# Home Network Attached Storage (HOMENAS) Using Raspberry Pi with Telegram Bot Notification

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***Abstract*—This paper presents the development of the Home Network Attached Storage (HOMENAS) using Raspberry Pi with a Telegram Bot Notification. Network Attached Storage (NAS) is an independent storage system connected directly to the network that can be accessed easily. NAS devices are readily available on the market nowadays. However, the current price is too expensive, consumes more electricity and lacks a notification mechanism. This paper proposes the development of HOMENAS at a lower cost and consumes less power than the current NAS devices available on the market. The proposed HOMENAS is also integrated with the Telegram Bot, which can notify users of the progress of downloading files. 95% of the energy cost can be reduced by implementing a Raspberry Pi as the Home Network Attached Storage. A network performance test has been conducted to evaluate the streaming rate for single and multiple users with wired and wireless connections. The result finding shows that the Raspberry Pi not only matches the performance of laptop but, in some aspects, it has better results in torrent-based file downloading tasks.**

***Keywords—Home network; NAS; network attached storage; raspberry pi; telegram bot***

## I. Introduction

Network Attached Storage (NAS) is a dedicated storage solution providing file-based storage accessible over a network. Traditionally, NAS devices are employed for functions such as backup data servers, media streaming, and torrent downloads [1]. While NAS devices are increasingly popular in consumer environments due to the proliferation of multiple connected devices like desktops, laptops, smartphones, and tablets, their higher costs have limited broader adoption, particularly in home settings [2]. NAS systems are widely utilised for storing music, videos, and photos, offering a streamlined alternative to managing direct TV connections [3]. Despite their utility, NAS devices are relatively expensive and consume significant amounts of electricity.

In contrast, the Raspberry Pi is a compact and cost-effective computing device offering functionality comparable to that of a standard computer, including an operating system (OS), central processing unit (CPU), memory, and storage, while consuming minimal power. These characteristics position the Raspberry Pi as an operable substitute for traditional NAS devices in home networks.

Telegram is an online messaging application that bears similarity to platforms such as WhatsApp and Facebook Messenger. It is designed to prioritize security and speed in its internet-based messaging service. Notably, Telegram supports the incorporation of bots; small programs that can be integrated into chats to carry out specific functions. These bots play a pivotal role in enabling communication between humans and programmable machines, autonomously executing predefined tasks. They are particularly valuable for facilitating applications such as notification and alert systems [3].

In today's increasingly digital households, the need for cost-effective solutions providing centralized storage and seamless file sharing across multiple devices has become paramount. However, many consumers face challenges in finding an optimal Network Attached Storage (NAS) solution that balances affordability with robust centralized storage capabilities and efficient file-sharing functionalities. The rising cost of NAS devices often presents a barrier to entry for budget-conscious users seeking to streamline their data management and collaboration processes. Additionally, configuring and maintaining NAS systems for efficient file sharing among household members can be complex and time-consuming.

Therefore, this paper addresses the pressing need for cost-effective NAS solutions that prioritize centralized storage and simplify file-sharing processes. By exploring these solutions, households can effectively manage their digital assets while minimizing financial overheads and technical complexities. The aim of this study is to develop a low-cost Home Network Attached Storage (Home NAS) system utilizing a Raspberry Pi, complemented by a Telegram Bot for notifications. The proposed Home NAS leverages the Raspberry Pi's lower electricity consumption, portability, compact size, and cost-effectiveness compared to traditional NAS systems using PCs or pre-built NAS devices, thereby offering a practical and accessible solution for modern digital households.

The remainder of this paper is organized as follows: Section II describes the literature review that related to this topic. Section III explains the methodology used in the experimental setup. Section IV presents the results and analysis of the performance tests. Finally, Section V concludes the paper with a summary and potential directions for future work.

