Report: Encrypted VPN with Zero Trust MFA and Centralized Logging

Task Reference: Task 5: Encrypted VPN Tunnel with Zero Trust Access Control Layer

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Submitted To: Selin Tor

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Prepared For: Internal Review

1. Executive Summary

This report documents the implementation of a secure VPN infrastructure with Zero Trust access enforcement by Yashwardhan Singh. The setup involved deploying an OpenVPN tunnel between two virtual machines and integrating a Python-based TOTP multi-factor authentication (MFA) gateway. Access to the VPN was restricted until valid TOTP credentials were provided, enforcing Zero Trust principles. All access attempts were logged and visualized through a centralized dashboard for monitoring and correlation. The project successfully met its objectives, delivering the VPN configuration, working MFA system, logging mechanism, and test demonstration.

2. Objective and Scope

2.1. Objective

The primary objective was to design and implement a secure VPN solution incorporating Zero Trust principles using a Python-based multi-factor authentication gateway. This involved:

- Deploying an OpenVPN tunnel between two isolated virtual machines to ensure encrypted communication.
- Integrating a TOTP-based MFA system in Python to enforce identity verification before VPN access is granted.
- Logging all access attempts, including successful and failed authentications, for audit and monitoring purposes.

- Correlating authentication and connection logs through a centralized dashboard to enhance visibility and incident response.
- Demonstrating the effectiveness of the system through controlled tests, including valid access, failed logins, and real-time log monitoring.

2.2. Scope of Work

The project included the following key activities:

- VPN Tunnel Deployment: Configuration and setup of OpenVPN server and client instances across two virtual machines to establish encrypted communication.
- MFA Gateway Development: Implementation of a Python-based web application using TOTP (Time-based One-Time Password) to authenticate users before granting VPN access.
- Access Logging Mechanism: Collection and storage of authentication and connection events using system logs or custom logging scripts.
- Log Correlation Dashboard: Setup of a centralized visualization platform to correlate and display access events in real time.
- System Testing and Validation: Execution of various test cases to ensure the VPN and MFA mechanisms function correctly, and that logs accurately reflect user actions.
- Deliverables Compilation: Preparation of configuration files, source code, testing evidence, and video documentation demonstrating the complete workflow.

3. Tools and Technologies

- **OpenVPN**: An open-source VPN solution used to create an encrypted communication tunnel between the Ubuntu server and Kali Linux client. It provides confidentiality, integrity, and secure remote access.

- **Python**: Used to develop the custom TOTP-based MFA gateway, which enforces identity verification before granting VPN access.

- **PyOTP**: A Python library implementing the Time-based One-Time Password algorithm. It was used to generate and verify MFA codes in the authentication process.

- **Microsoft Authenticator**: The MFA app used by users to generate TOTP codes for authentication, providing an additional security layer before VPN access.

- **Flask**: A lightweight web framework used to serve the MFA interface, allowing users to input and verify their TOTP codes before connecting to the VPN.

- **Ubuntu (VPN Server)**: Hosted the OpenVPN server and MFA authentication logic. Chosen for its compatibility with OpenVPN and ease of configuration.

- **Kali Linux (VPN Client)**: Acted as the VPN client system, configured to initiate connections to the OpenVPN server only after MFA validation.

- **System Logging**: All access attempts and authentication events are logged in the **/var/log/mfa_access.log** file on the Ubuntu server for audit and monitoring.

- **ELK Stack (Elasticsearch, Logstash, Kibana)**: Used as the centralized logging and visualization platform. Logs from the MFA system are ingested via Logstash into Elasticsearch and visualized in Kibana, enabling real-time correlation and analysis of VPN access attempts.

- **Testing Tools (Terminal)**: Command-line tools were used to validate VPN connectivity and test the TOTP gateway.

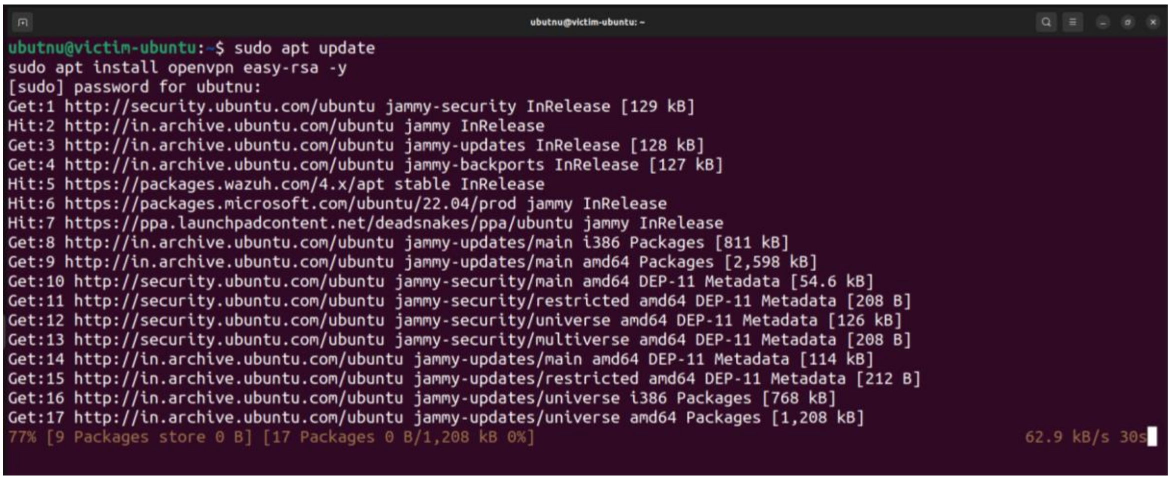
4. Methodology and Implementation Details

This section outlines the step-by-step approach taken to design, implement, and validate the encrypted VPN tunnel with an integrated Python-based MFA gateway. The project was structured into distinct phases encompassing environment setup, MFA integration, testing, and log correlation. Each phase details the key actions and configurations performed to achieve secure, authenticated VPN access with effective monitoring.

4.1. OpenVPN Environment Setup

The initial phase involved the deployment and configuration of the OpenVPN infrastructure on the Ubuntu server and Kali Linux client to establish a secure VPN tunnel.

