

# VLAN-Based Network Optimization as Mechanism of Improving Data Security and Performance

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## ABSTRACT

Nowadays in the digital world, organizations like schools need strong network systems to help them work smoothly. Pondok Pesantren Darul Hikmah Kutoarjo Islamic School had some problems with its old network setup. These included data being shared between different parts of the school, too much broadcast traffic, and slower performance because of network conflicts. This study focuses on improving the network by using VLAN technology, which is simulated with Cisco Packet Tracer. The research uses a qualitative approach, including direct observation and reviewing existing literature. The findings show that VLANs can separate data traffic between different groups, like teachers, students, and visitors, without needing extra hardware. Testing the system showed big improvements in performance. The maximum delay went down from around 200 ms to just 10 ms, and the network became more stable by reducing jitter.



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## A. INTRODUCTION

Nowadays in the digital world, technology and information are changing rapidly, which leads to big changes in many areas of life, including computer networks that help manage and store information. Progress in information technology allows organizations to use more dependable and efficient network systems to support their day-to-day activities. However, some issues can arise, such as data leaking between departments, network speed slowing down because of traffic conflicts, and challenges in monitoring and controlling the network, which need quick solutions. According to Manafe, et al. (2022), VLAN (Virtual Local Area Network) technology is essential for effectively segregating data traffic between departments. To help with operations and stop unwanted access, it's necessary to separate the network so that traffic between different parts of the company can be kept apart. VLAN technology is a great choice for use in different areas because it can isolate data traffic between departments that are on the same physical network. With VLANs, data from each department can be grouped logically, improving security and stopping interference between departments. Also, VLANs help use

bandwidth better by cutting down on unnecessary traffic and making the network run more smoothly. Implementing VLAN on Cisco switches helps keep the network setup stable and makes it easier to manage and watch traffic between departments. VLAN lets physical networks be divided into several networks without needing extra hardware. This helps keep traffic between departments separate and stops unauthorized access from other departments. This not only makes the network more secure but also makes it work better. Moreover, VLAN makes it easier for organizations with complicated network traffic needs to manage their systems.

Cisco is a company engaged in network technology and has created various network devices, such as routers and switches. These devices are typically used by institutions or companies to build and manage computer network-based communications systems (Yunita et al., 2024). Meanwhile, Cisco Packet Tracer is a very important network simulation application in this context because it enables the development of basic to advanced skills in designing and managing computer networks. Packet Tracer has the advantage of being an effective network simulation tool, such as free of charge, allowing users to create complex and large networks, as well as providing interactive learning (Reza, 2021). Cisco Packet Tracer allows users to create, visualize, and test network configurations without the need for physical hardware (Martias et al., 2020). This tool helps understand basic network concepts such as subnetting, routing, and VLANs relevant to current technology. Because simulations are carried out virtually, there is no need to purchase expensive network hardware, thus helping educational institutions and students train without major investments. However, there are some drawbacks to this device. Cisco Packet Tracer does not have all the features that the actual Cisco networking device has (Rahman et al., 2020). In addition, Cisco Packet Tracer is not ideal for large or complex network simulations. When too many devices are added, application performance can decrease, causing lags or even crashes, making it less ideal for large-scale network topology simulations (Salam and Jenih, 2022).

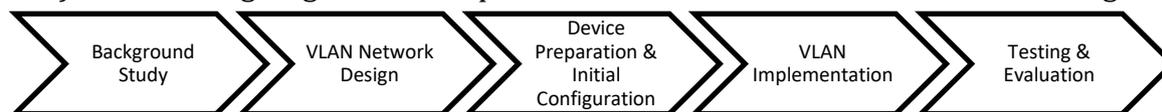
The rapid advancement of information and communication technology has significantly increased the dependence of educational institutions on reliable and secure computer networks. At Pondok Darul Hikmah, the network infrastructure supports academic activities, administrative operations, and internet access for teachers and students. However, the growing number of users and connected devices has exposed limitations in the existing conventional network design, which operates within a single broadcast domain. This condition leads to excessive broadcast traffic, reduced network performance, potential data leakage between departments, and limited traffic control. Without proper logical segmentation, all devices share the same network segment, increasing congestion and security vulnerabilities. Therefore, implementing Virtual Local Area Network (VLAN) technology is considered an urgent solution to logically separate network traffic, reduce broadcast domains, enhance bandwidth efficiency, and strengthen internal network security.

