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Cloud Computing Analysis of Hybrid Networks on Raspberry

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Abstract: There are already a lot of cloud services on the internet which provide services, some of them even provide free facilities, but they are still limited in usage and capacity. Capacity is calculated based on saved files, temporary files, and even trash files. Moreover, data security cannot be guaranteed because the hardware is not properly set or owned by someone else. The cloud used cannot guarantee the connection and the bandwidth. The stigma of building cloud computing revolves around huge costs, not limited to operational and maintenance costs, nor the proper location for the cloud network equipment. As an effort to build data storage with large capacity, bandwidth regulation, and data protection, which is located in a private location, building a cloud computing service system which is efficient in time, cost, and place, and has good performance is no longer an impossible thing to do. With the help of Microcontroller technology, Raspberry Pi, a Cloud Computing with a Hybrid network could be built to reduce cost, time and space for the system. With the NextCloud application embedded into the cloud computing server, performance can be improved, including easy data synchronization that will flawlessly operate as a Client Server on a wide variety of today's devices with examples being PCs, Tablets, Notebooks or Smartphones.

Keywords: *Raspberry pi; Cloud Computing; NextCloud; Server; Hybrid Network*

INTRODUCTION

The concept of *Cloud Computing* has attracted a lot of interest from business, industry and education world. *Cloud-based* solutions seemed to be the key for IT organizations that have limitations in budgets. *Cloud Computing* is a new paradigm in distributed computation presenting a lot of ideas, concepts, technologies and various architectural types which are presented in a *service-oriented* form (Yan et al., 2016). According to Foster, *Cloud Computing* is a large-scale distributed computing paradigm that is driven by economic factors that contain a collection of abstract virtualization, dynamic scalability, managing computing power, storage media, platforms, and services that can be accessed according to external customers' needs via the Internet (Aziz et al., 2022; Kurniawan, 2015).

Cloud server configuration that can be done anywhere and anytime is a fundamental requirement, besides the ease, speed, and flexibility in machine order. To achieve this, there is a requirement for a system which could handle the problems. "Cloud computing with Infrastructure-As-A-Service (IAAS) can provide a reliable infrastructure (S. Nazihah, S. A. Fitri, I. Nathasia, 2018).

Cloud computing has to have a storage server. Most servers typically require large spaces and cost huge sums of money. Creating the infrastructure is expensive and not all companies, communities or private users can manage the expense. To overcome the issue, a cloud computing system using Raspberry Pi is considered very appropriate and useful for a company, community and personal user at this time (Alfiandi et al., 2020). Creating an infrastructure of cloud computing system using Raspberry Pi which is a third-party resource system that can be accessed via a computer network is an affordable way to curb the expense. Raspberry Pi is a helpful solution for minimizing resources and finances in creating a cloud storage server (Louis et al., 2021).

Raspberry Pi is a form of third-party resource system that can be accessed through a computer network at a low cost. *Raspberry Pi* is one of the helping solutions for minimizing resources and finance used in building a server cloud storage (Louis et al., 2021).

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Hybrid is a term that is used to describe the combination of more than one type of *cloud system*, for example, public cloud with private, internal or external. It can also refer to the grouping of *cloud virtualization* on servers that work with physical hardware(Thirta, D., 2022).

With *hybrid network* technology implemented in the cloud system, users can access these resources via a high-speed Internet network connection or local network without having to connect directly to the hardware that stores these resources. Because the computing process is happening on a *remote server*, the hardware and software requirements to access the resources are lowered, which can reduce costs and maintenance processes (Sunaryo et al., 2017).

Creating a *cloud computing server* as storage that can be used by anyone with *hybrid network* technology using *Raspberry Pi* can provide easier and faster storage services.