## II. Literature Review

### A. Home Network

Home networks are established when multiple computers share a connection via either a wired or wireless network within a residence. According to Edwards, Grinter, Mahajan, and Wetherall [4], home networking adaptations provide numerous benefits for users in terms of entertainment, education, healthcare, and communication . These adaptations facilitate data sharing between two or more computers within the same network. Unlike enterprise networks, data centers, and ISPs, home networks are distinct in several ways.

Home networks are primarily managed by users themselves, relying on their technical skills, while other networks require dedicated personnel for maintenance and management. Additionally, privacy is a major concern in home networks, as users are vigilant about who connects to their network. In contrast, employees in most companies do not expect privacy due to company policies and the needs of the IT department [5]. It is important to note that modern homes offer considerable topological flexibility, often incorporating multiple wireless access points and various networking protocols. Consequently, not all applications may function optimally within this infrastructure.

### B. Home Network Architecture

Home network architecture refers to the structural design and organization of devices and systems that enable communication and data exchange within a residential setting. This architecture has evolved from simple configurations connecting a few computers to sophisticated systems integrating numerous smart devices. Understanding the architecture of home networks is essential for optimizing performance, ensuring security, and enhancing the user experience.

Traditional home networks typically consist of several key components: a modem, a router, and various end-user devices such as computers, printers, and smartphones. The modem connects to the Internet Service Provider (ISP) and translates the incoming internet signal. The router then distributes this connection to various devices within the home, either through wired Ethernet cables or wirelessly via Wi-Fi [4]. In a wired setup, Ethernet cables connect each device directly to the router, offering reliable and high-speed connections.

However, the prevalence of wireless technology has led to a preference for Wi-Fi due to its convenience and ease of setup. Wi-Fi networks, while generally slower than wired connections, provide sufficient speed for most home applications and offer the flexibility of connecting multiple devices without physical constraints [6].

To address the limitations of traditional Wi-Fi, particularly in larger homes with multiple floors, mesh networking has become a popular solution. Mesh networks consist of a main router connected to a series of nodes placed throughout the home. These nodes communicate with each other to create a seamless and extensive Wi-Fi coverage area, reducing dead zones and maintaining consistent connection speeds [7].

Modern home networks are characterized by the integration of Internet of Things (IoT) devices, such as smart thermostats, security cameras, smart TVs, and home assistants. These devices connect to the home network, enabling automation and remote control features that enhance convenience and efficiency. The increased number of connected devices necessitates a robust and scalable network architecture to manage traffic effectively and maintain performance [8].

Home network architecture has evolved significantly, driven by technological advancements and the increasing demand for connected devices [9]. While traditional networks were straightforward and primarily wired, modern networks incorporate wireless technologies, IoT devices, and advanced features like mesh networking and network segmentation. As technology advances, home network architecture will undoubtedly continue to evolve, offering enhanced performance, security, and convenience for users.

### C. Network Attached Storage (NAS)

Network Attached Storage (NAS) has emerged as a vital solution for managing the challenges posed by exponential data growth [10]. NAS serves as a dedicated storage device that offers file-based storage accessible over a network, allowing efficient file sharing across multi-platform environments at a cost-effective rate [10]. Its widespread adoption is a result of its user-friendly management capabilities and its capacity to facilitate file sharing among clients utilizing different operating systems. NAS provides various advantages, including parallel I/O operations, incremental scalability, and decreased operating costs.

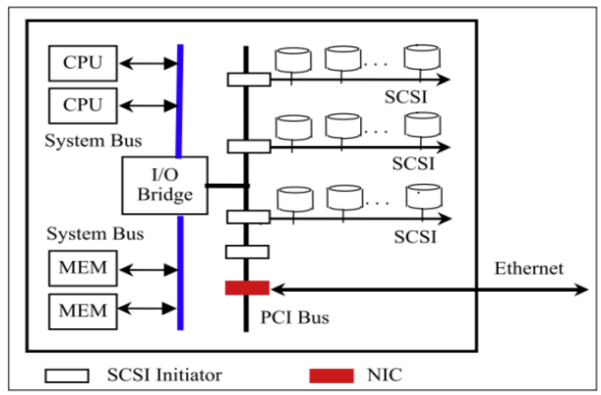


Fig. 1. Network attached storage architecture [11].