- Installation of OpenVPN on both server and client machines to enable encrypted communication.



```
ubutnu@victim-ubuntu:~$ sudo apt update
sudo apt install openvpn easy-rsa -y
[sudo] password for ubutnu:
Get:1 http://security.ubuntu.com/ubuntu jammy-security InRelease [129 kB]
Hit:2 http://in.archive.ubuntu.com/ubuntu jammy InRelease
Get:3 http://in.archive.ubuntu.com/ubuntu jammy-updates InRelease [128 kB]
Get:4 http://in.archive.ubuntu.com/ubuntu jammy-backports InRelease [127 kB]
Hit:5 https://packages.wazuh.com/4.x/apt stable InRelease
Hit:6 https://packages.microsoft.com/ubuntu/22.04/prod jammy InRelease
Hit:7 https://ppa.launchpadcontent.net/deadsnakes/ppa/ubuntu jammy InRelease
Get:8 http://in.archive.ubuntu.com/ubuntu jammy-updates/main i386 Packages [811 kB]
Get:9 http://in.archive.ubuntu.com/ubuntu jammy-updates/main amd64 Packages [2,598 kB]
Get:10 http://security.ubuntu.com/ubuntu jammy-security/main amd64 DEP-11 Metadata [54.6 kB]
Get:11 http://security.ubuntu.com/ubuntu jammy-security/restricted amd64 DEP-11 Metadata [208 B]
Get:12 http://security.ubuntu.com/ubuntu jammy-security/universe amd64 DEP-11 Metadata [126 kB]
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Get:14 http://in.archive.ubuntu.com/ubuntu jammy-updates/main amd64 DEP-11 Metadata [114 kB]
Get:15 http://in.archive.ubuntu.com/ubuntu jammy-updates/restricted amd64 DEP-11 Metadata [212 B]
Get:16 http://in.archive.ubuntu.com/ubuntu jammy-updates/universe i386 Packages [768 kB]
Get:17 http://in.archive.ubuntu.com/ubuntu jammy-updates/universe amd64 Packages [1,208 kB]
77% [9 Packages store 0 B] [17 Packages 0 B/1,208 kB 0%]                              62.9 kB/s 30s
```
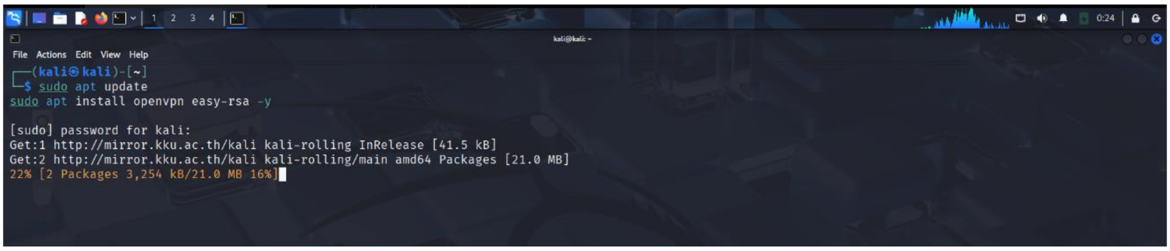
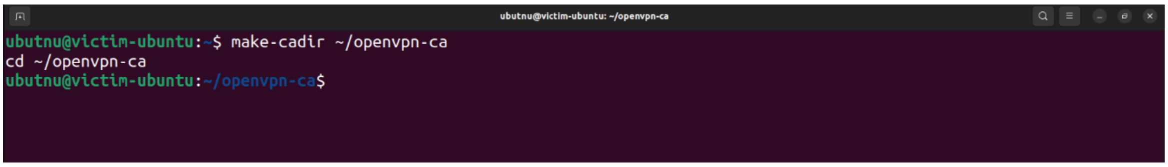



```
┌──(kali㉿kali)-[~]
└─$ sudo apt update
sudo apt install openvpn easy-rsa -y

[sudo] password for kali:
Get:1 http://mirror.kku.ac.th/kali kali-rolling InRelease [41.5 kB]
Get:2 http://mirror.kku.ac.th/kali kali-rolling/main amd64 Packages [21.0 MB]
22% [2 Packages 3,254 kB/21.0 MB 16%]
```

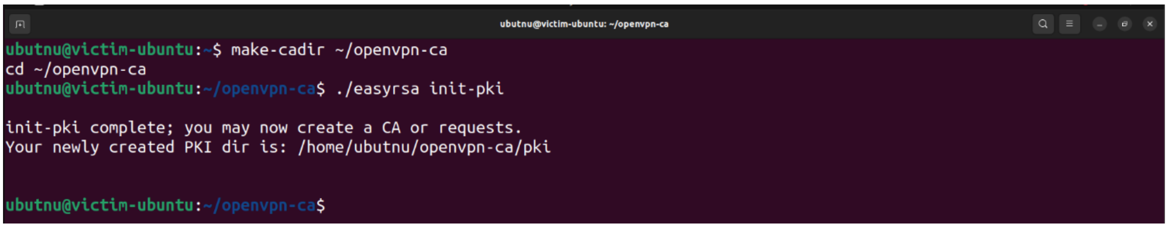
- Initialization of the Public Key Infrastructure (PKI) using EasyRSA:

a) Executed make-cadir ~/openvpn-ca to create the EasyRSA directory structure.



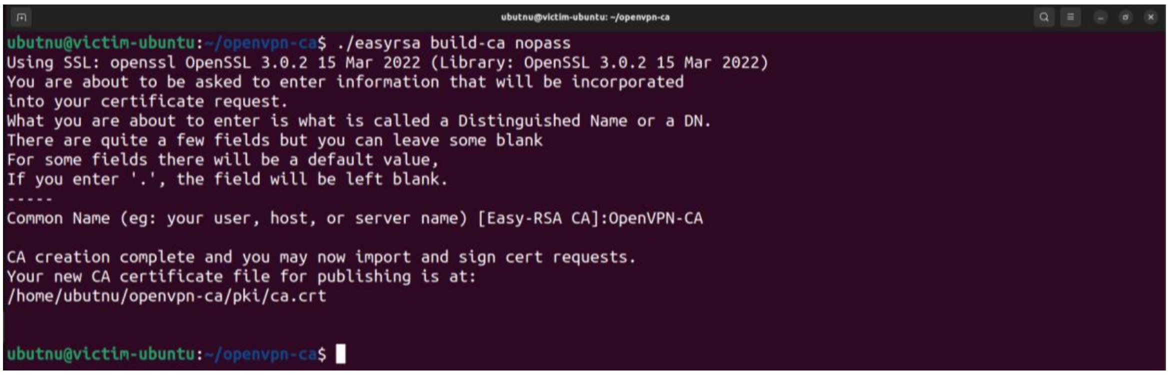
```
ubutnu@victim-ubuntu:~$ make-cadir ~/openvpn-ca
cd ~/openvpn-ca
ubutnu@victim-ubuntu:~/openvpn-ca$
```

b) Initialized the PKI environment with ./easyrsa init-pki.



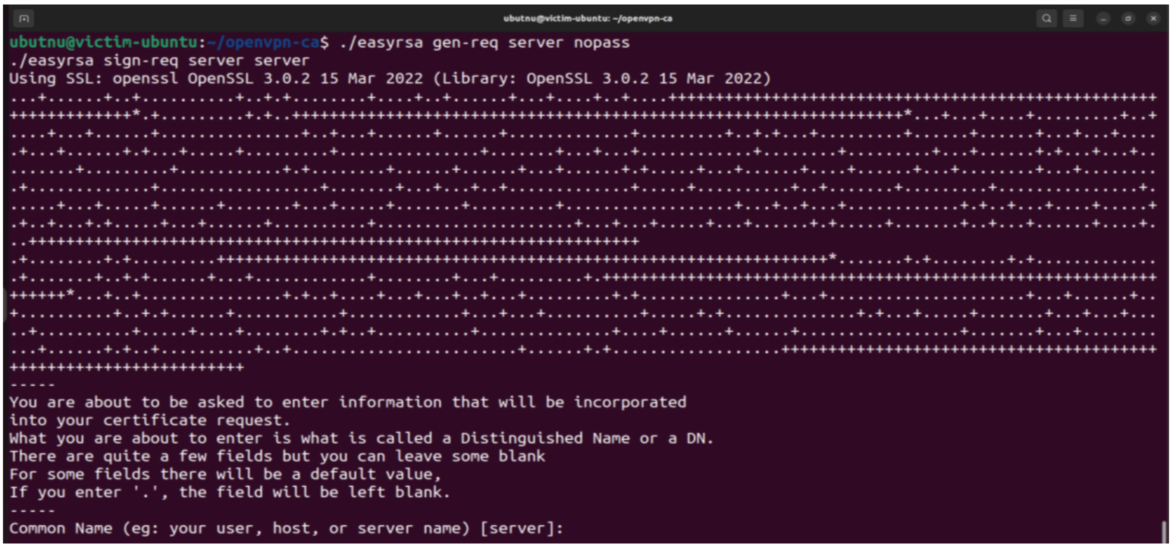
```
ubutnu@victim-ubuntu:~$ make-cadir ~/openvpn-ca
cd ~/openvpn-ca
ubutnu@victim-ubuntu:~/openvpn-ca$ ./easyrsa init-pki

init-pki complete; you may now create a CA or requests.
Your newly created PKI dir is: /home/ubutnu/openvpn-ca/pki


ubutnu@victim-ubuntu:~/openvpn-ca$
```

c) Generated the Certificate Authority (CA) using ./easyrsa build-ca nopass without a passphrase to streamline automation.



```
ubutnu@victim-ubuntu:~/openvpn-ca$ ./easyrsa build-ca nopass
Using SSL: openssl OpenSSL 3.0.2 15 Mar 2022 (Library: OpenSSL 3.0.2 15 Mar 2022)
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Common Name (eg: your user, host, or server name) [Easy-RSA CA]:OpenVPN-CA

CA creation complete and you may now import and sign cert requests.
Your new CA certificate file for publishing is at:
/home/ubutnu/openvpn-ca/pki/ca.crt


ubutnu@victim-ubuntu:~/openvpn-ca$ 
```