LITERATURE REVIEW

Previous research about cloud computing or cloud storage. As an effort to enhance and improve the development of cloud computing, conducting a literature study has to be done in one of the research application methods, such as:

1. Research conducted by Ferdinand Louis, M. Ficky Duskarnaen, and Hamidillah Ajie (2021) on testing the speed of Raspberry Pi as private cloud storage for small office home office with occuring problems at Upt Tik. Seeing how far the speeds are made by Raspberry Pi in the transfer data process.
2. Research conducted by P. Dhanu Thirta (2022) about utilizing cloud computing technology in the business world. It explained the available storage capacity that can be used for a business. The real focus was on the facility of storage capacity in the cloud. The problem is that the data was still in another location.
3. Research conducted by T. Alfiandi, T. Diansyah, and R. Liza (2020), about testing the utilization of cloud computing technology which described the speed of data transfer and access rights. The utilizations used were Ansible configuration management and Shell Script on the Aws Deployment cloud server.
4. Research conducted by A. Nazihah Surosa, I. Fitri, and N. D. Nathasia (2018) about the development of Hybrid Cloud Storage using the base of Infrastructure-As-A-Service (IAAS). Several things stand out in this model.

From several literature review sources, we know that research on cloud computing using Raspberry Pi for collaboration of data access on hybrid networks in simple servers has not been conducted.

Cloud Computing

Cloud computing is a model that allows devices to use resources together and easily provides network access everywhere, able to be configured, and on-demand services. In cloud computing technology, three service models can be selected according to one's needs. The three service models presented are Infrastructure-As-A-Service (IAAS), Platform-As-A-Service (PAAS), and Software-As-A-Service (SAAS). This classification is done to help adjust to the user's needs, helping the user with the provided service. IAAS or Cloud IAAS is a type of cloud computing service that emphasizes the provision of network facilities, network hardware, server computers, storage media, processors and virtualization processes which support the computing process.

PAAS or Cloud PAAS is a type of service that emphasizes providing a platform to help the software development process fast and easy. The platform services used are generally web-based, where a lot of features are provided to make it easier for programmers and general users to develop applications without the need for extensive usage of code writing (coding).

SAAS is a type of service provided by cloud computing technology for users in sharing software (application). SAAS services are generally provided in the form of a web-based interface.

Raspberry Pi

Raspberry Pi is a small and cheap Advanced RISC Machine / Acorn RISC Machine (ARM) processor which can run Linux-based operating systems or other light operating systems. The Raspberry Pi already has several ports such as a High-Definition Multimedia Interface (HDMI) port, a Radio Corporation of America (RCA) video port, an audio port, an Ethernet port, and a Universal Serial Bus (USB) 2.0 port. Take a glance at Figure 1 to understand how it looks.

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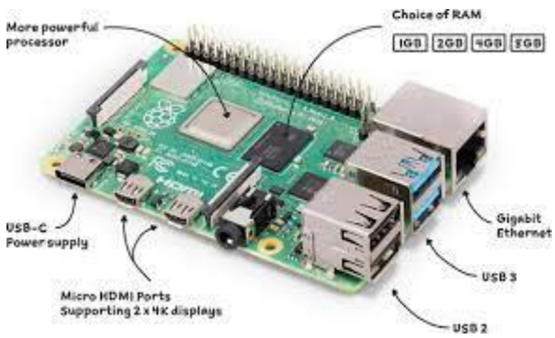

Figure 1. Raspberry Pi 4 has RAM options ranging from 1 GB to 8 GB of RAM capacity.
Source: https://assets.raspberrypi.com/

Raspbian Operating System Installation

Raspbian is a completely Linux-based operating system, open source and is supported by the community, general and professional experts. Raspbian is an operating system derived from the Debian Linux distro. As an open-source and Debian-based operating system, Raspbian is increasingly enjoyed by its users, especially as it is an operating system specifically made for Raspberry Pi.

Python Programming Language

Based on the official Python website https://wiki.python.org/moin/, Python is a multipurpose interpretive programming language with a design focused on code readability. Python is claimed as a programming language that combines capabilities, clear-to-read code syntax, equipped with a large and comprehensive library standard for functionality.