Typically, NAS operates as a file server, presenting a file interface to the network through protocols such as the Windows Common Internet File System (CIFS) or the Network File System (NFS). It connects to a local area network (LAN) and provides file-sharing services to multiple clients [12]. The typical architecture of NAS comprises a CPU, main memory, multiple disk drives, and an I/O bridge with interfaces for the system bus and memory bus, which connect to the CPU and memory, respectively. Fig. 1 illustrates the architecture of a typical NAS and its corresponding storage subsystem [11].

### D. Telegram Bot Notification

Telegram bots are automated programs within the Telegram app that engage with users, send notifications, and perform various tasks [13]. They are popular for their user-friendly nature and ability to provide timely and relevant information. This paper explores their architecture, functionalities, and applications, emphasizing their integration capabilities and wide range of services. Telegram bots can respond to messages and commands, send notifications, manage group activities, and integrate with other applications, enhancing communication and operational efficiency within the app.

Telegram bots function within a framework that enables smooth interaction with users. They make use of Telegram's Bot

API, which simplifies the creation and deployment of these automated programs. The API accommodates different types of messages such as text, audio, video, and documents, allowing bots to execute complicated tasks [14]. Furthermore, bots are capable of managing inline queries, delivering instant information and services without requiring extra input from the user.

The adaptable nature of Telegram bots enables seamless integration into numerous applications, thereby significantly enhancing their utility. They can be utilized for sending personalized notifications, managing and moderating group chats, conducting polls and surveys, and providing customer support. Furthermore, Telegram bots have the capability to integrate with external applications and services, including payment systems, social media platforms, and home automation systems, thereby further extending their functionality.

Telegram bots signify a notable advancement in automated communication, offering a diverse array of services that enhance user experience and operational efficiency [14]. Their ability to seamlessly interact with users and integrate with various applications underscores their significance in modern digital communication. As the usage of messaging platforms continues to expand, the role of Telegram bots is likely to evolve, yielding even more sophisticated and personalized services.

### *E. Related Works*

The study in [15] investigates the feasibility of creating a network-attached storage system using Raspberry Pi and Nextcloud, highlighting its potential for file and photo storage, as well as communication through a chat feature, making it a versatile solution for users. The proposed system is focus on centralized data access. Study [16] on successfully designing a Network Attached Storage (NAS) system using Raspberry Pi, which focus on scalable and flexible storage solutions. The other study [17] proposed a solution for a personal cloud storage using Raspberry Pi and external hard disk. This study allowing users to have full control over their data and customize their storage capacity without relying on third-party services.

Most of the previous works used Raspberry Pi for network storage solutions has gained traction due to its affordability, flexibility, and ease of implementation. Previous researches show Raspberry Pi can be effectively utilized to create both Network Attached Storage (NAS) systems and personal cloud storage solutions. It offering a cost-effective alternative to traditional storage methods.

Collectively, the previous study indicate that Raspberry Pi is a viable solution for low cost data storage. There is less consensus regarding the services that can be integrated with the Raspberry Pi like streaming, local backup, Torrent Box and notification mechanism. This study proposed the integration of those services in developing a NAS storage using Raspberry Pi.

## III. METHODOLOGY

### *A. Design and Development*

*1) Conceptual design for HOMENAS using raspberry Pi with telegram bot notification:* The conceptual design of the HOMENAS is illustrated in Fig. 2. In this setup, multiple PCs, mobile phones, and a Raspberry Pi are connected to the internet via a router. The Raspberry Pi serves as the central server, linked to both the portable HDD storage and the router, which provides an internet connection with a speed of 4 Mbps. Client devices connect to the server through the router. The server manages processes such as downloading, uploading, and video streaming. Data is stored on an external hard disk attached to the Raspberry Pi. Upon completion of a download, a notification is sent to the mobile phone via the Telegram application.

