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AI-Based Smart Cane for The Blind Using Raspberry Pi 3B

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Abstract –*The eye is one of the human sensory organs that plays an important role in human life. The main function of the eye is to record the surrounding conditions, so that it can provide information in everyday life. People who have visual impairments are called blind. This limitation is one of the causes of disruption in the daily activities of blind people. Therefore, in their daily activities, blind people use assistive devices, such as canes. In this study, the author will create a system that can later be implemented in a cane with features to facilitate the activities of blind people. This cane has a camera that captures object images, which are later processed by the Raspberry Pi 3B+ using the Faster R-CNN algorithm. Faster R-CNN is a deep learning method used to detect objects in images. In addition, this cane is equipped with several supporting sensors, including an HC-SR04 ultrasonic distance sensor and a water level sensor for detecting water puddles. The output of all systems is sound, transmitted via wireless earphones and a buzzer as an information source/alarm for the visually impaired. The results of this research can assist the visually impaired by providing an assistive device for daily activities.*

Keywords*: Blind, Cane, Faster R-CNN, Raspberry Pi*

I. Introduction

The eye is a vital part of the body that plays a vital role in human life. One of its functions is as a sense of sight, recording the surrounding conditions and allowing us to identify objects. A person with visual impairment is referred to as blind. Etymologically, the word "tuna" means injured, damaged, lacking, or no sight. Blind people are generally still able to engage in activities, albeit in limited contexts, with the aid of a walking stick. At this time, a new infrastructure concept emerged: the Software-Defined Network. SDN is an innovative approach to designing, implementing, and managing networks that separates network control (control plane) from forwarding (data plane), resulting in many advantages in terms of network flexibility and controllability.

Blind people have limited mobility in their daily lives. Mobility is the act of moving from one place to another. Mobility is a desired ability for every individual, especially those with visual impairments. The mobility they desire can be seen physically, such as the availability of facilities and infrastructure that facilitate mobility in carrying out activities. It can be said that the concept of modern network architecture is very different from that of traditional architecture. The concept in the network layer is an example of network abstraction before the concept of Software Defined Network. The concept of this layer is also limited to abstracting the data plane; no concept represents the control plane. [3]

Currently, assistive technology for people with disabilities has developed rapidly. Blind people already have several assistive devices for mobility and activities. One such device is a special cane for the Blind. However, in use, it is still a conventional cane, a type of mobility aid widely used by blind people. However, these canes have the drawback that they cannot detect objects in front of the user at a certain distance. Therefore, the user will only be aware of the object or obstacle if the cane first touches it. This can cause collisions between the user and the object.

Along with the rapid development of technology today, it has led to the creation of many innovative tools that will be very helpful to the Blind. In this study, an assistive device was created in the form of a cane equipped with a camera that has the same function as the eye. The camera can capture or record an object integrated with the Raspberry Pi microcontroller and the HC-SR04 distance sensor. The HC-SR04 sensor is used to determine the distance to the object. For the system to detect an object, image processing data is needed. The method used in this study is Faster R-CNN. Faster R-CNN is a deep learning method for detecting objects in images.

Furthermore, this cane is equipped with a water-level sensor that detects puddles of water in front of the user, potentially disrupting their activities. The hope is that this research will produce a cane with several advantages over standard canes, making it easier for blind people to carry out their activities.

II. Related Works

In 2018, Tata Supriyadi, in a journal article titled "Smart Cane as a Tool to Monitor the Whereabouts of Blind People Through Smartphones", created a cane equipped with a GPS module integrated with a microcontroller to process location data in the form of longitude and latitude. The location data is then sent to a web server via a GSM modem. The location data on the web server is then plotted on Google Maps using the Google Maps API. According to the test results, this smart cane can provide blind people with location information via a smartphone, displayed on Google Maps. [1]Agung Dwi Rahmawan et al. conducted a comparative analysis of Quality of Service (QoS) values for SDN implementations using Floodlight and Ryu Controllers, running linear and mesh topologies across 4, 8, 12, and 16 switches. During the test, background traffic from the source node to the same destination node ranged from 50 to 200 Mbps. The results show that the Ryu Controller achieves better QoS than Floodlight across all the topologies tested. The latency and jitter values on floodlight are higher than those on Ryu and tend to increase at 100 Mbps traffic. [1]