Some advantages of the Python programming language are as follows:

1. It has an extensive library. Python provides modules that can be used for various purposes.
2. It has a clear and simple structure to understand.
3. It has layout rules for source code that make it easier to be checked, read back and rewritten.
4. It is an object-oriented language.
5. It has an automatic memory processing system (garbage collection used by Java). Modules are easy to be developed by creating new modules. These modules can be built in Python and C/C++.

METHOD

Flowchart System

Cloud Computing is a computing model, where resources such as *processor power, storage, network, and software* become abstract and are provided as services on the network/internet using remote access patterns (Kholil & Mu'min, 2018). Meanwhile, *Hybrid cloud* is a *cloud computing deployment* model which is a combination of *private cloud and public cloud*. In this *hybrid deployment* model, SLA (Service Level Agreement) rules are used to refer to which data will be placed on *public cloud* (Internet) storage or *private cloud* (Internet) storage. It aims to make data security management easier. The following picture is the flowchart system that will be built.

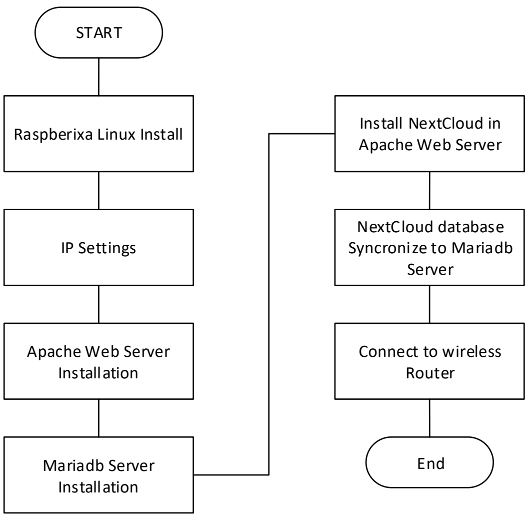

Figure 2. Flowchart System

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Figure 2 shows the process of how to build cloud computing using 2 *Raspberry Pi microcontrollers*, starting from the process of installing *Raspbian Linux* to having it connected to a *Wireless Router*.

Installation

There are several supporting software that must be installed on the *Raspberry Pi* to build a *NextCloud system* such as *PHP 7*, *Apache web server*, *MariaDB server* and *NextCloud* application. The following are some of the syntaxes that were used to install the *NextCcloud* System on Raspbian:

1. *IP Address Interfaces Configuration*
   "root@raspberrypi:/home/pi# nano /etc/network/interfaces"
   Description: explains how to enter the *interfaces* directory for configuring the IP *Address*.

2. IP Addressing
   "auto enxb827ebe9a18d
   iface enxb827ebe9a18d inet static
   address 200.100.10.1
   netmask 255.255.255.0

   allow-hotplug wlan0
   iface wlan0 inet manual
   wpa-roam /etc/wpa_supplicant/wpa_supplicant.conf
   iface default inet static
   address 192.168.1.18
   netmask 255.255.255.0
   gateway 192.168.1.1"
   Description :
   auto enx : label of the installed NIC
   iface enxb : static inet to make the IP appear static
   address: identity address
   netmask: address grouping
   IP 200.100.10.1: used when the device is connected to a wired network
   IP 192.168.1.18: used when the device is accessed using a wireless network

3. *Installing Apache2*
   "root@raspberrypi:/home/pi# apt-get install apache2"

4. *Installing PHP7*
   "root@raspberrypi:/home/pi# apt-get install php7"

5. *Installing MariaDB-Server*
   "root@raspberrypi:/home/pi# apt-get install mariadb-server"

6. *Unzipping Nextcloud*
   "root@raspberrypi:/var/www# unzip nextcloud-13.0.0.zip"

RESULT

Use Case Diagram

A use case diagram is used to define a system from a user's perspective so that the *use case* diagram will be focused on the system's functionality, and not based on the flow or sequence. A *use case diagram* represents an interaction between an actor with the system (Damayanti & Khairunnisa, 2018). *The use case diagram* can be seen in Figure 3 and Figure 4.