In a summary, Raspberry Pi acts as a central server that hosts a variety of services such as media streaming, local backup and torrenting. The use of Telegram for notifications enhances the user experience by informing them of important updates (like torrent completion) directly on their mobile device. Devices can communicate seamlessly with the Raspberry Pi for data access, media streaming, and backups, all on a home LAN. This system is ideal for home users looking for an all-in-one solution for media management, data backups, and torrenting, all centered around a low-cost Raspberry Pi.

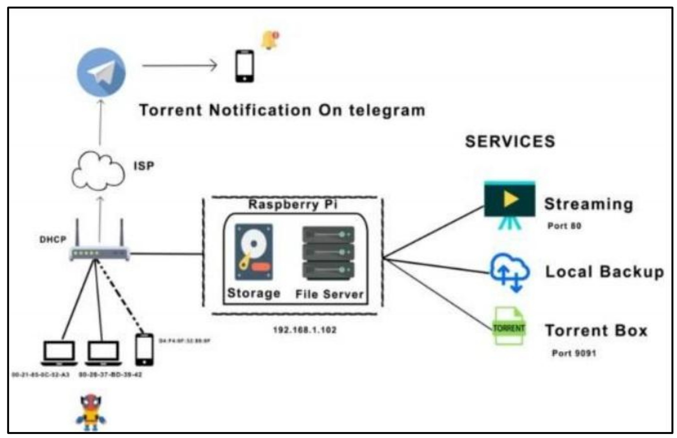


Fig. 2. Conceptual design for HOMENAS.

*2) Flowchart for HOMENAS:* Fig. 3 presents the flowchart of the HOMENAS system. This flowchart outlines a clear and structured way for users to interact with a NAS server, providing options for file management and media access, along with automated alerts for torrent downloads. The process begins with the user initiating interaction with the NAS server. The Raspberry Pi needs to be connected to a local network to allow system access. The user connects to the NAS server through the local area network (LAN). This is typically done via a Wi-Fi router or an Ethernet connection.

The user attempts to log into the NAS system. This involves providing credentials to gain access to the server's storage and services. Users with the correct username and password credentials are granted access to the server. Initially, users must log in to enter the system. Once authenticated, users can access the file server via Windows Explorer. Additionally, the system includes a web server that users can utilize for streaming purposes.

When users access the web server through a browser, they are provided with options to upload videos to the server or stream videos directly. The system also supports torrent downloads, enabling users to upload a torrent file or use a magnet link to start the download process. Upon completing a download, the system notifies the user via Telegram on their smartphone. Additionally, the system allows users to create personal folders for file organization and offers the capability to perform file backups on the server.

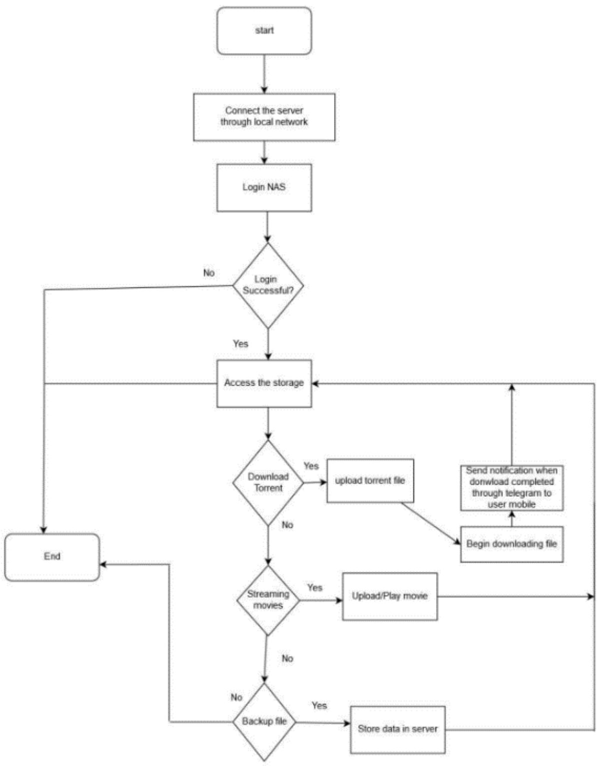


Fig. 3. Flowchart for HOMENAS.

