use is OpenMediaVault as configuring Raspberry Pi as Network Attach Storage (NAS). The system uses Raspberry Pi 3b with 1gb of ram hardware version. The secured cloud data uses Hard disk drive as their main source of storage. The goal of the project is to create a private cloud storage solution utilizing Raspberry Pi-controlled hard discs. This strategy seeks to preserve data privacy, facilitate simple data backup and retrieval. The author also mentioned proposes a blockchain based fair payment smart contract for public cloud storage auditing and another that concentrates on a secured multicloud storage policy.

TABLE I. Comparison of Previous Works

	Description	*Software*	*Hardware*	*Bandwidth Rate*	*Advantages*	*disadvantages*
Shrivastava, 2017	developed a home server and Network Attached Storage (NAS) with Raspberry Pi	• Apache, MySQL, and PHP for hosting web server • Owncloud for sync storage to the web server	• Raspberry Pi 3 • Hard Disk storage	• Write speed 636 KB/sec • Read speed 1.9MB/sec	• Low power consumption • Affordable •Opensource application • Privacy storage system	• Low bandwidth transfer rate • Low performance
Mythili et al., 2021	developed encrypted NAS using the Raspberry Pi 4	• True Nas • RC5 algorithm and SNAD security protocols for encryption	• Raspberry Pi 4 • 8gb of ram •SSD sata storage	• write speed 90MB/sec • Read speed 113.96MB/sec	• Low power consumption • Opensource application • High performance hardware and transfer rate • Secured and Encrypted data • Privacy storage system	• Raspberry pi 4 8gb version quite pricy
Prasath kumar et al., 2021	developed Raspberry Pi-based secured cloud data	• Apache, MySQL, and PHP for hosting cloud storage web server • OpenMediaVault as a system for configuring NAS system and sync with storage	• Raspberry Pi 3 • Hard Disk storage	• Not stated	• Low power consumption • Opensource application • Affordable hardware • Privacy storage system	• Low performance • Low bandwidth transfer rate

III. Methodology

The project used physical Raspberry Pi 4B to act as a Storage Area Network (SAN) system. SAN systems need powerful specifications to run the system and achieve peak transfer and upload bandwidth. The Raspberry Pi runs a Linux-based operating system like Raspbian. This project has an NVME SSD installed, which gives it high-speed SAN storage capability. Since the Raspberry Pi can link to the LAN router, client computers on the local area network may access the SAN through the network.

A. Hardware

Raspberry Pi is known as a versatile piece of small hardware computer that can perform such an amazing job on a desired project. This small and compact hardware is used for the implementation of the SAN system and web server for this project. Raspberry Pi Offers several specification, in this project the specification of Raspberry Pi 4B and SSD storage specified in table 2.

TABLE II. System Specifications

Specification	*Details*
Processor	Quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.8GHz
RAM	4GB LPDDR4-3200 SDRAM
Wireless Connectivity	2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE
Wired Connectivity	Gigabit Ethernet
USB Ports	2 × USB 3.0 ports; 2 × USB 2.0 ports
GPIO Header	Raspberry Pi standard 40-pin GPIO header
HDMI Ports	2 × micro-HDMI ports (up to 4kp60 supported)
Display Port	2-lane MIPI DSI display port
Camera Port	2-lane MIPI CSI camera port
Audio and Video Ports	4-pole stereo audio and composite video port

Specification	*Details*
Video Codecs	H.265 (4kp60 decode), H.264 (1080p60 decode, 1080p30 encode)
Graphics	OpenGL ES 3.1, Vulkan 1.0
Storage	Micro-SD card slot for loading the operating system and data storage
Power Input	5V DC via USB-C connector (minimum 3A*); 5V DC via GPIO header (minimum 3A*)
Power over Ethernet (PoE)	Enabled (requires a separate PoE HAT)

B. *Software*

SAN systems require high-performance hardware to achieve high-speed transfer results; for this project, Raspberry Pi OS Lite (32-bit) is used without a desktop UI. This operating system uses the Command Line Interface (CLI). By discarding the unwanted background processes by the operating system, the Raspberry Pi will achieve significant impact to performance for this SAN project.