In 2021, Parito et al. published a journal article entitled "DESIGN AND CONSTRUCTION OF SMART STICKS FOR THE BLIND BASED ON MICROCONTROLLERS". Created a design for a tool that helps users avoid objects in front of them, which will detect water within the stick's range with sound notifications according to sensor readings. In addition, users get pick-up mobility if something happens on the road by pressing the emergency button on the tool. The tool then sends a Telegram message to the family with the stick's GPS location coordinates. So that users of this stick can be easily found if they need emergency assistance while far from home. Based on testing the tool as a whole, this Smart Stick for the Blind can work well: it can detect obstacles and water in front of it, emit a warning sound to the user, and send a telegram message. [2]

In 2022, Sofia Ariyani et al. conducted research in their journal entitled "Object Detection Assistance for the Blind Based on AI Mobilenet on Raspberry Pi 3B", using a camera integrated with a Raspberry Pi as a microcontroller and a distance sensor HC-SR04. The HC-SR04 sensor in this study allows the system not only to detect objects but also to determine their distance. For the system to detect an object, data from an image processing system is needed. The model used in this study is the pre-trained Mobilenet model. The results of this study show that the system can detect up to 80 objects. System testing was carried out using 5 objects with 50 variant types: books, glasses, bottles, cell phones, and people. For each type of object variant, testing was carried out 10 times with 3 different distance variations (100cm, 150cm, and 200cm) as determining factors for accuracy. Based on the object detection tests conducted, the average success rate is 40%. The results of the distance test showed an average success rate of 53% at 100 cm, 39% at 150 cm, and 27% at 200 cm. [3]

In 2023, Agung Pambudi et al., in their journal entitled "DESIGN OF INNOVATIVE STICKS FOR THE BLIND USING GYROSCOPE, GPS, AND ULTRASONIC SENSOR TECHNOLOGY", conducted research aimed at developing a blind aid in the form of a sensor-based alternative walking stick. The development method used the Rapid Application and Development approach. Testing used an alpha test, namely a usability test that detected system errors on the stick. The test results stated that the IoT-based alternative stick could function well. This alternative stick is controlled via an Android device using the Telegram application. This application functions as a controller and position detector based on the stick's coordinates, enabling detection of the user's presence. [4]

III. System Design

Figure 1 presents the block diagram of the entire system used in this study. This system works by having the camera capture images in real time, which are used as input. Then, the camera input is processed by the Raspberry Pi using the Faster Region-Based Convolutional Neural Network (Faster R-CNN) as a classifier for detected objects. Then, there is an HC-SR04 ultrasonic sensor as an object distance detector, and a water level sensor as an obstacle detector for puddles. All data collected by the camera, ultrasonic sensor, and water level sensor will be converted to sound using the eSpeak Library and output as information through wireless earphones.

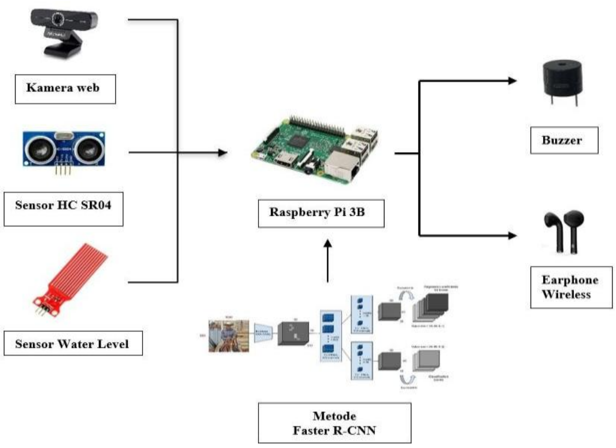

Fig. 1. Design system

This research uses several stages of implementation or methodology as shown in the figure 2.

Fig. 2. Methodology system

Based on the methodology block diagram above, the first step in this research is to identify reference sources as a knowledge base and a reference for conducting this research. The next step is to design and build the system to be used. The system is then tested using predetermined parameters. Based on the test results, an analysis and conclusion are made to determine whether the system can function properly.

A. *Object Detection System Design*

This stage involves designing an object detection system using the faster R-CNN algorithm used in this study. The following is a block diagram of the object detection system design.