*3) Development process:* The development process is divided into three main components: hardware configuration, software installation, and web development. The required hardware includes a Raspberry Pi, a TP-LINK WR1043N router, a LAN cable, 1 terabyte of external storage, DSL, and an external USB hub. The Raspberry Pi is connected to the router via the LAN cable, and the router is linked to the DSL connection, providing an internet speed of 4 Mbps. The external storage and the external USB hub are both connected to the Raspberry Pi. Fig. 4 shows the hardware setup.

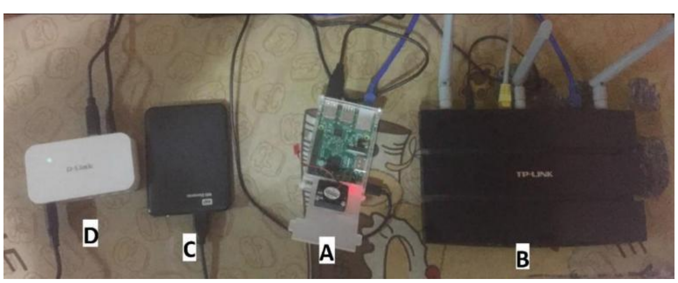


Fig. 4. Hardware setup.

To facilitate communication between the hardware components, OpenMediaVault is installed on the Raspberry Pi, serving as the operating system. Access to the Raspberry Pi can be achieved in two ways: through the web-based Graphical User Interface (GUI) or via SSH using PuTTy. The external storage must be added to the Raspberry Pi, and this can be configured through OpenMediaVault. During this configuration process, access rights for the storage can be set, and users can be created with credential information, such as passwords.

For file sharing among the created users, the Samba file server, which uses the SMB protocol, can be implemented. After enabling Samba, folders can be created with specific user permissions, such as Read/Write, Read-only, or No access. Additionally, OpenMediaVault Transmission (a BitTorrent client) is installed to facilitate downloading from multiple peers and uploading files.

The overall process of developing the HOMENAS can be referred to in Fig. 5. This figure visually represents the step-by-step process of setting up a Raspberry Pi as a server with OpenMediaVault (OMV) and additional functionalities. The first step is to assemble all necessary components for the Raspberry Pi, such as the board, power supply, SD card, network cable, and any additional peripherals needed.

Then followed by the process of installing the operating system. The OMV operating system image need to be downloaded and flash it to the Raspberry Pi's SD card using a tool like Balena Etcher. OMV is a specialized OS designed for network-attached storage (NAS). The next step, boot up the Raspberry Pi with OMV, access the web interface, and start the initial server configuration including network settings, system updates, and general preferences.

The fourth step is connecting a storage device (such as external USB drives or SSDs) to the Raspberry Pi. Once connected, you should configure these storage devices within the OMV interface to effectively organize how data will be stored and accessed.

Next is the process for set up user accounts in OMV. This may involve creating an administrative user and other accounts with specific permissions depending on their roles and usage needs. Followed by the process of transmission configuration for Torrent and setup notification for download completion. Then, proceed with the process of installation and configuration media server application to stream the content stored. The last part is implementing encryption to secure the data stored.

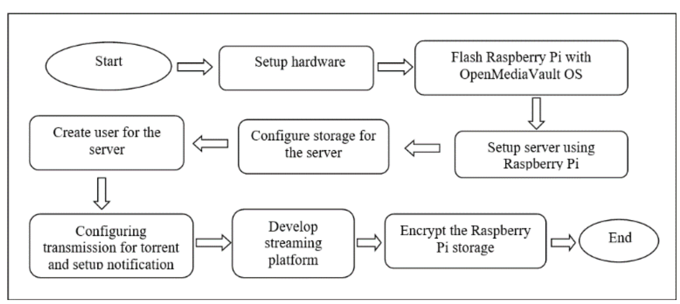


Fig. 5. Process in developing HOMENAS.