For this SAN storage system project, a lightweight operating system used for the Raspberry Pi is called Raspberry Pi OS Lite (32-bit). It provides a scaled-down version of the Raspberry Pi OS with minimum resource use and effective performance. Since Raspberry Pi OS Lite by default lacks a graphical user interface, it is perfect for this particular project. It offers a command-line interface that enables users to communicate with the system and execute different applications and services.

C. *iSCSI Protocol*

A storage area networking (SAN) protocol is known as Internet Small Computer Systems Interface (iSCSI). It is a networking standard based on Internet Protocol for sending data conveying SCSI directives across a TCP/IP network. iSCSI connects data storage facilities and offers access to storage devices at the block level. Figure 1 shows the different components in iSCSI protocol.

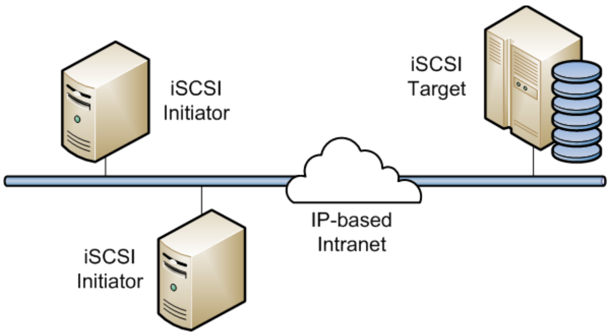

Fig. 1. iSCSI Protocol

- iSCSI Initiator: The initiator allows data to be sent to and from the storage array, is host-based software that is installed in the server. A data migration across storage arrays can also be started by the source array. The storage network for the software initiator may be built using standard Ethernet components, and iSCSI initiators manage several concurrent communication channels to numerous destinations target.
- iSCSI Target: The system installed on a storage device, which functions as a server to host storage resources and give access to storage, is the target. The storage resources on an iSCSI server that are the "iSCSI targets" are often represented by hard disc storage and are frequently accessible via Ethernet-based networks. Targets are data providers like tape libraries or disc arrays. For business storage, iSCSI targets are logical entities even though they expose one or more SCSI LUNs to particular iSCSI initiators.
- iSCSI performance: The performance of iSCSI allows for quick and large-scale data transfer, which is commonly accepted for businesses organization. iSCSI enables local device access to central storage resources in a shared-storage network with several servers and clients.

D. *OpenMediaVault*

OpenMediaVault (OMV) is an open-source network-attached storage (NAS) system created to offer a simple and user-friendly web interface for managing storage devices and services. OpenMediaVault's web-based interface, which eliminates the need for tricky command-line interactions, is what allows users to manage storage devices, network settings, user accounts, and a variety of services. The capability to manage storage is one of OpenMediaVault's key features. It supports a broad variety of storage technologies, including external storage devices, RAID arrays, hard drives, and solid-state drives. To maintain the functionality and efficiency of their storage infrastructure, users may quickly establish and manage file systems, mount and unmount drives, and enable disc monitoring using OpenMediaVault.

There are two additional plugins that need to be installed in the system. With the LVM (Logical volume management) plugin installed in the system, OpenMediaVault users may easily build and manage logical volumes via the web-based interface with the help of the LVM plugin. Create logical volumes, add or remove physical volumes, resize volumes, and manage volume groups are just a few of the chores made easier by this plugin's user-friendly graphical interface. The TGT (target) plugin installed in the system to have iSCSI (Internet Small Computer System Interface) targets inside the system may be configured and managed by users using the TGT plugin in OpenMediaVault. A protocol called iSCSI makes it possible to send SCSI commands across IP networks, enabling the development of virtual SCSI storage devices.

E. *User Interface*

For managing the SAN system, the OpenMediaVault (OMV) user interface offers a simple web-based interface. OpenMediaVault provides user-friendly interface environment in which to setup and keep track of different system components. It has a menu on the left side that allows access to many settings and sections. Users may quickly obtain the needed functionality by navigating through the interface.The primary dashboard gives a summary of the system's state and includes data on CPU, RAM, disc, and network activities. It acts as the main hub for keeping track of the SAN system's functionality and state. Figure 2 shows the OpenMediaVault's dashboard.