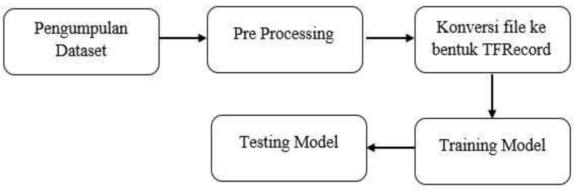

Fig. 3. Block diagram of object detection system

a) Dataset Collection

To perform object recognition, a dataset is first collected. A dataset is a collection of images collected and labeled by humans, which are then processed by a machine/computer for learning before classification. In this study, two datasets will be used: a pretrained model dataset from the COCO dataset, which is then filtered to include only 3 object classes: humans, tables, and cupboards. In addition, the number of classes is increased by 2 object classes independently, and images are downloaded from the internet using a scraping method, also called large-scale data collection at once. The added object classes include cars and motorcycles.

b) Preprocessing

This stage prepares all datasets by resizing the images to ensure they are all the same size. Labeling is then performed to identify the specific characteristics of each object in the image. These characteristics will later be used in the training process. The data file is then saved in XML format and stored in a folder with the other XML files. Next, all XML data is converted to a CSV format to identify the features to be extracted.

c) Converting the file to TFRecord format

After collecting all the features in CSV format, the next step is to convert the CSV file to binary format for processing with TensorFlow.

d) Model Training

This stage trains the dataset to be used as a model using the Faster R-CNN method. This method is trained to learn object patterns by searching for object characteristics in images. The search is performed across several layers using a convolutional process, commonly known as a Convolutional Neural Network (CNN).

e) Model Testing

Next, the model is tested by showing several images imported from a laptop. From the training dataset, a model will be generated that can be run to detect objects, eliminating the need for further system training.

The following is an image in the form of a flowchart that will explain how the object detection system works:

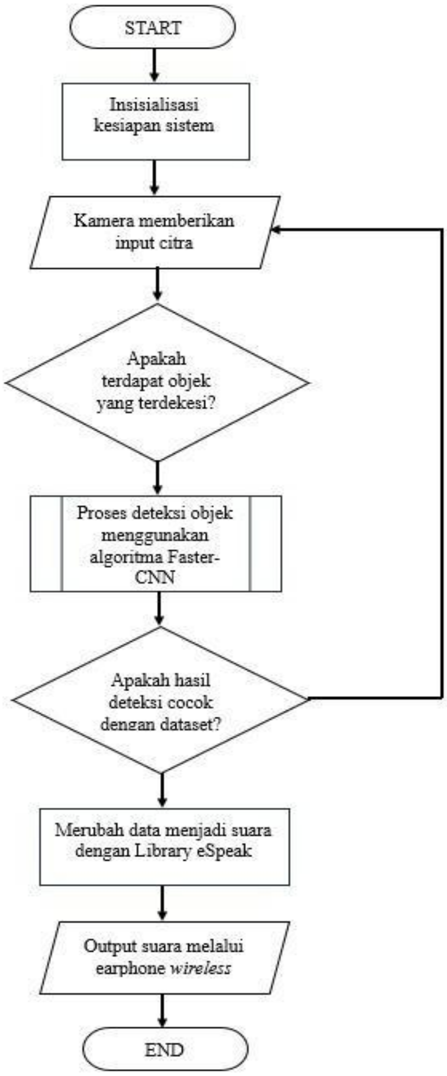

Fig. 4. Object detection system design flowchart

In figure 4, it is explained that both access points will be configured by saving a Python file containing commands to call the server URL. In addition, the server IP is added, namely 192.168.100.3. This process aims to ensure that when the access point network is available, the web server displays active or inactive information.

B. *Network Topology Design*

The topology used in this study is a star topology. This topology connects several computers via a central device, such as a hub or switch. The SDN infrastructure consists of 2 layers: the control plane and the data plane. In the first layer (control plane), there is a server that serves as a controller. On the second layer (data plane), there is an access point used to send data packets from the server.