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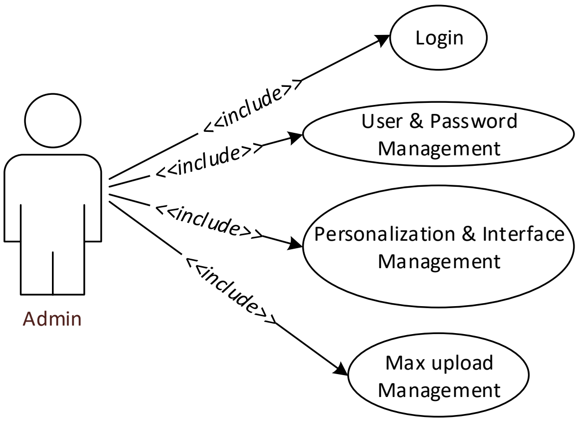

Figure 3. Use Case Admin Diagram

The *use case diagram* above shows the process of how the admin does a management of user identification and password before they can log into the application, they could personalize the user interface so it does not appear boring and manage maximum upload. Here an admin is limiting a user from uploading a file and other prohibited activities.

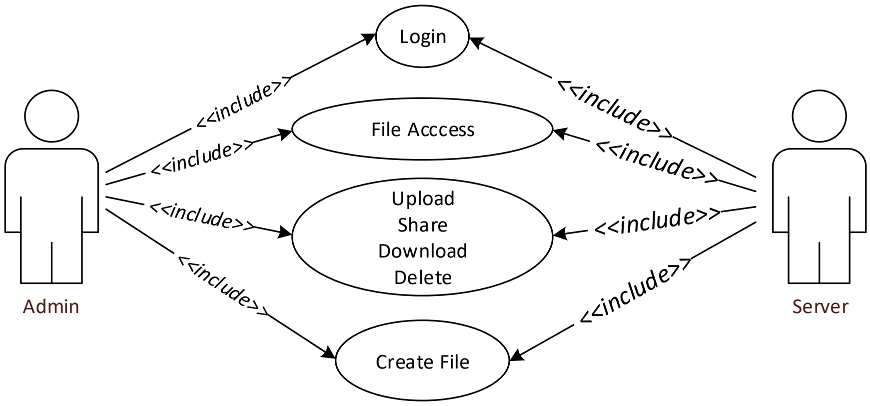

Figure 4. *Use Case Client Server Diagram*

The use case diagram above shows the process of how a client uses the created application starting from *login*, *file access*, *upload, download, share*, *delete* and *create file*. It also shows how the server does the same thing as the client does.

Activity Diagram

The Activity Diagram below describes a series of sequences which is used to describe activities that are formed in an operation and can also be used for other activities (Reka et al., 2022). The creation of *activity diagrams* at the beginning of the modelling process can be used to understand the entire process. *Activity diagrams* are also used to describe interactions between several *use cases*. It can be seen in Figure 5.

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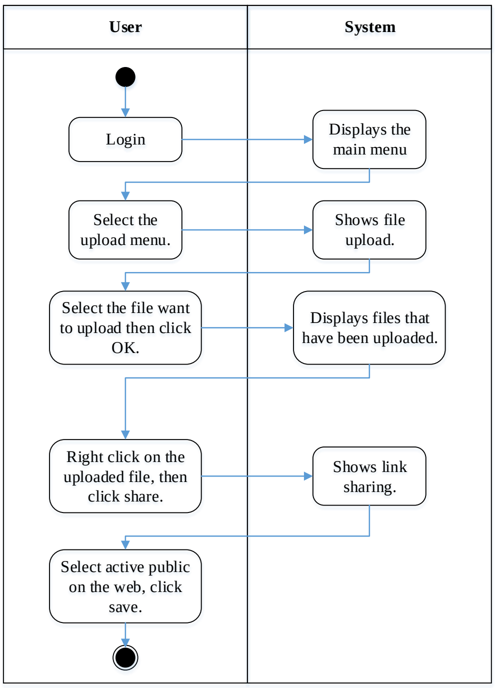

Figure 5. Activity Diagram Upload and Share file

Network Topology Scheme

The depiction of the network topology schematic will be implemented with the help of the *Cisco Packet Tracer* application. The following figure is a schematic view of the built network topology.