## B. Network Performance Testing

Network performance test is conducted to test the performance of the developed HOMENAS using Raspberry Pi with Telegram Bot notification. There are several experiments being conducted using wired and wireless connection to identify the uploaded speed and the downloaded speed.

# IV. Results and Findings

## A. Power Consumption

Table I shows the comparison of the power consumption for HOMENAS and a Laptop. The comparisons are based on the power usage for each device with runtime for 24 hours, as well as the estimation of the energy cost based on per day and per month. HOMENAS uses 6 watts and consumes only 144 watts per day. The estimated energy cost per day is RM0.03 and RM0.87 for 30 days. In contrast, the laptop consumes 120 watts and consumes 2880 watts per day. The estimated energy cost per day is RM0.62 and RM18.75 per month. This highlights that developing HOMENAS using Raspberry Pi can reduce around 95% of the energy cost.

TABLE I. POWER CONSUMPTION COMPARISON ACROSS HARDWARE PLATFORMS: HOMENAS AND LAPTOP

| Hard ware | Power (Watt) | Usage (Hour) | Watt / day (W) | Estimates the energy cost /day | Estimates the energy cost/month |
|---|---|---|---|---|---|
| HOM ENAS | 6 | 24 | 144 | RM0.03 | RM0.87 |
| Laptop | 120 | 24 | 2880 | RM0.62 | RM18.75 |

## B. Torrenting Performance

File downloading using torrents is tested on both Raspberry Pi and a laptop. The test is conducted three times on two different size of files which 100Mb and 300Mb without other users are on the network. Based on the Table II, the maximum speed for downloading 100Mb file for Raspberry Pi and laptop are similar which is 425kbps. There is a bit different for downloading 300Mb file which Raspberry is 469kbps and laptop 428kbps. Overall, the average speed is quite stable for both Raspberry Pi and laptop.

The experimental evaluation of torrent file downloading on both Raspberry Pi and a conventional laptop demonstrates that the Raspberry Pi is a viable and efficient alternative for such tasks. Both devices achieved similar maximum download speeds for the 100MB file (425 kbps), while the Raspberry Pi exhibited a marginally higher maximum speed (469 kbps) compared to the laptop (428 kbps) when downloading the 300MB file.

Furthermore, the Raspberry Pi consistently reached optimal download speeds (above 350 kbps) in a shorter amount of time and completed downloads more quickly on average. Additionally, the system's integration with Telegram for user notification proved to be highly responsive, with alerts delivered in under one second. These findings suggest that, under the tested conditions, the Raspberry Pi not only matches but, in some aspects, surpasses the performance of a traditional laptop in torrent-based file downloading tasks.

TABLE II. TORRENTING PERFORMANCE COMPARISON

| Device | *Raspberry Pi* | | *Laptop* | |
|---|---|---|---|---|
| File size | 100MB | 300MB | 100MB | 300MB |
| Maximum speed | 425kbps | 469kbps | 425kbps | 428kbps |
| Average speed | 350kbps | 350kbps | 306kbps | 300kbps |
| Time take to achieve optimum speed | 47s | 60s | 123s | 353s |
| Average time to download | 6 m 12s | 15m 13s | 7m 18s | 18m 23s |
| Time to notify user | Less than 1s | Less than 1s | N/A | N/A |

## C. Streaming Performance

Streaming performance refers to how well a network can transmit audio, video, or other data in real-time, allowing users to consume content without interruptions or delays. Several factors influence streaming performance, and understanding these elements can help readers appreciate its significance in the context of a Home Network Attached Storage (HOMENAS) system like the one developed with a Raspberry Pi.

In this study, the performance is evaluated based on the connection type and number of users in the network.