Fig. 2. OpenMediaVault's dashboard

F. Design of Use-Case

Raspberry Pi as OpenMediaVault, Users, and Iscsi initiator are the three actors displayed in the use case diagram. The Raspberry Pi will need to be connected to the local network in order to administer storage on the application system. The storage must be configured and authorized users must be granted access. The storage has now established a connection with the user's Iscsi initiator protocol and granted the user access to the storage. Figure 3 shows system's use-case.

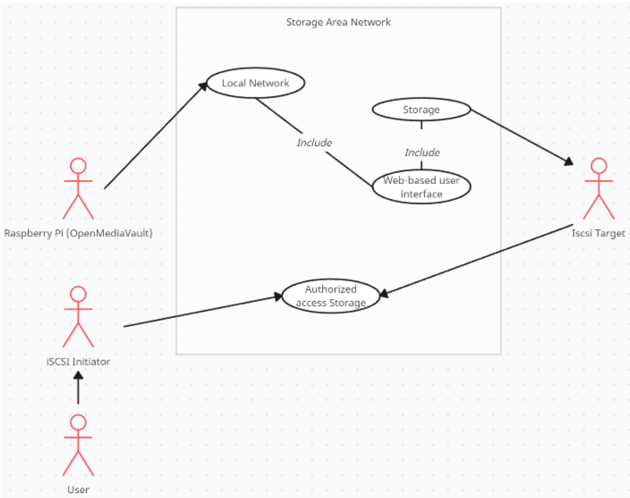

Fig. 3. System's use-case

IV. System Implementation

A. Install Raspberry Pi Operating System

A microSD card is required, and Raspberry Pi OS Lite (32-bit) is selected for the operating system. The microSD card will then be installed inside the hardware. Then, connections via SSH are implemented to enable remote configuration on personal computers, as shown in figure 4 and 5.

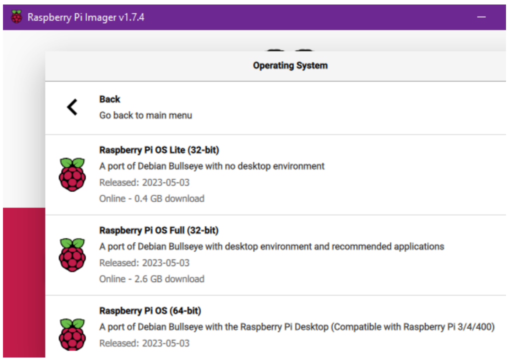

Fig. 4. Installing Raspberry Pi Operating System

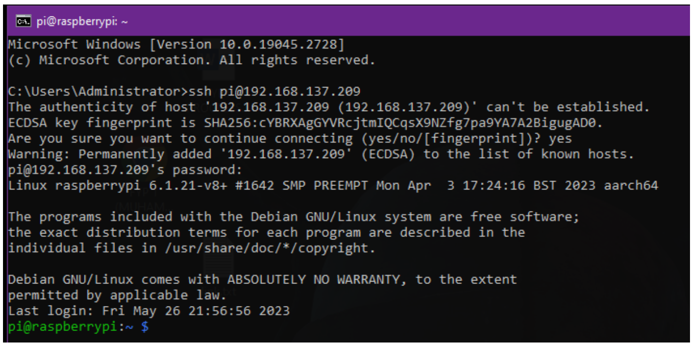

Fig. 5. SSH Connection

B. Install OpenMediaVault

The command below is for update Raspberry Pi OS and Installing OpenMediaVault software inside Raspberry Pi hardware:

sudo apt update && sudo apt upgrade

wget -O - https://github.com/OpenMediaVault-PluginDevelopers/packages/raw/master/install | sudo bash

sudo apt update

sudo apt install openmediavault

C. Install external storage drive

Plug in external storage in USB 3.0 slot at Raspberry pi's I/O interface and the storage drive need to be clean format before mount to OpenMediaVault. Logical volume management are needed, so the next step is to install Logical volume management (LVM) plugin in OMV for creating Virtualisation storage as shown in figure 6.