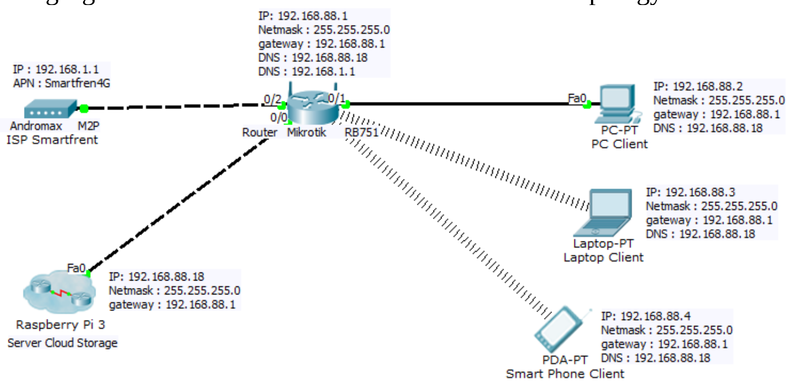

Figure 6. Network Topology Scheme Using Cisco Packet Tracer

With the *Cisco Packet Tracer* application, we can easily build simulations and design schemes in creating a network topology without having to use genuine devices while preventing damage and data loss if an error occurs during the installation or configuration within each device that is being used.

The following is the description of Figure 7:

1. PC, as the *Client device* accesses the *server* using a UTP transmission media cable.
2. Smartphone, as *Client device* accesses *server* with a wireless network.
3. *Andromax* M2P, as the systems' Internet Services Provider.
4. *Cloud Server System Raspberry Pi 3*.
5. *MikroTik RB751*, as a *Central network routing* media.

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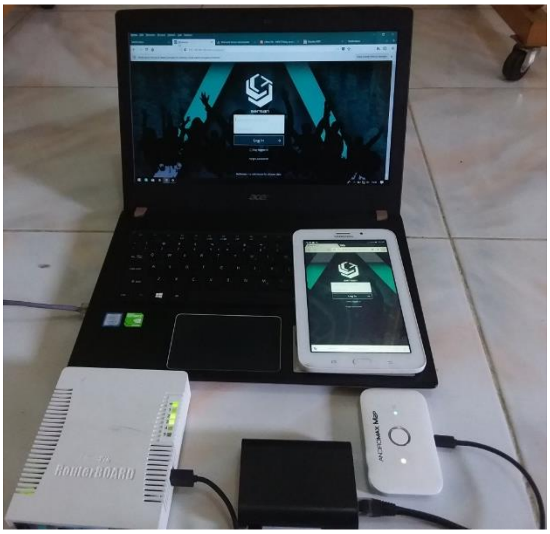

Figure 7. Topology of Hybrid Cloud Raspberry Pi 3 Network

Result Display of The Modified Cloud System Interface

To enter the *cloud storage system* login page, the IP address that has been configured must be pinged. In this case, the researcher has configured the *cloud system's* IP with the address 192.168.88.18. The system will then display a login page and will ask for a username and password.