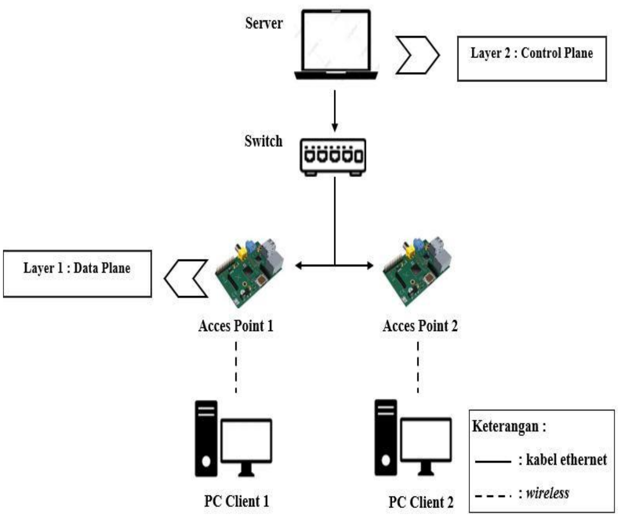

Fig. 5. Network topology design

In figure 6, the system's operation is shown. First, initializing the software and hardware: designing and building a web server, installing the VNC viewer on the server, designing the network topology, and configuring the Raspberry Pi as an access point. Then, connect the access point to the server. If the access point is successfully connected to the server, then the PC server can monitor and control both access points.

C. *Configure The Raspberry Pi to Become an Access Point*

At this stage, remotely configure the Raspberry Pi on the server to act as an access point using PuTTY. Apart from that, a block diagram is also made to explain the flow of each Raspberry Pi configuration process to become an access point.

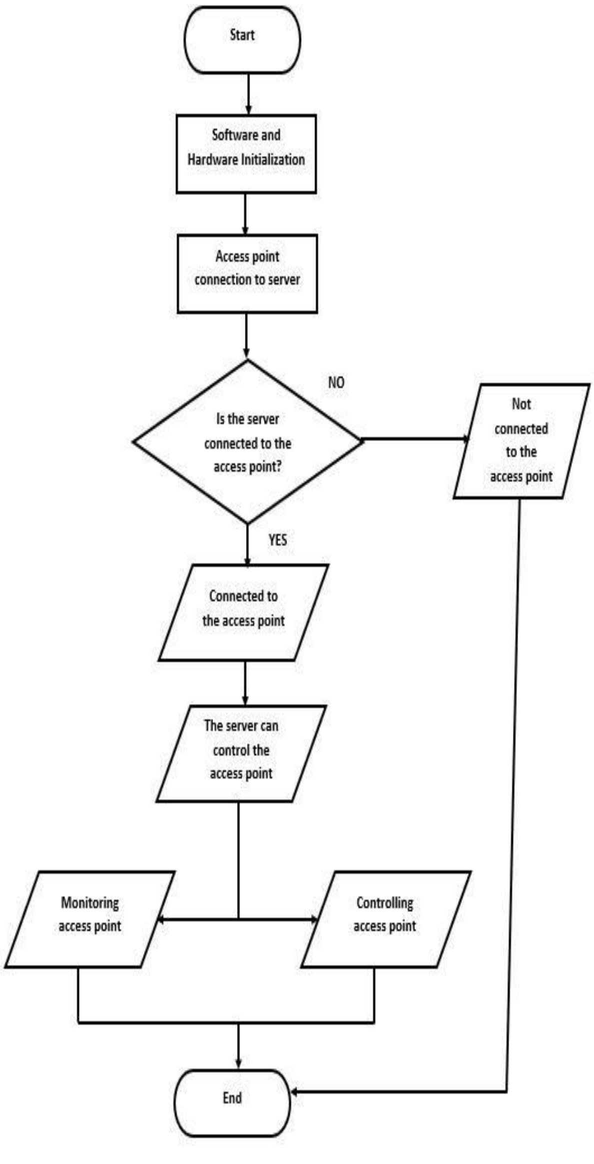

Fig. 6. Flowchart of how the system works

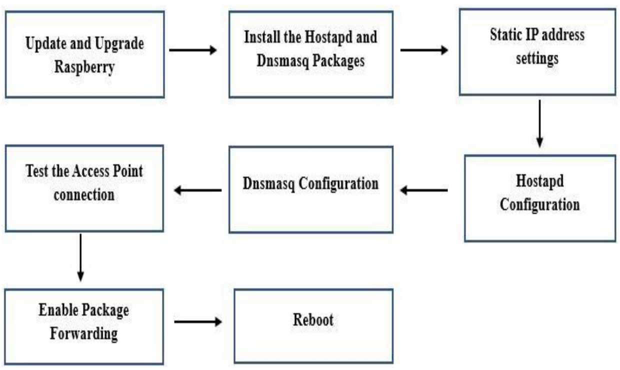

Fig. 7. Block diagram of Raspberry Pi configuration process to become an access point

The following is a description of each command, presented in tabular form, along with an explanation of the steps to configure the Raspberry Pi as an access point.