Although VLAN implementation has been widely discussed in previous studies and simulated using tools such as Cisco Packet Tracer, most research focuses on general configurations or small-scale laboratory scenarios without addressing case-specific institutional needs. Limited studies evaluate VLAN deployment in a multi-switch environment tailored to dormitory-based educational institutions with diverse user groups. This research aims to fill that gap by designing and evaluating a VLAN-based network model adapted to the operational structure of Pondok Darul Hikmah. The novelty of this study lies in its problem-driven approach, emphasizing multi-switch VLAN

configuration, traffic isolation testing, and performance optimization to improve network efficiency and security in a real educational setting.

## B. METHODS

The research activity took place at the Darul Hikmah Islamic School, which is also known as an Islamic Boarding School. The type of research conducted using qualitative methods is structured through several stages so that goals can be achieved properly. Each stage is designed to form a systematic work process ranging from problem identification to evaluation of the results of VLAN implementation in Islamic boarding schools (Majid, 2021). The working stages of this implementation can be illustrated in the following chart:



**Figure 1.** Practice Working Stages

Figure 1 shows the steps taken in the implementation of this practice, ranging from preliminary studies to the preparation of final documentation. Each step has a specific goal of achieving optimal VLAN implementation.

Description of Stage:

### 1. Preliminary Study

To understand existing conditions and identify major problems (Majid, 2021), initial observation of the existing network infrastructure in Pondok Darul Hikmah was made to understand the existing conditions.

### 2. VLAN Network Design

Create a VLAN network topology based on observations, including network segmentation, device grouping, and IP Address assignments.

### 3. Device Preparation and Initial Configuration

Set up network devices such as manageable switches and Microtics routers and perform the basic configuration required before VLAN deployment.

### 4. VLAN Implementation

Configures VLANs according to the design, including trunking and access port settings, VLAN ID sharing, and cross-segment connectivity testing.

### 5. Testing and Evaluation

Test network performance and security after VLAN is implemented, and record evaluation results.

In the implementation of this design, the following device systems were used:

### 1. Hardware

#### A. Router

Routers are used to manage routing between VLANs and connections to the internet. The router also acts as a gateway that manages the distribution of data packets between different VLANs (Cisco, 2020).

#### B. Switch Managed

These kinds of switches let you set up VLANs based on ports and create separate broadcast areas, which helps make the network work better. Using managed switches is typical in VLAN setups because they offer better segmentation and stronger security options (Cisco, 2020).

#### C. Access Point

This allows users to connect wirelessly. The Access Point can be set up so that each SSID is on a separate VLAN, which helps keep different users isolated

from each other, like keeping the teacher network separate from the student network (Basan, 2024).

D. UTP Cat6 Cable

These cables can handle data transfer speeds of up to 1 Gbps and are great for modern local networks that need fast and reliable performance.

E. Laptop and PC Client

These are used both by end-users and technicians to set up and manage the network. Each client is placed into a VLAN based on their role, such as teachers, administrators, or students (Sathujoda, 2023).

2. Software

A. Cisco Packet Tracer

This simulation tool helps in designing, testing, and visualizing VLAN networks before they are set up physically. Cisco Packet Tracer is widely used by students and network professionals to experiment with virtual network setups (Cisco, 2020)

B. Winbox

Winbox is a graphical tool that makes it simple and fast to configure Microtic routers.

C. Web Browser (Chrome/Firefox)

Browsers are used to access web-based management interfaces on network devices like access points and switches.

D. Draw.io / Microsoft Visio

These tools are used to create network topology diagrams and other documentation.

E. Operation System

Windows 10 or 11 is the main operating system used by technicians and client computers. It works well with most network and configuration software.

C. RESULT AND DISCUSSION

A. VLAN Network Design

Create a VLAN network topology based on observations, including network segmentation, device grouping, and IP Address assignments.