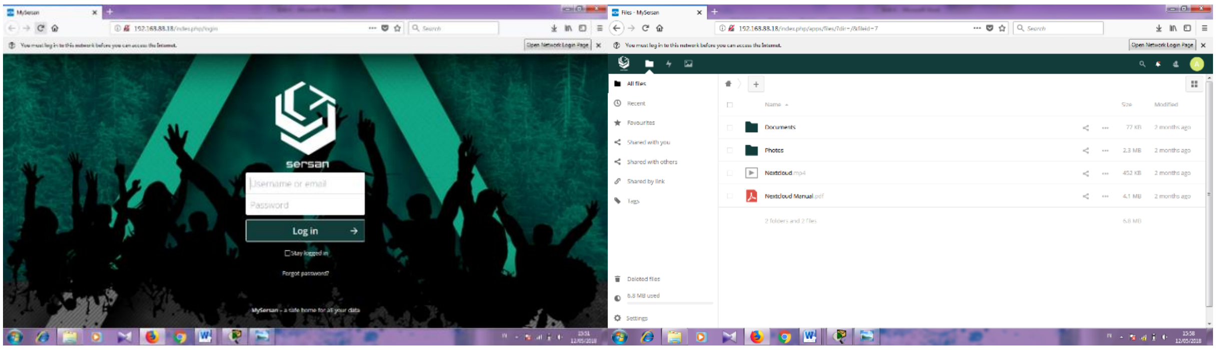

Figure 8. Login Page on desktop/PC and Cloud System Home

***Hybrid Network* Testing Using Ping Test on Terminal**

Several ping tests were executed on both local networks internet networks and other devices used in the system development. Ping testing was carried out via Terminal/Command Prompt on client devices that were connected to the cloud system network.

Below are the connection test results between the Cloud System Server, Mikrotik Router, and the Internet with user1, user2, and user3.

1. Ping Testing on Cloud Systems
   Ping testing is tried on a cloud server. The ping test will be carried out three times on each client device to get satisfactory results and information, then the ping speed test results for each device will be calculated to get the average speed.

Table 1. Ping Testing on Cloud Server

User	***Device***	**Ping Speed Everage**		
		1st Testing	**2nd Testing**	**3rd Testing**
user1	PC	5 ms	4 ms	5 ms
user2	PC Wireless	6 ms	7 ms	5 ms
user3	Smartphone	4 ms	5 ms	4 ms

From the results of all three upload speed tests above, the average ping speed for each device is calculated using the specific formula that follows:

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Average Speed = Sum of ping speed / Number of data samples
Average Speed of user1 = (5 + 4 + 5) / 3
= 4.6 ms
Average Speed of user2 = (6 + 7 + 5) / 3
= 6 ms
Average Speed of user3 = (4 + 5 + 4) / 3
= 4.3 ms.

2. Ping Testing on Mikrotik RB751 Router
Ping testing will be executed three times on each client device to receive satisfactory results and information, the ping testing results of every device will then be calculated to receive the average ping speed.

Table 2. Ping Testing on Router

User	***Device***	**Ping Speed Everage**		
		1st Testing	**2nd Testing**	**3rd Testing**
user1	PC	4 ms	4 ms	4 ms
user2	PC Wireless	4 ms	5 ms	4 ms
user3	Smartphone	5 ms	4 ms	4 ms

From the results of all three upload speed tests above, the average ping speed for each device is calculated using the specific formula that follows:

Average Speed = Sum of ping speed / Number of data samples
Average Speed of user1 = (4 + 4 + 4) / 3
= 4 ms
Average Speed of user2 = (4 + 5 + 4) / 3
= 4.3 ms
Average Speed of user3 = (5 + 4 + 4) / 3
= 4.3 ms.

3. Ping Testing to Internet
Tests carried out on internet connections. Connection and access depends on the internet provider. Ping testing will be carried out three times on each client device to get satisfactory results and information, then the ping speed test results for each device will be calculated to get the average speed.

Table 3. Ping Testing to Internet

User	***Device***	**Ping Speed Everage**		
		1st Testing	**2nd Testing**	**3rd Testing**
user1	PC	190 ms	230 ms	280 ms
user2	PC Wireless	320 ms	310 ms	270 ms
user3	Smartphone	260 ms	290 ms	270 ms

From the results of all three upload speed tests above, the average ping speed for each device is calculated using the specific formula that follows:

Average Speed = Sum of ping speed / Number of data samples
Average Speed of user1 = (190 + 230 + 280) / 3
= 233.3 ms
Average Speed of user2 = (320 + 310 + 270) / 3
= 300 ms
Average Speed of user3 = (260 + 290 + 270) / 3
= 273.3 ms.