TABLE I
COMMANDS IN PROCESS CONFIGURATION

Commands	Information
Sudo apt-get & upgrade	updates and upgrades for the Raspberry Pi
Sudo apt-get install hostapd	Hostapd program installation
Sudo apt-get install dnsmasq	Installing the dnsmasq program
sudo nano /etc/dhcpcd.conf	Network configuration
sudo nano /etc/network/interfaces	Static IP settings for Wifi interfaces
sudo nano /etc/default/hostapd	Access Point Configuration
sudo mv /etc/dnsmasq.conf /etc/dnsmasq.conf.bak	Configure so that hostapd doesn't change when the device is off
sudo nano /etc/dnsmasq.conf	Rename the default dnsmasq file.
sudo reboot	IP address configuration is automatic.
sudo nano /etc/sysctl.conf	Restart command
sudo iptables -A FORWARD -i eth0 -o wlan0 -m state --state RELATED,ESTABLISHED -j ACCEPT	IPV4 Configuration
sudo iptables -A FORWARD -i wlan0 -o eth0 -j ACCEPT	Configuration added routing
sudo sh -c "iptables-save > /etc/iptables.ipv4.nat"	Configure routing eth() -o to wlan()
sudo nano /etc/rc.local	Configure wlan() to eth() routing
Sudo shutdown -r now	NAT rule assignment configuration

IV. Experimental Results

At the system testing stage, several tests were carried out, namely server-side, access point-side, and PC Client-side testing. Server-side testing verifies the monitoring and control features of the access point on the web server that has been built. Then, to test the access point (i.e., the internet network speed), Wireshark was used to test the PC Client, namely, the time required for the server to send data packets containing photos, pictures, and videos.

A. Access Point Monitoring Feature on Web Server

This testing process is carried out on a web server that has been created. When the Raspberry Pi is turned on, it will connect to the access point's network and access the web server. So that later the web server has succeeded in providing information about the active or inactive status of the access point network.

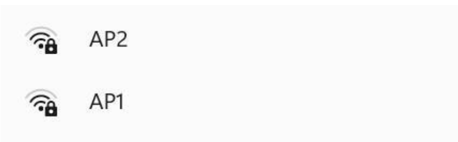

Fig. 8. Access point network successfully connected to PC server.

In figure 8, it can be seen that the two access points have been successfully connected to the PC server. So that the monitoring dashboard displayed on the web server will provide information in the form of green color or active status, as shown in figure 9.

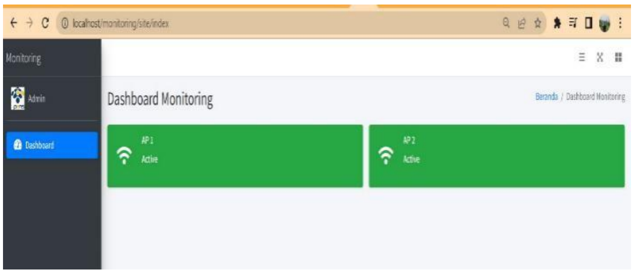

Fig. 9. Monitoring dashboard display when access point networks are available

However, if the access point network is unavailable or not connected to the PC server, the monitoring dashboard on the web server will display information in gray or as not active, as shown in figure 10.

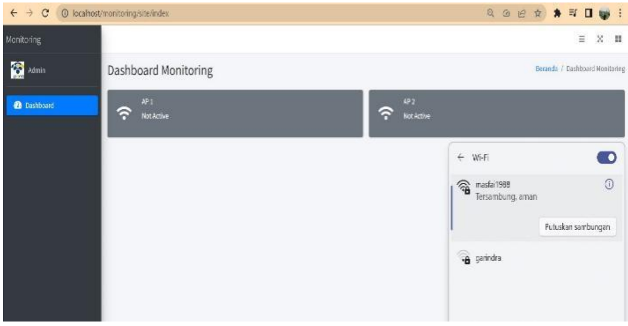

Fig. 10. Monitoring dashboard display when the access point networks are not available

B. Controlling Access Point feature

In this testing process, the VNC viewer software and Raspbian OS were installed on the PC server. After the Raspberry has been successfully configured as an access point, it can be controlled remotely from the server using the VNC Viewer software, so that on the Raspbian OS page display there is a Raspberry logo with the shutdown, reboot, and logout features.