*1) Streaming rate:* wired and wireless for single user Fig. 6 shows the wired streaming rate fluctuates significantly, reaching peaks at 6.94 Mb/s and 11.62 Mb/s, but dropping to zero multiple times throughout the timeline. In contrast, the wireless streaming rate in Fig. 7 shows a more stable performance, with the wireless streaming rate remaining between 2.14 Mb/s and 4.54 Mb/s, without any complete drop to zero. While wired streaming exhibits higher peaks, it also experiences sharp interruptions, whereas wireless streaming remains more consistent, albeit at lower speeds.

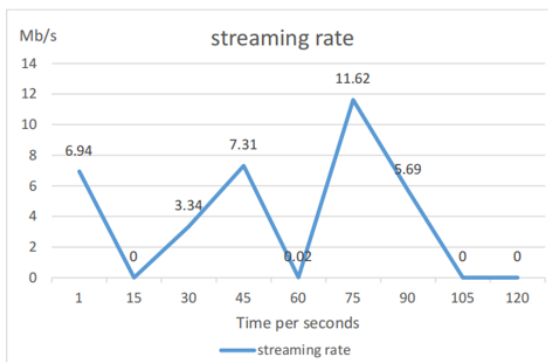


Fig. 6. Wired streaming rate for single user.

When streaming rate is high, it indicates that the data being transmitted at a faster pace. More data can be transmitted and better quality of video and audio. It also indicates content tends to play smoothly without buffering or lagging. However, high streaming rate requires more bandwidth and if network has limited capacity, this could result in slower performance for other application for the same network. If the connection cannot sustain the high streaming rate consistently as Fig. 7, it might cause by less capable devices or network congestion.

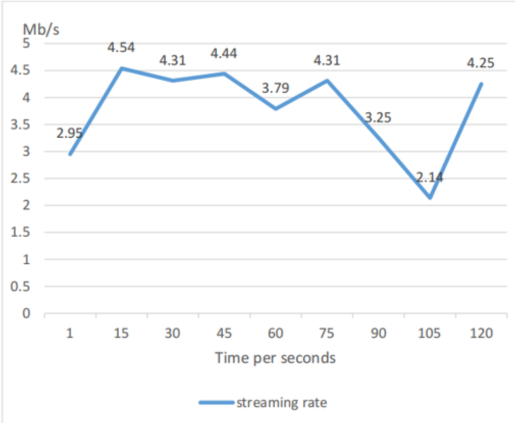


Fig. 7. Wireless streaming rate for single user.

*2) Streaming rate:* Wired and wireless for multiple users The graph in Fig. 8 shows the wired streaming rates in megabits per second (Mb/s) for three different users over a period of 120 seconds. User 1 (Blue Line) starts at a rate of about 3.31 Mb/s, peaks early at 7.64 Mb/s around the 15-second mark, and then generally maintains a high streaming rate, ending around 4.1 Mb/s. User 2 (Orange Line) begins around 3.81 Mb/s, dips significantly to 0.01 Mb/s at around the 60-second mark (indicating almost no data being streamed), and then recovers back to about 3.78 Mb/s by the end of the period. User 3 (Gray Line) shows a gradual decline from an initial 3.71 Mb/s to about 0.09 Mb/s by the end of the period, indicating a consistent decrease in streaming rate.

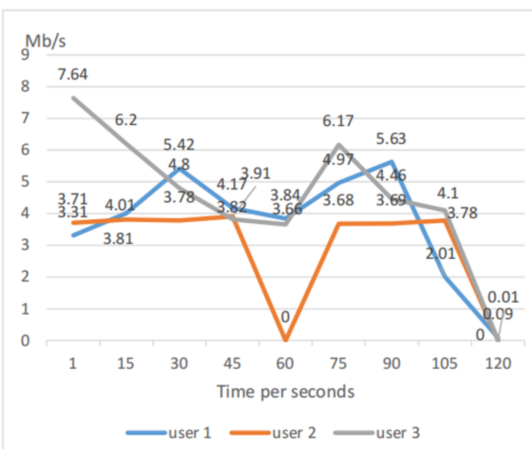


Fig. 8. Wired streaming for multiple users.