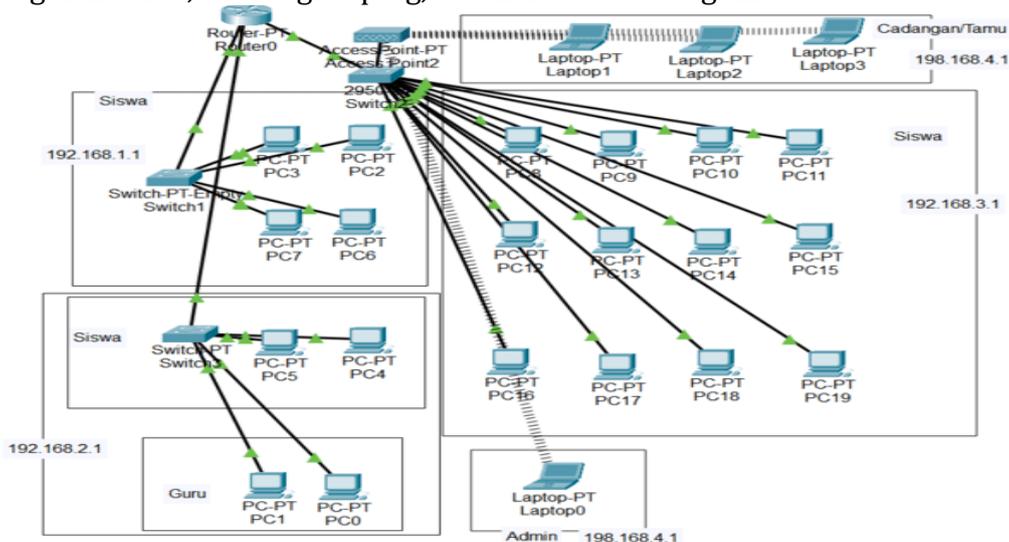


Figure 2. VLAN Topology Diagram for Pondok Darul Hikmah

The following is an explanation of the VLAN topology:

- Router0 acts as the routing centre between VLANs.
- Access Point2 is used to connect wireless devices such as admin and guest laptops.
- Switch1 and Switch2 manage the student and teacher segments (192.168.1.0/24 and 192.168.2.0/24) respectively.
- Switch0 acts as the core switch, connecting all devices to the main network.
- Devices such as PC0 – PC19 and Laptop0 – Laptop3 are connected according to the designed VLAN segmentation.

In Figure 2 above, in the network structure used, Switch0 acts as a core switch or server switch, which functions as the centre for combining all network data from various divisions. This switch is directly connected to the router as a device that handles routing between VLANs. This core switch serves VLAN 10 (teachers), VLAN 10-30 (students), and VLAN 40 (guests), and is the main connection for Switch 1 and Switch 2 via a trunk connection. This trunking function allows various VLANs to be sent through a single physical line without eliminating segmentation between divisions. With VLAN trunking between Switch 0 and the router, as well as from Switch 0 to Switch 1 and Switch 2, this network is able to isolate traffic between VLANs. This isolation ensures that communication between divisions can only occur through routing controlled by the router, thereby increasing data security, reducing collision domains, and speeding up network performance. In this architecture, the network is built with a hierarchical switching approach divided into two layers: the core layer represented by Switch 0, and the access layer represented by Switch 1 and Switch 2. This structure not only provides efficiency in data traffic management but also allows for easier and more measurable network development in the future.

## B. Device Preparation and Initial Configuration

### 1. Configuration

#### A. Sub-interface configuration on the router:

```
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#interface fa0/0
Router(config-if)#ip address 192.168.1.1 255.255.255.0
Router(config-if)#no shutdown
Router(config-if)#
```

---

**Figure 3.** Interface Configuration Fa0/0 Ip 192.168.1.1

```
Router#configure terminal
Router(config)# interface fa0/0
Router(config-if)# ip address 192.168.1.1 255.255.255.0
```

```

Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#interface fa1/0
Router(config-if)#ip address 192.168.2.1 255.255.255.0
Router(config-if)#no shutdown
Router(config-if)#

```

**Figure 4.** Interface Configuration Fa0/0 Ip 192.168.2.1

```

Router#configure terminal
Router(config)# interface fa1/0
Router(config-if)# ip address 192.168.2.1 255.255.255.0
Router#
%SYS-5-CONFIG_I: Configured from console by console

Router#configure terminal
Enter configuration commands, one per line. End with CNTL/Z.
Router(config)#interface fa6/0
Router(config-if)#ip address 192.168.3.1 255.255.255.0
Router(config-if)#no shutdown
Router(config-if)#

```

**Figure 5.** Interface Configuration Fa0/0 Ip 192.168.3.1

```

Router#configure terminal
Router(config)# interface fa6/0
Router(config-if)# ip address 192.168.3.1 255.255.255.0

```

## 2. IP Allocation

Network design utilises VLANs to differentiate user segments as follows:

**Table 1.** VLAN Division

VLAN	Name	Subnet	User
	Teacher	192.168.2.0	PC0, PC1
		-	
		192.168.2.24	PC4, PC5
		-	
	Student	192.168.1.0	PC2 – PC7
		-	
	Student	192.168.1.24	PC8 – PC19
		-	
	Admin & Guest	192.168.3.0	Laptop0 – Laptop3
		-	
		192.168.3.24	
		-	
		192.168.4.0	
		-	
		192.168.4.24	
		-	

Each VLAN has a different gateway and is configured using the Router-on-a-Stick technique on a router device connected to the main switch according to research (Saibi & Rahim, 2014). Thus, with this design, each user group has

its own network and can only communicate with other VLANs through inter-VLAN routing controlled by Mikrotik routers.