Fig. 11. Raspberry features on Raspbian OS.

In figure 11 can be seen that there are several features in the Raspbian OS. The shutdown feature is used to deactivate the access point, so that both client PCs cannot connect to it and cannot use the internet, as shown in figure 12 and 13.

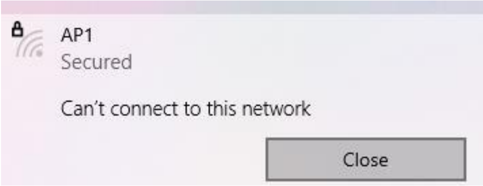

Fig. 12. Display of PC client 1, which cannot be connected to access point 1

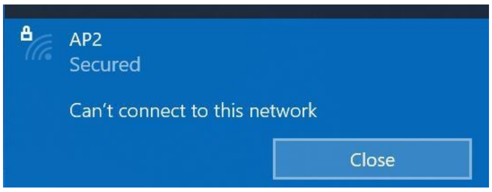

Fig. 13. Display of PC client 2, which cannot be connected to access point 2

C. *Access Point Network Speed*

In this test, a network test is performed from the access point using Wireshark. Wireshark is an application used to analyze network data packets. In this test, we will analyze data packets captured by Wireshark while playing a video on YouTube. Then, the captured data packets will be analyzed using the quality of service parameter calculation method. Several parameters that have been successfully tested are throughput and packet loss.

TABLE II
CALCULATION RESULTS OF THROUGHPUT AND PACKAGE LOSS AT BOTH ACCESS POINTS

No.	Test	AP 1		AP 2	
		Throughput (bits/sec)	Packet Loss	Throughput (bits/sec)	Packet Loss
1.	1 st	1,534	0 %	3,673	0 %
2.	2 nd	1.691	0 %	6,849	0 %
3.	3 th	2,336	0 %	9,123	0 %
Average		1,853	0	6,548	0

Table II shows the results of calculating the data packets obtained from a capture using the Wireshark software. The average throughput for access point 1 is 1.853 bits/sec. Meanwhile, the access point 2 is 6.548 bits/sec. The difference in average throughput between the two access points is 4.695 bits/sec. In the table above, it can be seen that the longer it takes to capture data, the more data packets you get, so the values of the calculation results differ between the two access points.

In Table III, it can be seen that the results of testing internet speed using both access points differ slightly from those using regular wifi. So, both access points are feasible to use.

TABLE III
AP INTERNET NETWORK SPEED TEST RESULTS WITH ORDINARY WIFI

No.	Network Used	Internet speed
1.	AP 1	35 ms
2.	AP 2	36 ms
3.	Normal Wi-Fi	39 ms

D. *Connectivity Testing Between Access Point and PC Client*

In this test, connectivity is tested between the access point and the PC client using the ping command in the terminal. Before running the ping command, the client PC must be connected to the network via the access point. On PC client 1, it is connected to AP 1. Meanwhile, PC client 2 is connected to AP 2. Then, to see the IP address of the access point, run ipconfig on both client PCs.

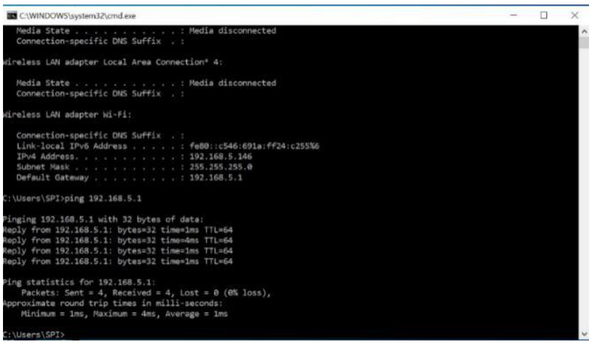

Fig. 14. Process ping o. PC client 1

In figure 14, it can be seen that PC client 1 has successfully connected to AP 1's network, so it receives an IP address from AP 1 and also via DHCP, for the AP 1 IP address connected to PC client 1, namely 192.168.5.1. Meanwhile, the DHCP IP address is 192.168.5.146.