- Created certificate signing requests for the server and client with ./easyrsa gen-req server nopass and ./easyrsa gen-req client nopass respectively.



```
ubutnu@victim-ubuntu:~/openvpn-ca$ ./easyrsa gen-req server nopass
./easyrsa sign-req server server
Using SSL: openssl OpenSSL 3.0.2 15 Mar 2022 (Library: OpenSSL 3.0.2 15 Mar 2022)
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-----
You are about to be asked to enter information that will be incorporated
into your certificate request.
What you are about to enter is what is called a Distinguished Name or a DN.
There are quite a few fields but you can leave some blank
For some fields there will be a default value,
If you enter '.', the field will be left blank.
-----
Common Name (eg: your user, host, or server name) [server]:
```
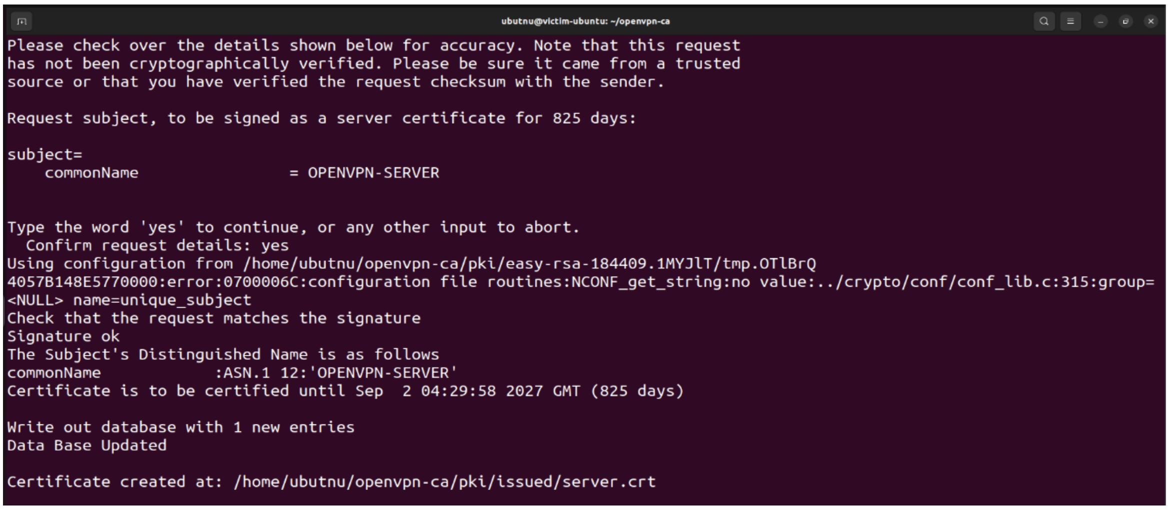
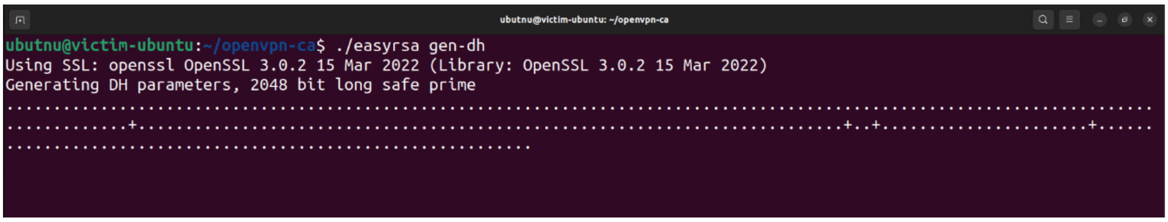



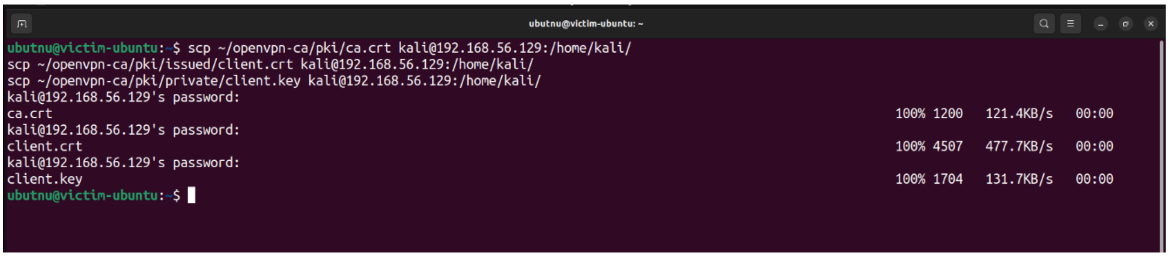
```
Please check over the details shown below for accuracy. Note that this request
has not been cryptographically verified. Please be sure it came from a trusted
source or that you have verified the request checksum with the sender.

Request subject, to be signed as a server certificate for 825 days:

subject=
    commonName                = OPENVPN-SERVER


Type the word 'yes' to continue, or any other input to abort.
  Confirm request details: yes
Using configuration from /home/ubutnu/openvpn-ca/pki/easy-rsa-184409.1MYJlT/tmp.OTlBrQ
4057B148E5770000:error:0700006C:configuration file routines:NCONF_get_string:no value:../crypto/conf/conf_lib.c:315:group=
<NULL> name=unique_subject
Check that the request matches the signature
Signature ok
The Subject's Distinguished Name is as follows
commonName            :ASN.1 12:'OPENVPN-SERVER'
Certificate is to be certified until Sep  2 04:29:58 2027 GMT (825 days)

Write out database with 1 new entries
Data Base Updated

Certificate created at: /home/ubutnu/openvpn-ca/pki/issued/server.crt
```

- Generated the certificate database using ./easyrsa gen-db to manage issued certificates.



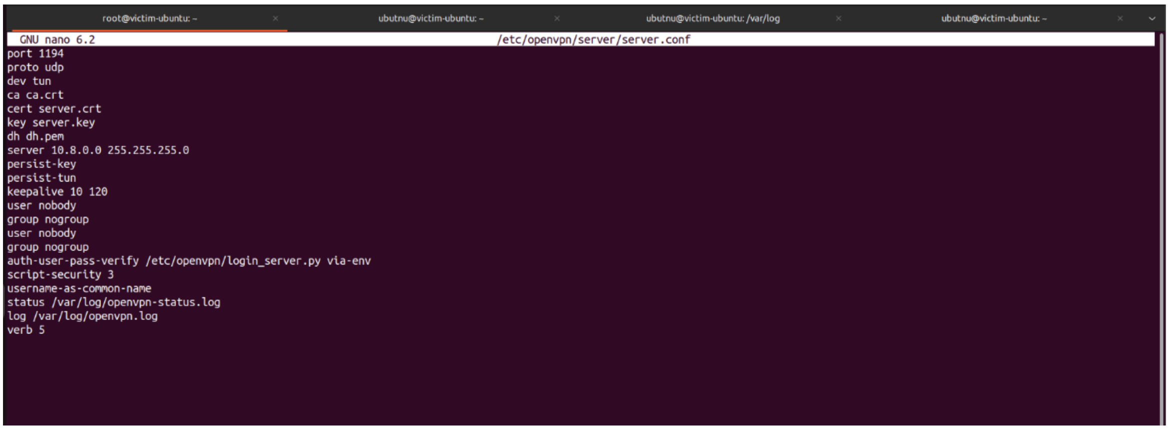
```
ubutnu@victim-ubuntu:~/openvpn-ca$ ./easyrsa gen-dh
Using SSL: openssl OpenSSL 3.0.2 15 Mar 2022 (Library: OpenSSL 3.0.2 15 Mar 2022)
Generating DH parameters, 2048 bit long safe prime
.....................................................................................................................
.............+........................................................................+..+.....................+.....
......................................................
```

- Securely transferred client certificates and keys to the Kali client via SCP for authentication purposes.