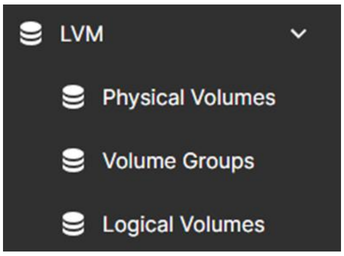

Fig. 6. Creating Virtualisation storage

D. Install and Setup the Raspberry Pi as iSCSI Target

For OpenMediaVault to use iSCSI features, the TGT plugin must be installed first to enable the system to act as an iSCSI target. Figure 7 shows the configuration that has been made for this hardware.

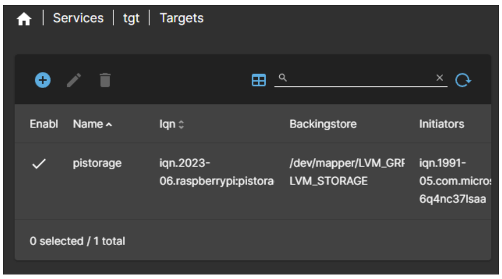

Fig. 7. Setup the Raspberry Pi as iSCSI Target

E. Install user as client iSCSI Initiator

Every user must own an iSCSI initiator on their device for connection to the target; figure 8 and 9 below show how to configure it. First, the user needs to have the SAN system IP address, then connect from this iSCSI initiator to the iSCSI target. If the connection is successful, the storage drive will need to be formatted to a new local drive, and the user will successfully create a new local disk drive using this SAN storage.

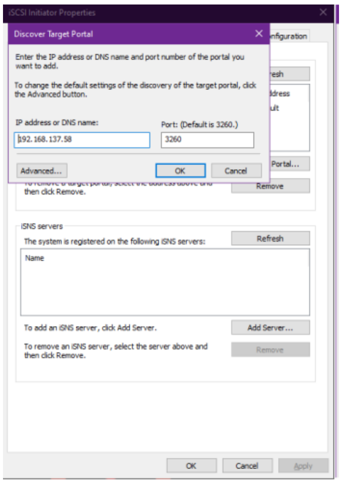

Fig. 8. Configure the IP address and port number for iSCSI initiator

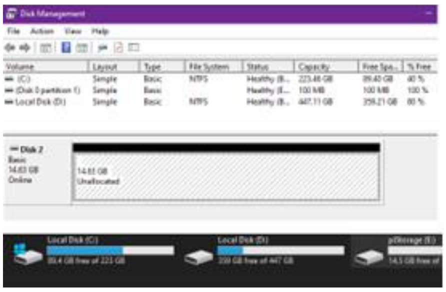

Fig. 9. A new local disk drive using this SAN storage

V. SYSTEM EVALUATION

To evaluate the system's general functionality, a few tests were done as in table 3.

TABLE III. SYSTEM GENERAL FUNCTIONALITY

Test Case	***Description***	***Test Step***	***Result***
Access to web-based dashboard	Raspberry Pi's IP Address is where the dashboard can be accessed	Administrators needs to know the IP address or set to fixed IP address.	Pass
Storage File system	External drive needs to convert to file system	Hard drive needs to be fresh clean and create Logical Volume Management	Pass
User connection to the system	User needs to use iSCSI Initiator to sync with iSCSI target	The user needs to configure the Raspberry Pi IP address assigned to the iSCSI initiator and connect to the target.	Pass
Storage configuration	Assign drive from SAN system to computer	Open the disk management system and assign a disk to create a volume on the computer.	Pass
Storage capability and stability test	Upload, download and delete file	Transfer small and bigger size of file to the storage, delete and download it.	Pass

The hardware monitoring tool can be accessed through the dashboard, where all the essential information of the hardware is displayed. Such as CPU usage, CPU temperature, memory usage, file system and others information.