Based on Fig. 8, user 1 exhibits the most stable and high streaming rate, suggesting a strong and reliable connection throughout the period. The user 2 experiences a dramatic drop in the middle of the session, which could indicate a temporary disruption or bandwidth competition. The recovery suggests that the issue was resolved while user 3 demonstrates a steady decline in streaming rate, which might suggest network degradation or increasing network congestion over time.

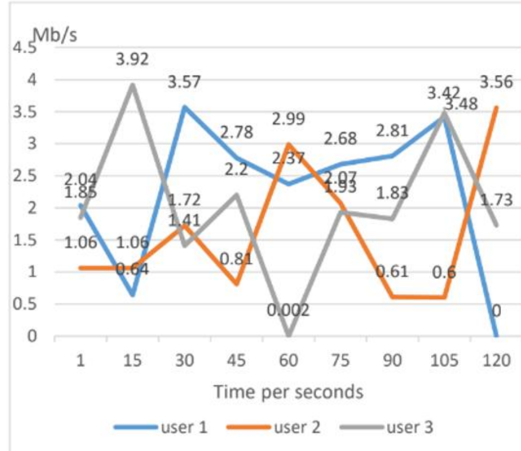


Fig. 9. Wireless streaming for multiple users.

Fig. 9 shows a graph for the wireless streaming rates for three different users over a period of 120 seconds. The x-axis represents time in seconds, and the y-axis represents the streaming rate in megabits per second (Mb/s), ranging from 0 to 4 Mb/s. User 1 (blue line) starts with a low streaming rate of 1.85 Mb/s and fluctuates throughout the 120-second period. The rate peaks at 3.57 Mb/s around the 25-second mark, before experiencing a drop. The connection becomes unstable, with notable dips close to 0 Mb/s around 60 and 120 seconds, showing intermittent or poor performance at those points.

The orange line which refer to user 2, starts at rate of 1.06 Mb/s and experiences highly fluctuating streaming rates. It has several points where the connection reaches 0 Mb/s, particularly at 45 seconds, 75 seconds, and at the 120-second mark. The rate peaks near 3.48 Mb/s at around the 105-second mark, followed by a sharp decline to 0.

Meanwhile, the grey line represents the user 3 starts off stronger than the other two users with a rate of 2.04 Mb/s. It shows a peak at 3.92 Mb/s around the 15-second mark, maintaining relatively consistent streaming rates, although some dips are evident. The user 3 has more stable connection compared to the other users. However, it still has noticeable declines, especially between 70 and 80 seconds where the streaming rate reaches 0 Mb/s.

Fig. 9 indicates variability in wireless streaming rates among multiple users over time. The fluctuations and instances of 0 Mb/s indicate potential wireless network challenges such as interference, bandwidth limitations, or device performance, which can affect user experience and cause interruptions in streaming quality.

## V. Conclusion and Future Recommendation

In conclusion, Raspberry Pi can be configured to develop a Home Network Attached Storage (HOMENAS) for a lower cost. Different microcontrollers or hardware can be used to develop HOMENAS and may produce different results in terms of performance. The developed HOMENAS can be used with different connectivity, either guided or unguided transmission medium. The guided transmission medium is faster compared to the unguided transmission medium for single as well as for multiple users. In terms of torrent performance, the results show that stability is better on Raspberry Pi compared to the PC. File also can be downloaded faster while using the Raspberry Pi and it consume lower electricity. Therefore, the Raspberry Pi can be another alternative to create a HOMENAS.

Future research could explore the integration of advanced security features in NAS systems using Raspberry Pi, focusing on data encryption and user authentication methods to enhance data protection for small organization instead of as a personal data storage. Another area for future research could involve the optimization of NAS performance through the implementation of various file systems and network protocols, assessing their impact on data transfer speeds and overall system efficiency in different operational environments.

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