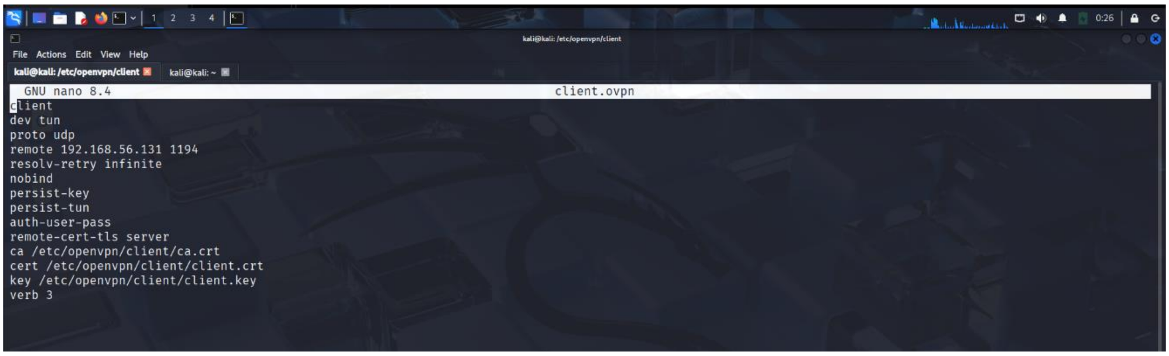


```
ubutnu@victim-ubuntu:~$ scp ~/openvpn-ca/pki/ca.crt kali@192.168.56.129:/home/kali/
scp ~/openvpn-ca/pki/issued/client.crt kali@192.168.56.129:/home/kali/
scp ~/openvpn-ca/pki/private/client.key kali@192.168.56.129:/home/kali/
kali@192.168.56.129's password:
ca.crt                                                                       100% 1200   121.4KB/s   00:00
kali@192.168.56.129's password:
client.crt                                                                   100% 4507   477.7KB/s   00:00
kali@192.168.56.129's password:
client.key                                                                   100% 1704   131.7KB/s   00:00
ubutnu@victim-ubuntu:~$ 
```

- Developed and applied tailored OpenVPN server and client configuration files (server.conf and client.conf), defining encryption protocols, certificate paths, and authentication parameters.



```
  GNU nano 6.2                          /etc/openvpn/server/server.conf
port 1194
proto udp
dev tun
ca ca.crt
cert server.crt
key server.key
dh dh.pem
server 10.8.0.0 255.255.255.0
persist-key
persist-tun
keepalive 10 120
user nobody
group nogroup
user nobody
group nogroup
auth-user-pass-verify /etc/openvpn/login_server.py via-env
script-security 3
username-as-common-name
status /var/log/openvpn-status.log
log /var/log/openvpn.log
verb 5
```



```
  GNU nano 8.4                          client.ovpn
client
dev tun
proto udp
remote 192.168.56.131 1194
resolv-retry infinite
nobind
persist-key
persist-tun
auth-user-pass
remote-cert-tls server
ca /etc/openvpn/client/ca.crt
cert /etc/openvpn/client/client.crt
key /etc/openvpn/client/client.key
verb 3
```

4.2. MFA Gateway Implementation

This stage involved developing and integrating a Python-based Multi-Factor Authentication (MFA) gateway to enhance VPN access security through time-based one-time passwords (TOTP).

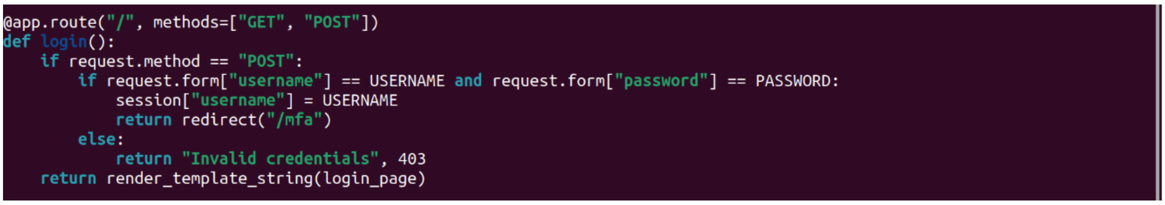
This Python script implements a TOTP-based Multi-Factor Authentication (MFA) system for OpenVPN. It uses a Flask web interface to collect user credentials and OTPs generated through Microsoft Authenticator. For VPN integration, the user submits a combined password where the last 6 digits are treated as the OTP and the rest as the static password. These components are parsed and verified using the pyotp library. The script supports two modes: web-based authentication and OpenVPN environment variable-based validation. All access attempts, whether successful or failed, are logged to /var/log/mfa_access.log for audit and review purposes.

For enhanced security and maintainability, the Python MFA login system references user credentials from an external configuration file, preventing hardcoding of sensitive information within the code.

- Developed a Python Flask application to implement multi-factor authentication using TOTP, providing secure user login flows
  - login() function
  - mfa() function.

- The login() function handled initial username and password verification:

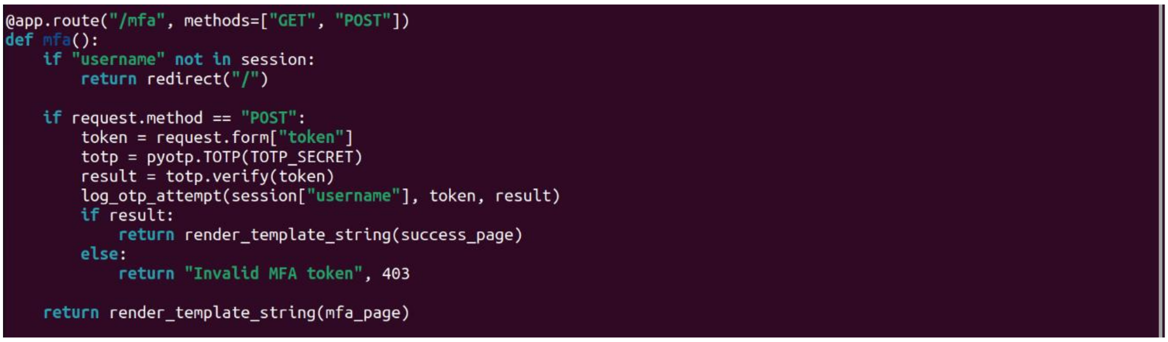
```
@app.route("/", methods=["GET", "POST"])
def login():
    if request.method == "POST":
        if request.form["username"] == USERNAME and request.form["password"] == PASSWORD:
            session["username"] = USERNAME
            return redirect("/mfa")
        else:
            return "Invalid credentials", 403
    return render_template_string(login_page)
```



```
@app.route("/", methods=["GET", "POST"])
def login():
    if request.method == "POST":
        if request.form["username"] == USERNAME and request.form["password"] == PASSWORD:
            session["username"] = USERNAME
            return redirect("/mfa")
        else:
            return "Invalid credentials", 403
    return render_template_string(login_page)
```

- The mfa() function validated time-based OTP tokens against the shared secret using PyOTP, completing the second authentication step:

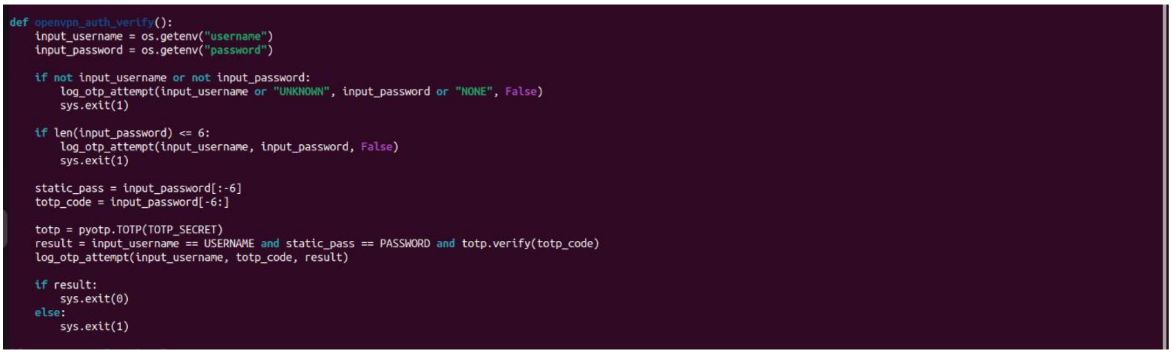
```
@app.route("/mfa", methods=["GET", "POST"])
def mfa():
    if "username" not in session:
        return redirect("/")
    if request.method == "POST":
        token = request.form["token"]
        totp = pyotp.TOTP(TOTP_SECRET)
        result = totp.verify(token)
        log_otp_attempt(session["username"], token, result)
        if result:
            return render_template_string(success_page)
        else:
            return "Invalid MFA token", 403
    return render_template_string(mfa_page)
```



```
@app.route("/mfa", methods=["GET", "POST"])
def mfa():
    if "username" not in session:
        return redirect("/")

    if request.method == "POST":
        token = request.form["token"]
        totp = pyotp.TOTP(TOTP_SECRET)
        result = totp.verify(token)
        log_otp_attempt(session["username"], token, result)
        if result:
            return render_template_string(success_page)
        else:
            return "Invalid MFA token", 403

    return render_template_string(mfa_page)
```

- Integrated with OpenVPN’s auth-user-pass-verify hook through the openvpn_auth_verify() function, which extracts and validates combined password and OTP from environment variables during VPN login:

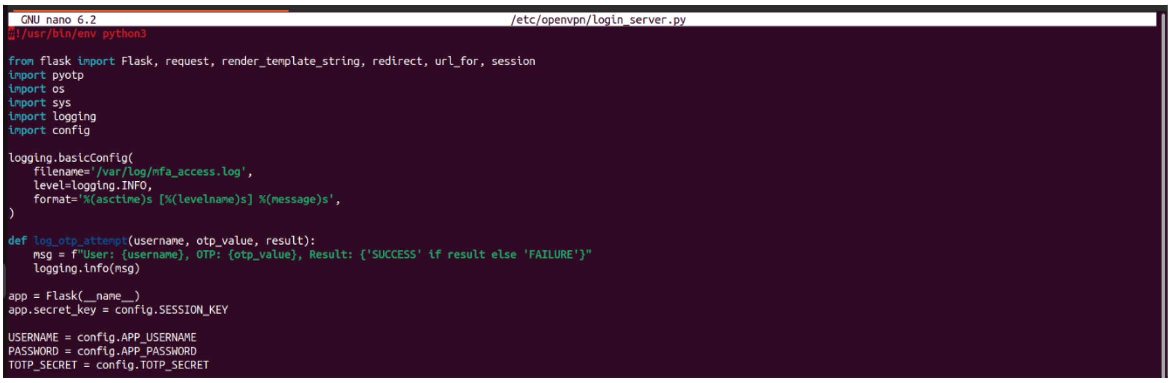
```
def openvpn_auth_verify():
    input_username = os.getenv("username")
    input_password = os.getenv("password")
    if not input_username or not input_password:
        log_otp_attempt(input_username or "UNKNOWN", input_password or "NONE", False)
        sys.exit(1)
    static_pass = input_password[:-6]
    totp_code = input_password[-6:]
    totp = pyotp.TOTP(TOTP_SECRET)
    result = input_username == USERNAME and static_pass == PASSWORD and totp.verify(totp_code)
    log_otp_attempt(input_username, totp_code, result)
    sys.exit(0 if result else 1)
```



```
def openvpn_auth_verify():
    input_username = os.getenv("username")
    input_password = os.getenv("password")

    if not input_username or not input_password:
        log_otp_attempt(input_username or "UNKNOWN", input_password or "NONE", False)
        sys.exit(1)

    if len(input_password) <= 6:
        log_otp_attempt(input_username, input_password, False)
        sys.exit(1)

    static_pass = input_password[:-6]
    totp_code = input_password[-6:]

    totp = pyotp.TOTP(TOTP_SECRET)
    result = input_username == USERNAME and static_pass == PASSWORD and totp.verify(totp_code)
    log_otp_attempt(input_username, totp_code, result)

    if result:
        sys.exit(0)
    else:
        sys.exit(1)
```

- Implemented detailed logging of all authentication attempts, successful or failed, through the log_otp_attempt() function, ensuring full traceability:

```
def log_otp_attempt(username, otp_value, result):
    msg = f"User: {username}, OTP: {otp_value}, Result: {'SUCCESS' if result else 'FAILURE'}"
    logging.info(msg)
```



```
  GNU nano 6.2                                /etc/openvpn/login_server.py
#!/usr/bin/env python3

from flask import Flask, request, render_template_string, redirect, url_for, session
import pyotp
import os
import sys
import logging
import config

logging.basicConfig(
    filename='/var/log/mfa_access.log',
    level=logging.INFO,
    format='%(asctime)s [%(levelname)s] %(message)s',
)

def log_otp_attempt(username, otp_value, result):
    msg = f"User: {username}, OTP: {otp_value}, Result: {'SUCCESS' if result else 'FAILURE'}"
    logging.info(msg)

app = Flask(__name__)
app.secret_key = config.SESSION_KEY

USERNAME = config.APP_USERNAME
PASSWORD = config.APP_PASSWORD
TOTP_SECRET = config.TOTP_SECRET
```

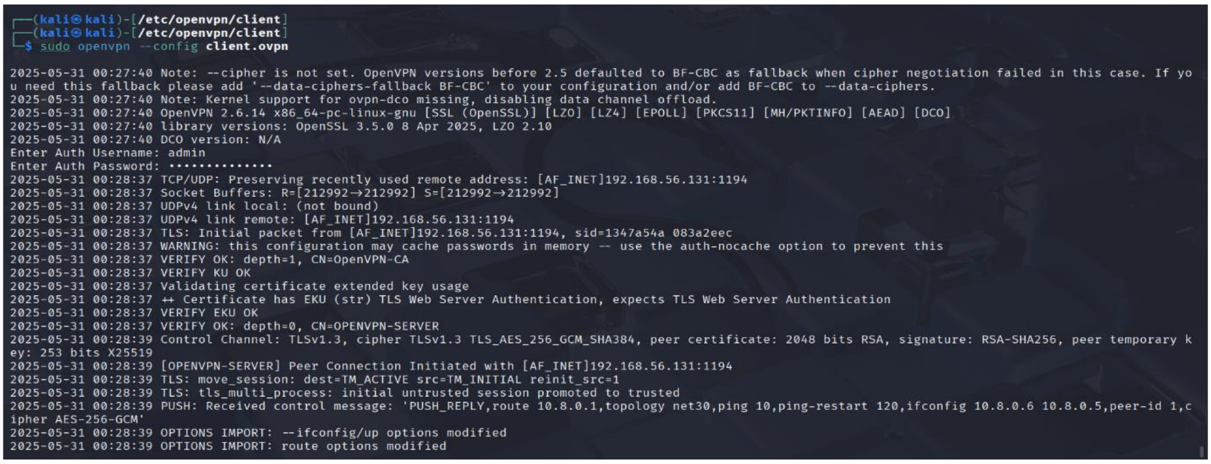
- This structured implementation enforced robust multi-factor authentication for VPN access, improving security posture while maintaining usability and enabling thorough monitoring of authentication events.