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Upload and Download Speed Testing on Cloud Systems

Upload and download speed testing for this cloud system was divided into three devices with three samples of users (user1, user2, and user3). The file that will be uploaded in this test is a video file with a duration of 04.32 minutes in .mp4 format that has 46,454 KB of capacity.

1. Upload Speed Testing on Cloud Systems
Upload testing will be executed three times on each client device to receive satisfactory results and information, the upload speed testing results of every device will then be calculated to receive the average speed.

Table 4. Upload Speed Testing on Cloud System

User	*Device*	**Upload Speed**		
		1st Testing	**2nd Testing**	**3rd Testing**
user1	PC	14.12 seconds	12.27 seconds	13.80 seconds
user2	PC Wireless	14.49 seconds	13.24 seconds	14.81 seconds
user3	Smartphone	16.02 seconds	14.46 seconds	14.39 seconds

From the results of all three upload speed tests above, the average upload speed for each device is calculated using the specific formula that follows:

Average Speed = Sum of upload speed / Number of data samples
Average Speed of user1 = (14.12 + 12.27 + 13.80) / 3
= 13.40 seconds
Average Speed of user2 = (14.49 + 13.24 + 14.81) / 3
= 14.18 seconds
Average Speed of user3 = (16.02 + 14.46 + 14.39) / 3
= 14.96 seconds.

The conclusion that was obtained from the upload tests above concluded that the speed of user1 who used a cable line on the network connection had a faster connection than other users who used a wireless-transmission network. By using cable, user1's upload speed is more stable and faster than others.

2. Download Speed Testing on Cloud Systems
Similar to the upload speed testing, this download speed testing will be implemented three times on each client device to receive trustable results and information, the download speed testing results of every device will then be calculated to achieve the average speed.

Table 5. Download Speed Testing on Cloud System

User	*Device*	**Download Speed**		
		1st Testing	**2nd Testing**	**3rd Testing**
user1	PC	01.53 seconds	01.46 seconds	01.34 seconds
user2	PC Wireless	02.64 seconds	04.02 seconds	02.07 seconds
user3	Smartphone	03.27 seconds	03.32 seconds	04.68 seconds

From the results of the three sequential download speed tests above, the average download speed for each device is calculated using a formula as follows:

Average Speed = Sum of download speed / Number of data samples
Average Speed of user1 = (01.53 + 01.46 + 01.34) / 3
= 01.44 seconds
Average Speed of user2 = (02.64 + 04.02 + 02.07) / 3
= 02.91 seconds
Average Speed of user3 = (03.27 + 03.32 + 04.68) / 3
= 03.76 seconds.

From the download test above, the speed of user1 who used a cable line on the network connection has a faster connection than others who used wireless transmission media. By using a cable line, user1's download speed is faster and more stable than others. Meanwhile, user2 and user3 who utilised wireless transmission media had a

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speed difference of approximately one second. The download speed for user2 and user3 are substantially slower than for user1 who used a cable line, since wireless networks are affected by weather conditions, temperature and humidity in the test room. The factors caused a relatively more unstable connection than using a cable line for data transfer.

DISCUSSIONS

This testing was carried out to examine how high a user's usage intensity was on the *hybrid technology cloud system* which was built using the Raspberry Pi 3 device for downloading files, uploading files, and internet network at the same time for twelve participants.

Table 6. *Maximum User Upload* Testing Result on *Cloud System*

Number of Users	Number of Upload File Capacity	Time to Finish	Upload Assessment Results
12 User	16,7 MB	+/- 50 seconds	96,33
Description in Letter			*A*

Table 7. *Maximum User Download* Testing Result on *Cloud System*

Number of Users	Number of Download File Capacity	Time to Finish	Download Assessment Results
12 User	16,7 MB	+/- 20 seconds	91,75
Description in Letter			*A*

The results of the Maximum User Upload and Download in Table 6 and Table 7 show that the cloud system ran smoothly without any failure response or other problems with twelve users accessing the upload or download service on the *cloud system* that was built using *Raspberry Pi* using NextCloud and *hybrid network* technology with a variety of file types such as images, audios, documents or videos.