C. VLAN Implementation

After all configurations have been applied, testing is carried out on:

- Inter-VLAN Connectivity

```
C:\Users\CLIENT 3>ping 192.168.1.5

Pinging 192.168.1.5 with 32 bytes of data:
Reply from 192.168.1.5: bytes=32 time=8ms TTL=64
Reply from 192.168.1.5: bytes=32 time=2ms TTL=64
Reply from 192.168.1.5: bytes=32 time=3ms TTL=64
Reply from 192.168.1.5: bytes=32 time=2ms TTL=64

Ping statistics for 192.168.1.5:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 2ms, Maximum = 8ms, Average = 3ms

C:\Users\CLIENT 3>
```

Figure 6. Ping 192.168.1.5

- Internet Access

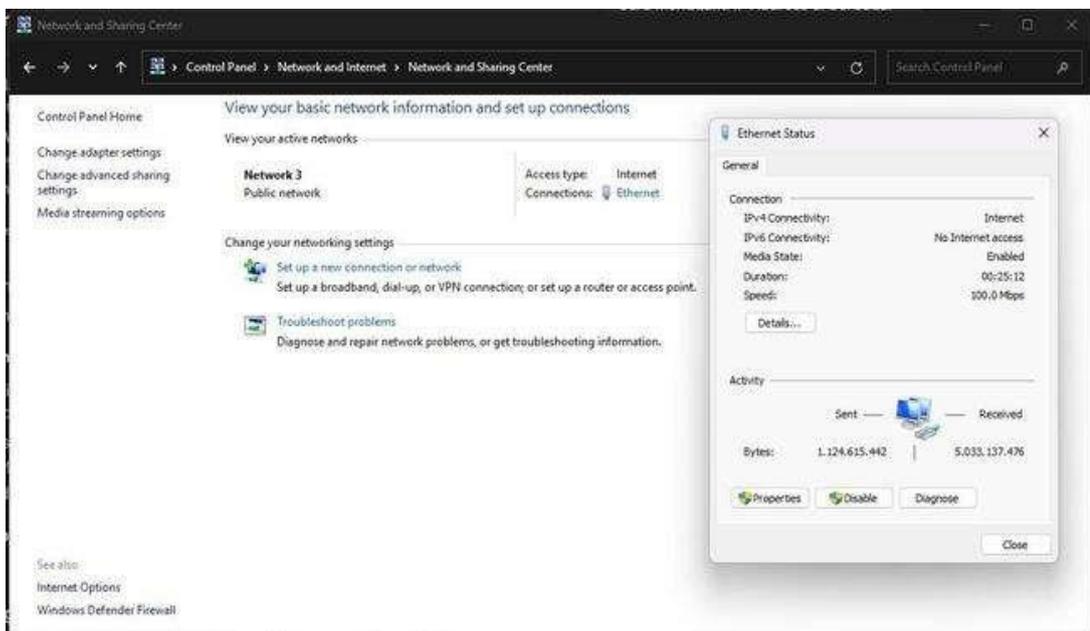


Figure 7. IPv4: Internet Connection Speed: 100Mbps

- Network Isolation Between Users (Reliability Test)

```
C:\Users\CLIENT 3>ping 192.168.1.1

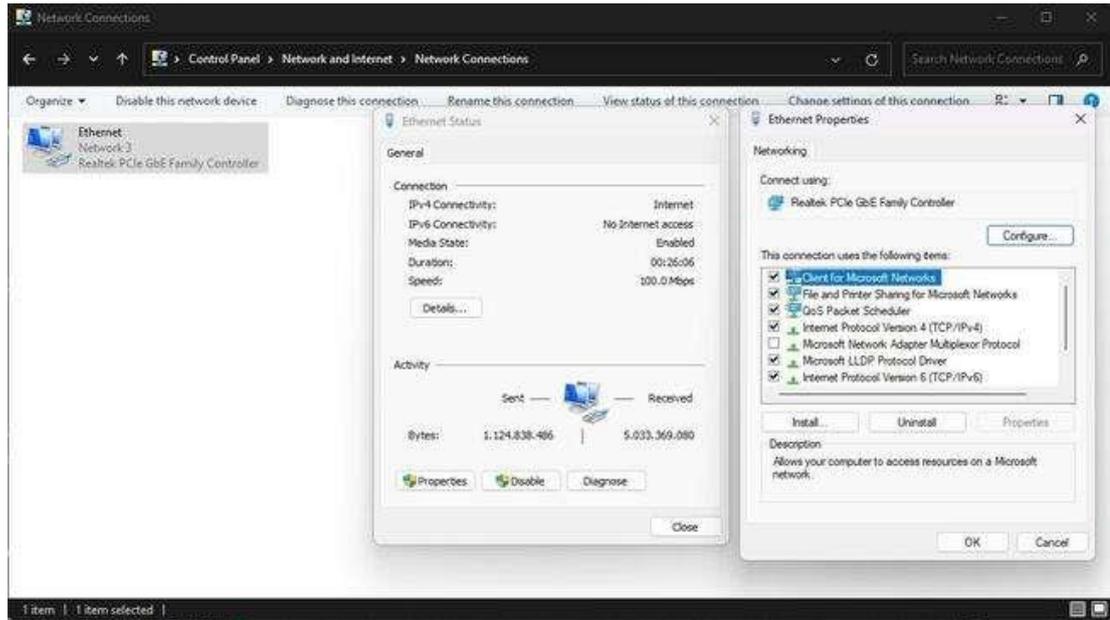
Pinging 192.168.1.1 with 32 bytes of data:
Reply from 192.168.1.1: bytes=32 time<1ms TTL=64

Ping statistics for 192.168.1.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\CLIENT 3>
```

Figure 8. Ping to IP/PC 192.168.1.1

## ● Network performance (latency & transfer speed)



**Figure 9.** Internet Protocol IPv4 is active and Client for Microsoft Networks is active (connected)

The test results show that the VLAN-based network system is running according to the design.

### D. Testing and Evaluation

The comparison between the Initial Condition and Final Condition shows a significant improvement in network performance after configuration. In terms of Reliability (Packet Loss), both conditions show perfect performance, where all visible packets are successfully received without any loss. However, the main and most crucial difference lies in network Performance, which is measured by Latency or packet travel time. Before configuration, the network was in a No Connection state, characterised by a Lowest Latency of no connection and an extreme Highest Latency spike of 200 ms. This wide time range resulted in High/Poor Stability (Jitter/Fluctuation), indicating obstacles, congestion, or high workload on the destination host during the stress test. Conversely, after