5. Log Correlation and Monitoring under Testing and Validation

To validate the security and operational effectiveness of the deployed VPN and MFA gateway, authentication scenarios were tested using both valid and invalid credentials. Additionally, the accuracy and integrity of access logs were verified by integrating them with a centralized ELK stack for real-time correlation and monitoring. This approach ensured that only authorized users gained access and that all login attempts were properly logged and available for analysis.

5.1. Successful Connection Test

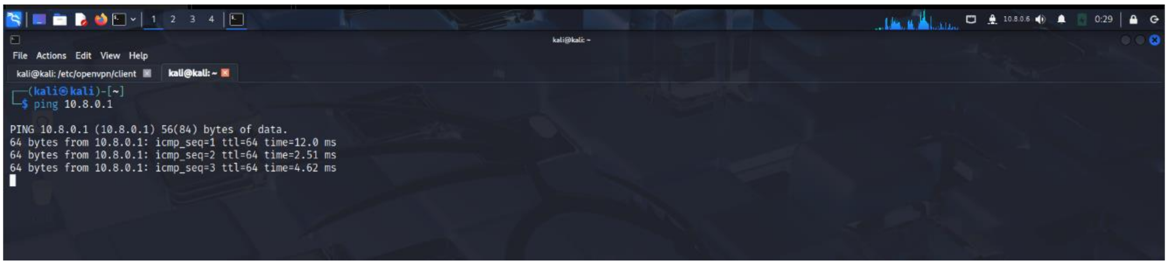
- Connected the Kali client to the Ubuntu VPN server using the correct username, static password, and valid 6-digit OTP from Microsoft Authenticator.



```
┌──(kali㉿kali)-[/etc/openvpn/client]
┌──(kali㉿kali)-[/etc/openvpn/client]
└─$ sudo openvpn --config client.ovpn

2025-05-31 00:27:40 Note: --cipher is not set. OpenVPN versions before 2.5 defaulted to BF-CBC as fallback when cipher negotiation failed in this case. If yo
u need this fallback please add '--data-ciphers-fallback BF-CBC' to your configuration and/or add BF-CBC to --data-ciphers.
2025-05-31 00:27:40 Note: Kernel support for ovpn-dco missing, disabling data channel offload.
2025-05-31 00:27:40 OpenVPN 2.6.14 x86_64-pc-linux-gnu [SSL (OpenSSL)] [LZO] [LZ4] [EPOLL] [PKCS11] [MH/PKTINFO] [AEAD] [DCO]
2025-05-31 00:27:40 library versions: OpenSSL 3.5.0 8 Apr 2025, LZO 2.10
2025-05-31 00:27:40 DCO version: N/A
Enter Auth Username: admin
Enter Auth Password: ••••••••••••••
2025-05-31 00:28:37 TCP/UDP: Preserving recently used remote address: [AF_INET]192.168.56.131:1194
2025-05-31 00:28:37 Socket Buffers: R=[212992→212992] S=[212992→212992]
2025-05-31 00:28:37 UDPv4 link local: (not bound)
2025-05-31 00:28:37 UDPv4 link remote: [AF_INET]192.168.56.131:1194
2025-05-31 00:28:37 TLS: Initial packet from [AF_INET]192.168.56.131:1194, sid=1347a54a 083a2eec
2025-05-31 00:28:37 WARNING: this configuration may cache passwords in memory -- use the auth-nocache option to prevent this
2025-05-31 00:28:37 VERIFY OK: depth=1, CN=OpenVPN-CA
2025-05-31 00:28:37 VERIFY KU OK
2025-05-31 00:28:37 Validating certificate extended key usage
2025-05-31 00:28:37 ++ Certificate has EKU (str) TLS Web Server Authentication, expects TLS Web Server Authentication
2025-05-31 00:28:37 VERIFY EKU OK
2025-05-31 00:28:37 VERIFY OK: depth=0, CN=OPENVPN-SERVER
2025-05-31 00:28:39 Control Channel: TLSv1.3, cipher TLSv1.3 TLS_AES_256_GCM_SHA384, peer certificate: 2048 bits RSA, signature: RSA-SHA256, peer temporary k
ey: 253 bits X25519
2025-05-31 00:28:39 [OPENVPN-SERVER] Peer Connection Initiated with [AF_INET]192.168.56.131:1194
2025-05-31 00:28:39 TLS: move_session: dest=TM_ACTIVE src=TM_INITIAL reinit_src=1
2025-05-31 00:28:39 TLS: tls_multi_process: initial untrusted session promoted to trusted
2025-05-31 00:28:39 PUSH: Received control message: 'PUSH_REPLY,route 10.8.0.1,topology net30,ping 10,ping-restart 120,ifconfig 10.8.0.6 10.8.0.5,peer-id 1,c
ipher AES-256-GCM'
2025-05-31 00:28:39 OPTIONS IMPORT: --ifconfig/up options modified
2025-05-31 00:28:39 OPTIONS IMPORT: route options modified
```

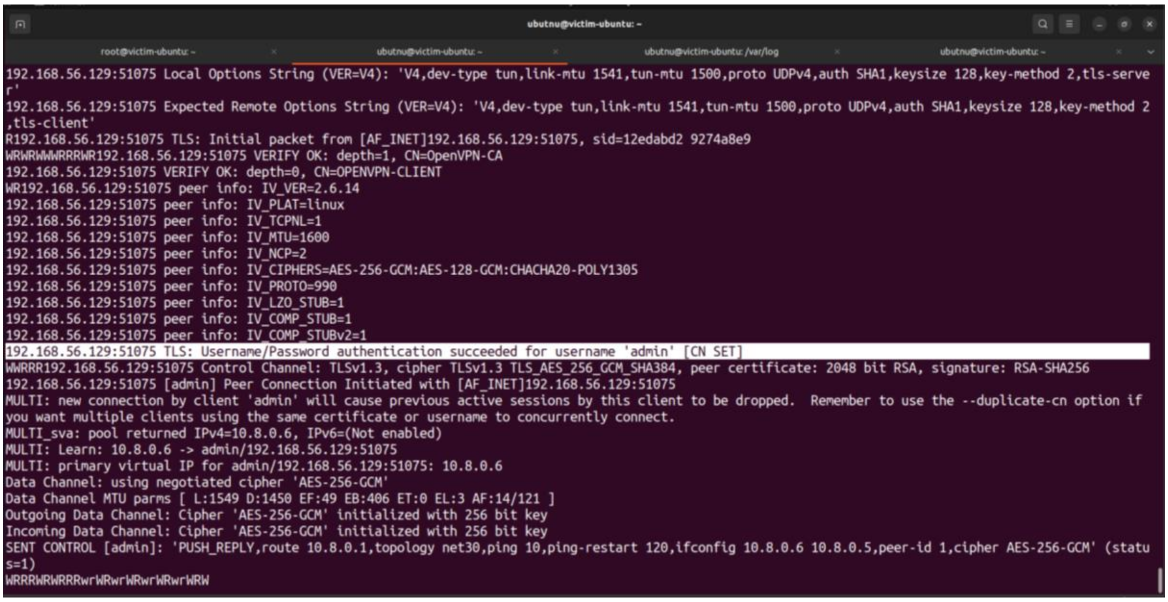
- Confirmed that the VPN tunnel was established and access was granted.

(Confirms VPN tunnel connectivity by successfully pinging the server IP.)