The connection is tested in the ping method using the command prompt in Windows and in the Raspberry Pi command line terminal. The first test is pinging the Raspberry Pi from user computer to determine the stability of the feedback as in figure 11. The second test is conducted via ssh on the Raspberry Pi, followed by pinging to any DNS to evaluate the overall stability of the network connection as shown in figure 12. The result from this internet connectivity test is a passed as the connection and stability meets the requirements for use in this project.

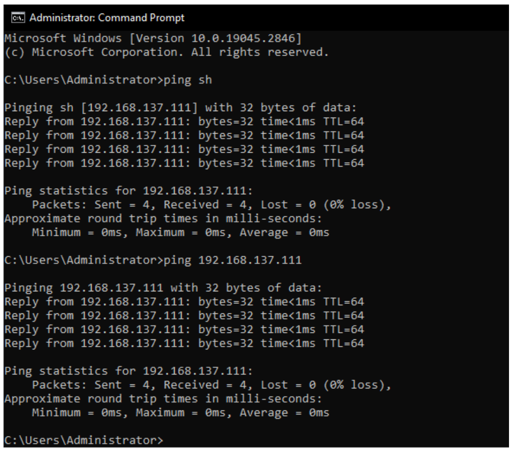

Fig. 10. Pinging the Raspberry Pi from user computer

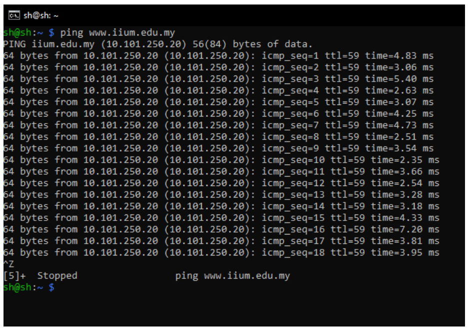

Fig. 11. Raspberry Pi pinging to iium.edu.my to evaluate the overall stability of the network connection

There are several files that have been tested for transfer rates, and the performance of the bandwidth results is unexpected. Files with 100 MB, 500 MB, and 1 GB of size are tested in this project to see the different outcomes. The download speeds are fast; the file transfer from the SAN drive folder to the local drive is up to 1 Gbps. Figure 12 shows the transfer speed of files, and Table 3 shows the result of bandwidth.

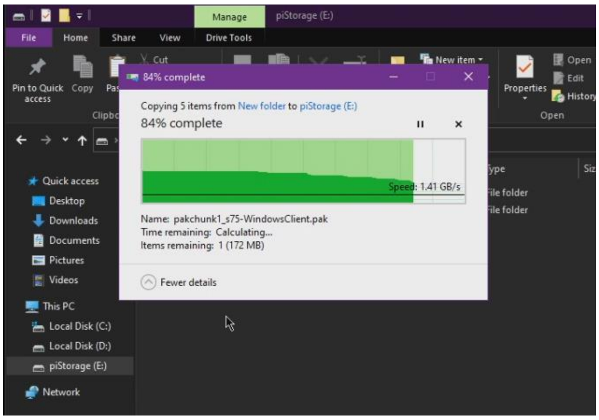

Fig. 12. Files transfer speed

TABLE IV. DATA TRANSFER RATES

Size	Upload transfer	Download Transfer
100mb	700 Mbps	1.4 Gbps
500mb	500 Mbps	1.2 Gbps
1Gb file	450 Mbps	1.1 Gbps

VI. RESULTS ANALYSIS

This project has three 3 main objectives which have been successfully achieved, and the project's development system is fully functioning. The first objective is to study existing solutions that are used to assist the SAN system on the Raspberry Pi. The second objective is to develop a SAN system using a Raspberry Pi along with external SSD storage. This second objective failed during the testing phase because the power consumption of the SSD is high compared to a normal external drive. To overcome these issues, use a powered USB hub that can resolve the wattage that SSDs need, and the second objective is achieved. The third objective is to manage and monitor the SAN system using a web-based user interface. This is a front-end user interface for administrators to do complex configuration, managing an iSCSI account and monitoring the system and hardware. This objective is crucial to ensuring accessibility, a user-friendly UI, and efficient management of the system. The Portable Storage Area Network (SAN) project has successfully achieved all the objectives. Through study and research, literature review provides insight and knowledge into the development of this project. Using the Raspberry Pi as a small computer and using SSD external storage to deliver the system to its users resulted in cost-effective, energy-efficient, and reliable solutions for remote storage and data storage.