Table 8. *Internet Maximum User Speed* Testing Result on *Cloud System*

Number of Users	Accessed Features	Time	Upload Result
12 User	*Youtube *Browsing *Socmed	+/- 30 Minutes	95,33
Description in Letter			*A*

Table 8 shows that the testing of the *internet network facility* that was built refers to *a cloud system* assembled using *Raspberry Pi* while utilising *NextCloud* with *hybrid network* technology which is distributed through *MikroTik RB751* as a router and Andromax Smartfren for filling the Internet Service Provider role. It is proven that the service was able to serve the usage of twelve users simultaneously with various accessed facilities starting from streaming online applications such as *YouTube*, internet browsing using the *Google* search engine, to communicating in social media, examples being *Facebook*, *Line* and *WhatsApp*

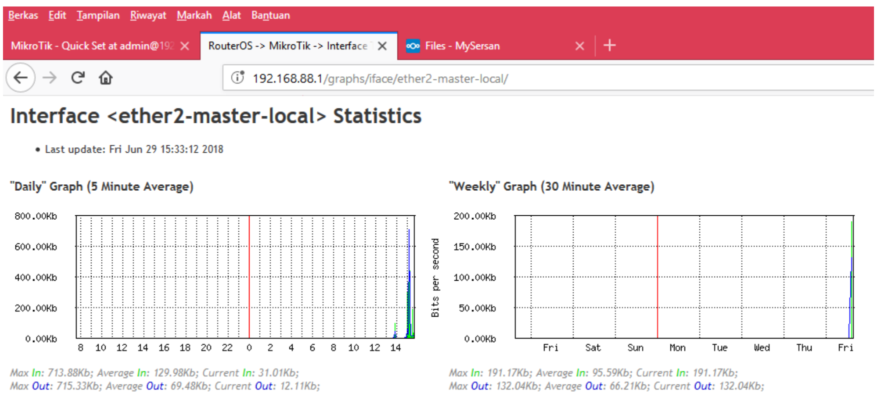

Figure 9. Testing Documentation of the Cloud System Usage

Figure 9 shows the network traffic of the *cloud system* coming from the Ethernet 2 port which was recorded via the graph service feature provided by the *MikroTik* router, the graph shows that the system can be said to be

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stable as the traffic did not show any problems nor the graph generated excessive reading. The traffic screenshot is also proven with evaluation from various users that directly test the performance of the assembled *cloud system*.

CONCLUSION

Cloud Computing with Hybrid Network Technology using Raspberry Pi Microcontroller has been completed and implemented successfully. The maximum number of users that can utilize the cloud system could not be firmly determined because of the limitations in used devices, but it is proven that at the very least, eight users accessing the cloud system simultaneously will not cause an error nor bring the server down. Based on this research, the Raspberry Pi 3 is highly recommended for supporting home or office systems and small communities that require cloud computing technology without the expenses a typical server would give. Using the Raspberry Pi 3 on a cloud server greatly minimizes costs and is more economical in terms of energy consumption, and it acquires smaller spaces too, hence the price and the minimalistic component size. Download and upload speed testing on user1 who used a cable line on a network connection had a faster connection than other users who used wireless transmission media. By using cable media, the user1's download and upload speed was more stable and faster than other users who used wireless network. Meanwhile, the user2 and user3 had a minuscule difference in terms of speed, only a second difference. Download and upload speed for user2 and user3 is seen to be slower than user1 who employed a cable line, because a wireless network is more prone and can be affected by weather conditions, temperature and room humidity, causing less stable connection than those who used cable transmission media which is not affected by said factors.

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