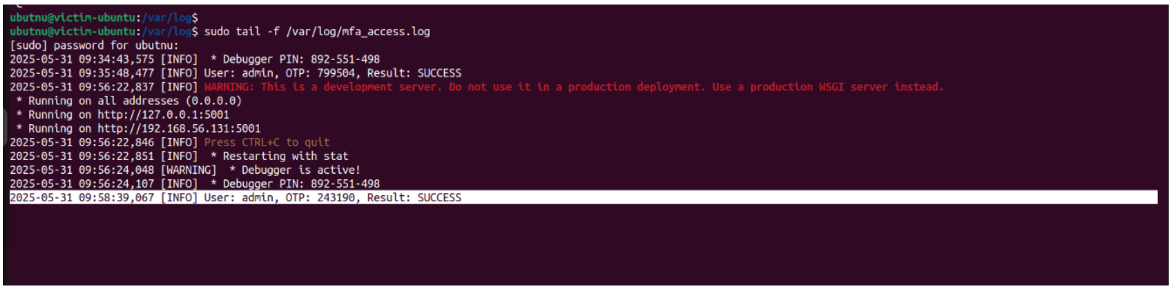
```
┌──(kali㉿kali)-[~]
└─$ ping 10.8.0.1

PING 10.8.0.1 (10.8.0.1) 56(84) bytes of data.
64 bytes from 10.8.0.1: icmp_seq=1 ttl=64 time=12.0 ms
64 bytes from 10.8.0.1: icmp_seq=2 ttl=64 time=2.51 ms
64 bytes from 10.8.0.1: icmp_seq=3 ttl=64 time=4.62 ms
```

(Successful client connection and authentication to the VPN server.)



```
192.168.56.129:51075 Local Options String (VER=V4): 'V4,dev-type tun,link-mtu 1541,tun-mtu 1500,proto UDPv4,auth SHA1,keysize 128,tls-serve
r'
192.168.56.129:51075 Expected Remote Options String (VER=V4): 'V4,dev-type tun,link-mtu 1541,tun-mtu 1500,proto UDPv4,auth SHA1,keysize 128,key-method 2
,tls-client'
R192.168.56.129:51075 TLS: Initial packet from [AF_INET]192.168.56.129:51075, sid=12edabd2 9274a8e9
WRWRWWWRRRWR192.168.56.129:51075 VERIFY OK: depth=1, CN=OpenVPN-CA
192.168.56.129:51075 VERIFY OK: depth=0, CN=OPENVPN-CLIENT
WR192.168.56.129:51075 peer info: IV_VER=2.6.14
192.168.56.129:51075 peer info: IV_PLAT=linux
192.168.56.129:51075 peer info: IV_TCPNL=1
192.168.56.129:51075 peer info: IV_MTU=1600
192.168.56.129:51075 peer info: IV_NCP=2
192.168.56.129:51075 peer info: IV_CIPHERS=AES-256-GCM:AES-128-GCM:CHACHA20-POLY1305
192.168.56.129:51075 peer info: IV_PROTO=990
192.168.56.129:51075 peer info: IV_LZO_STUB=1
192.168.56.129:51075 peer info: IV_COMP_STUB=1
192.168.56.129:51075 peer info: IV_COMP_STUBv2=1
192.168.56.129:51075 TLS: Username/Password authentication succeeded for username 'admin' [CN SET]
WWRRR192.168.56.129:51075 Control Channel: TLSv1.3, cipher TLSv1.3 TLS_AES_256_GCM_SHA384, peer certificate: 2048 bit RSA, signature: RSA-SHA256
192.168.56.129:51075 [admin] Peer Connection Initiated with [AF_INET]192.168.56.129:51075
MULTI: new connection by client 'admin' will cause previous active sessions by this client to be dropped.  Remember to use the --duplicate-cn option if
you want multiple clients using the same certificate or username to concurrently connect.
MULTI_sva: pool returned IPv4=10.8.0.6, IPv6=(Not enabled)
MULTI: Learn: 10.8.0.6 -> admin/192.168.56.129:51075
MULTI: primary virtual IP for admin/192.168.56.129:51075: 10.8.0.6
Data Channel: using negotiated cipher 'AES-256-GCM'
Data Channel MTU parms [ L:1549 D:1450 EF:49 EB:406 ET:0 EL:3 AF:14/121 ]
Outgoing Data Channel: Cipher 'AES-256-GCM' initialized with 256 bit key
Incoming Data Channel: Cipher 'AES-256-GCM' initialized with 256 bit key
SENT CONTROL [admin]: 'PUSH_REPLY,route 10.8.0.1,topology net30,ping 10,ping-restart 120,ifconfig 10.8.0.6 10.8.0.5,peer-id 1,cipher AES-256-GCM' (statu
s=1)
WRRRWRWRRRwrWRwrWRwrWRwrWRW
```

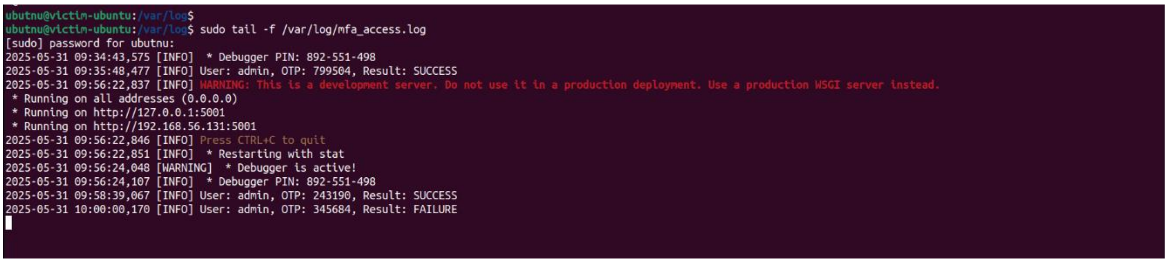
(Record a successful multi-factor authentication validating user access.)



```
ubutnu@victim-ubuntu:/var/log$
ubutnu@victim-ubuntu:/var/log$ sudo tail -f /var/log/mfa_access.log
[sudo] password for ubutnu:
2025-05-31 09:34:43,575 [INFO]  * Debugger PIN: 892-551-498
2025-05-31 09:35:48,477 [INFO] User: admin, OTP: 799504, Result: SUCCESS
2025-05-31 09:56:22,837 [INFO] WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.
 * Running on all addresses (0.0.0.0)
 * Running on http://127.0.0.1:5001
 * Running on http://192.168.56.131:5001
2025-05-31 09:56:22,846 [INFO] Press CTRL+C to quit
2025-05-31 09:56:22,851 [INFO]  * Restarting with stat
2025-05-31 09:56:24,048 [WARNING]  * Debugger is active!
2025-05-31 09:56:24,107 [INFO]  * Debugger PIN: 892-551-498
2025-05-31 09:58:39,067 [INFO] User: admin, OTP: 243190, Result: SUCCESS
```