VII. CONCLUSION

To conclude, the development of Portable Storage Area Network (SAN) using Raspberry Pi for remote storage and data backup is one of the technologies should be considered or alternative to current storage system due to compactness and portability. Raspberry Pi is a lowered power, small computer and has shown its capability to manage the system very well. IT effectiveness further enhanced by using SSD storage which offer high speed bandwidth to deliver the best experiences for the users. This innovative idea not only meets the demand for easily accessible and flexible storage options, but it also shows how versatile the Raspberry Pi can be in a variety of environments.

For the future work, there are several improvements that can be made such as security enhancements. By implementation security like encryption protocol, access controls and authentication protocols, this ensures data integrity and protection against unauthorized access. Additionally, cloud services implementation offers a promising way to increase the SAN system's capabilities. Cloud environment can provide opportunities for remote access to stored data, effective data synchronization, and automated backups. The combination of the SAN system with cloud services can offer an adaptable and long-lasting storage solution that keeps up with changing user demands and technological trends as cloud technologies continue to progress..

REFERENCES

[1] A. R. Shrivastava and J. Gadge, "Home server and nas using raspberry PI," 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Udupi, India, 2017, pp. 2270-2275, doi: 10.1109/ICACCI.2017.8126184.

[2] R. Mythili, P. N. Reddy, B. Keerthivasan and V. Sooriya, "Encrypted NAS using Raspberry Pi 4," 2021 5th International Conference on Electrical, Electronics, Communication, Computer Technologies and Optimization Techniques (ICEECCOT), Mysuru, India, 2021, pp. 675-680, doi: 10.1109/ICEECCOT52851.2021.9707921.

[3] Prasath kumar, S., Rayavel, P., Anbarasi, N., Renukadevi, B., & Maalini, D. (2021). Raspberry pi based secured cloud data. Journal of Physics: Conference Series, 1964(4), 042101. https://doi.org/10.1088/1742-6596/1964/4/042101

[4] Lakshay, Chawla. "Live NAS Server with Raspberry Pi." Https://Www.researchgate.net/Publication/353482240_Live_NAS_Server_with_Raspberry_Pi, July 2021, www.researchgate.net/publication/353482240_Live_NAS_Server_with_Raspberry_Pi.

[5] Chawla, L. (2021). Live NAS Server with Raspberry Pi. Unpublished research paper, Department of Electronics and Communication Engineering, University Institute of Engineering, Chandigarh University, India.

[6] Smita Vishwakarma, and Sankalp Bagaria. "ISCSI Simulation Study of Storage System." ISCSI Simulation Study of Storage System, no. 10.1109/UKSIM.2008.18, 1 Apr. 2008, https://doi.org/10.1109/uksim.2008.18.

[7] G, Ravi Kumar M., and Et Al. "Network-Attached Storage: Data Storage Applications." Turkish Journal of Computer and Mathematics Education (TURCOMAT), vol. 12, no. 12, 23 May 2021, pp. 2385–2396, turcomat.org/index.php/turkbilmat/article/view/7830/6182.

[8] Ritzkal, Ritzkal, et al. "Enhancing Data Storage and Access in CSN Labs with Raspberry Pi 3B+ and Open Media Vault NAS." Information Dynamics and Applications, vol. 2, no. 2, 24 May 2023, pp. 13–26, library.acadlore.com/IDA/2023/2/2/IDA_02.02_02.pdf, https://doi.org/10.56578/ida020202. Accessed 10 June 2023.

[9] Princy, S. Emima, and K. Gerard Joe Nigel. "Implementation of Cloud Server for Real Time Data Storage Using Raspberry Pi." IEEE Xplore, 1 Nov. 2015, ieeexplore.ieee.org/abstract/document/7453790. Accessed 30 Nov. 2021.