configuration, the network condition changed to Very Stable and Very Fast. The Lowest Latency dropped dramatically to very low/perfect, proving that the implemented network configuration successfully optimised the communication path, eliminated bottlenecks, and effectively reduced jitter (time fluctuation) to a minimal level.

**Table 2.** Comparison of Conditions Before and After Trunk VLAN

Criteria	Initial Conditions (Before Trunk VLAN)	Final Condition (After Trunk VLAN)
<b>Testing Environment</b>	Network without trunk VLANs (initial condition of flat/non-segmented network)	VLAN network with trunk configuration on the switch
<b>Reliabilitas (Packet Loss)</b>	No packet loss detected (0%), but performance is inconsistent.	No packet loss detected (0%), connection is more consistent
<b>Lowest Latency (Minimum Time)</b>	Offline	3 ms
<b>Highest Latency (Maximum Time)</b>	Up to $\pm$ 200 milliseconds	$\pm$ 10 ms
<b>Stability (Jitter/Fluctuation)</b>	High/Poor (Range) broadcast time: offline until 200ms)	Very Low/Perfect (Very short time frame) narrow: 3ms up to 10 milliseconds)
<b>Network Performance</b>	No connection	Very stable and faster

#### D. CONCLUSION AND SUGGESTIONS

Based on the results of research and testing that has been conducted, it can be concluded that the improved performance of VLAN implementation significantly increases network speed and stability. The lowest latency reached 3 ms and the highest latency was reduced from 200 ms to only 10 ms. Thus, VLAN data security successfully created traffic isolation between segments (teachers, students, and guests), thereby preventing unauthorized access between departments. Students cannot access IP segments or computers in VLAN usage allows a single physical switch to be divided into several logical networks, thereby optimising bandwidth usage and reducing collision domains without the need for additional hardware. The hierarchical switching network structure that is implemented facilitates data traffic management and enables more measurable future network development.

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