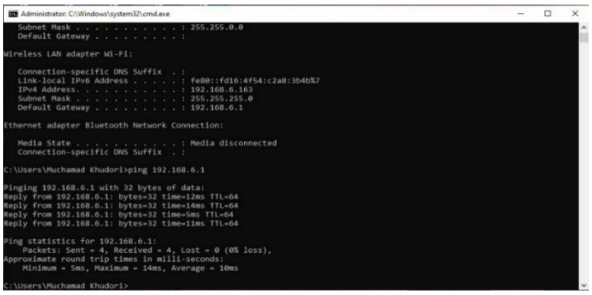

Fig. 15. Process ping o. PC client 2

In figure 15, it can be seen that PC client 2 has successfully connected to the AP 2 network, and there is information about the AP 2 IP address and the DHCP server for that IP address, namely 192.168.6.1, connected to PC client 2. Meanwhile, the DHCP IP address is 192.168.6. 163.

E. Data Package Delivery Test

In this test, testing is performed by sending data packets from the server PC to the client PC, where the two PCs are connected via a single access point network. The purpose of this test is to find the delivery time from the server PC to the client PC. On PC server and PC client 1, connected using the network from AP 1, namely 192.168.5.1. Then, on the PC server and PC client 2, connect using the network from AP 2, namely 192.168.6.1. The data packets sent are in the form of photos, videos, and files.

TABLE IV
SENDING DATA PACKAGES FROM SERVER TO PC CLIENT 1

No.	Data Package Type	Number of Files	Total Data Capacity	Delivery Time/Delay (Second)	Transfer Speed (Kb/s)
1.	Photo (jpg, png)	2	380 KB	0,27	1.407,40
2.	Video (mp4)	1	1,46 MB	0,59	2.474,57
3.	File (PPT, Word)	2	1,5 MB	0,88	1.704,54
Rata-rata				0,58	1.862,17

In Table IV, several types of data packets are shown, including the number of files, total data capacity, delivery time (delay), and transfer speed. The types of data packets sent include 2 photos (JPG and PNG), 1 video (MP4), and 2 files (PPT and Word). In addition, it also displays the delivery time or delay and the transfer speed obtained when sending data packets. For the package type photo, the delivery delay is 0.27s. The average delay is 0.58s, while the transfer speed is 1,862.17Kb/s.

TABLE V
SENDING DATA PACKAGES FROM SERVER TO PC CLIENT 2

No.	Data Package Type	Number of Files	Total Data Capacity	Delivery Time/Delay (Second)	Transfer Speed (Kb/s)
1.	Foto (jpg, png)	2	380 KB	0,36	1.055,55
2.	Video (mp4)	1	1,46 MB	0,85	1.717,64
3.	File (PPT, Word)	2	1,5 MB	1,34	1.119,40
Rata-rata				0,85	1.297,53

In Table V., several types of data packets, the number of files, total data capacity, delivery time (delay), and transfer speed are shown. The types of data packets sent include 2 photos (JPG and PNG), 1 video (MP4), and 2 files (PPT and Word). In addition, it also displays the delivery time or delay and the transfer speed obtained when sending data packets. In the photo data packet type, it gets a delivery delay of 0.85 s. The average delay is 0.58 s, while the transfer speed is 1,297.53 Kb/s.

V. Conclusion

In server-side testing, the monitoring and control feature of the access point has been successfully used. The server uses a web server to provide information on whether the access point is active. If the access point is available and connected, the web server displays active status information and appears green. However, if the access point is unavailable, it displays an inactive status description and appears gray. During testing, the PC server uses VNC viewer software, and the access point can be turned off on the PC server. So that the PC client can not connect to the access point network.

In testing from the access point side, the average throughput calculation result for AP 1 is 1.853 bits/s, while for AP 2 it is 6.548 bits/s. The difference in average throughput between the two access points is 4.695 bits/sec. It can be inferred that the number of data packets is directly proportional to the throughput. In addition, internet speed (ping) testing was also carried out on both access points and regular wifi. The results obtained on the access point with ordinary wifi are not far off or show only a slight difference. So that it can be said that both access points are feasible to use.

On the PC client, we test connectivity between the access point and the PC client by running the ping command against the access point's IP address. Obtained test results via the PC client; managed to ping the IP access point. This means that the PC client is already connected to the network access point. In addition, testing of sending data packets in the form of photos, videos and files was also carried out. The average delay value for access point 1 is 0.58. While the delay access point 2 is 0.85. Then, also obtained the average result of the value of the transfer speed on access point 1, which is 1,862.17 Kb/s and on access point 2, which is 1,297.53 Kb/s.

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