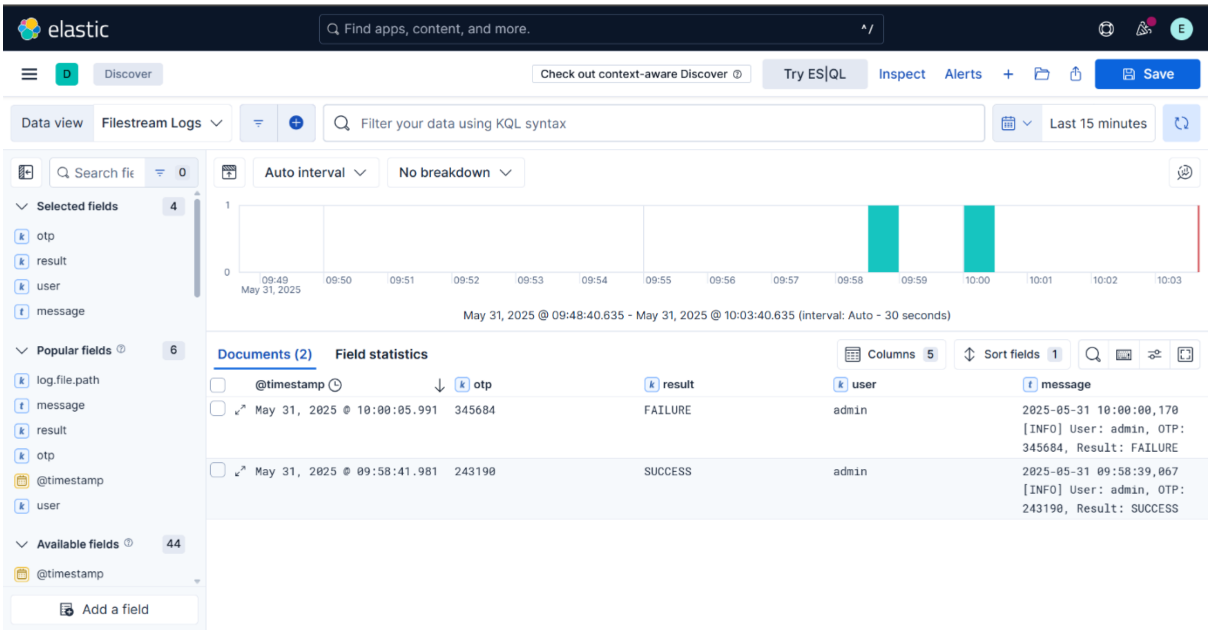
5.2. Failed Connection Test

- Attempted to connect using either an incorrect password or invalid OTP.



```
ubutnu@victim-ubuntu:/var/log$
ubutnu@victim-ubuntu:/var/log$ sudo tail -f /var/log/mfa_access.log
[sudo] password for ubutnu:
2025-05-31 09:34:43,575 [INFO]  * Debugger PIN: 892-551-498
2025-05-31 09:35:48,477 [INFO] User: admin, OTP: 799504, Result: SUCCESS
2025-05-31 09:56:22,837 [INFO] WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.
 * Running on all addresses (0.0.0.0)
 * Running on http://127.0.0.1:5001
 * Running on http://192.168.56.131:5001
2025-05-31 09:56:22,846 [INFO] Press CTRL+C to quit
2025-05-31 09:56:22,851 [INFO]  * Restarting with stat
2025-05-31 09:56:24,048 [WARNING]  * Debugger is active!
2025-05-31 09:56:24,107 [INFO]  * Debugger PIN: 892-551-498
2025-05-31 09:58:39,067 [INFO] User: admin, OTP: 243190, Result: SUCCESS
2025-05-31 10:00:00,170 [INFO] User: admin, OTP: 345684, Result: FAILURE
```

(Kibana Data View)



Data view: Filestream Logs

Filter your data using KQL syntax

Selected fields 4: otp, result, user, message

Popular fields 6: log.file.path, message, result, otp, @timestamp, user

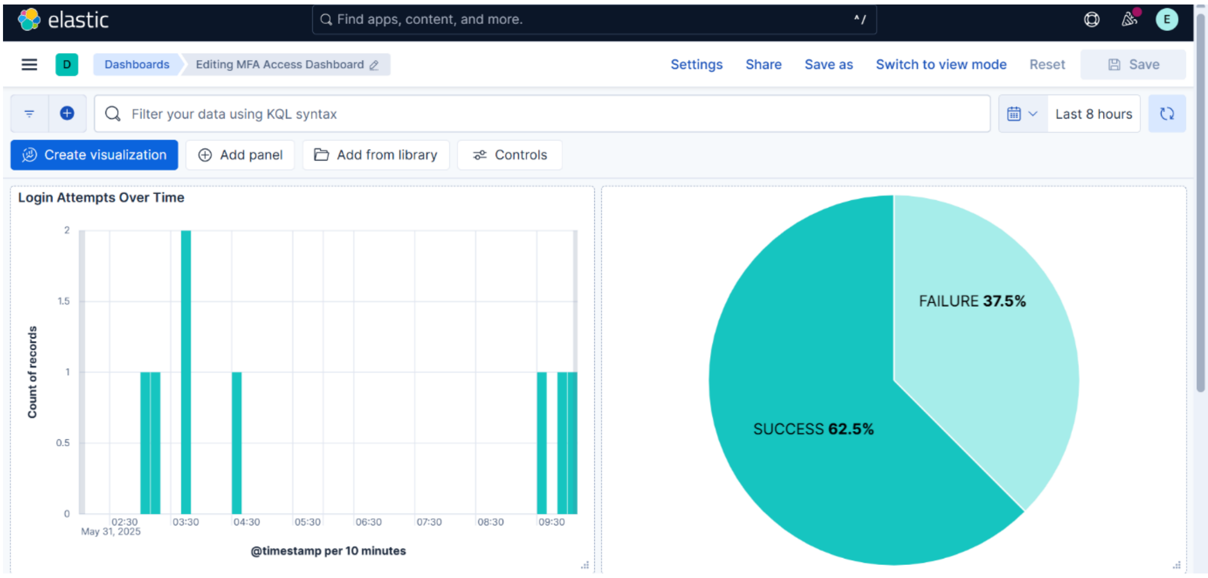
Available fields 44: @timestamp

May 31, 2025 @ 09:48:40.635 - May 31, 2025 @ 10:03:40.635 (interval: Auto - 30 seconds)

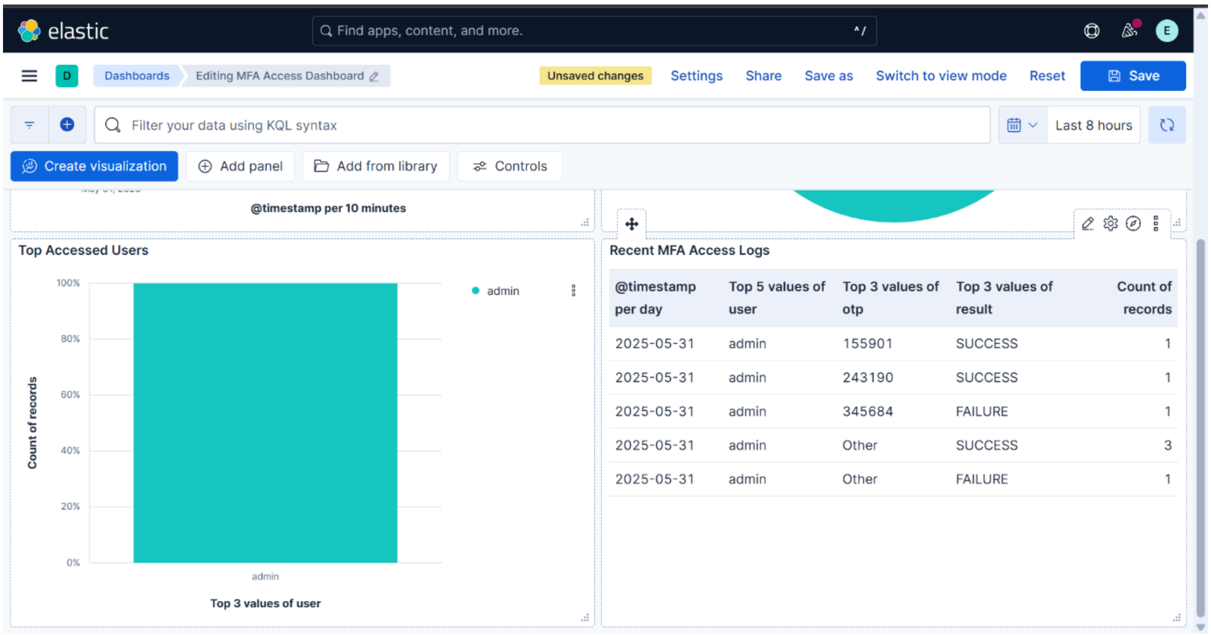
@timestamp	otp	result	user	message
May 31, 2025 @ 10:00:05.991	345684	FAILURE	admin	2025-05-31 10:00:00,170 [INFO] User: admin, OTP: 345684, Result: FAILURE
May 31, 2025 @ 09:58:41.981	243190	SUCCESS	admin	2025-05-31 09:58:39,067 [INFO] User: admin, OTP: 243190, Result: SUCCESS

5.3. Dashboard Correlation and Analysis

- Created a bar chart to visualize login attempts over time, highlighting peak activity periods.
- Designed a pie chart illustrating the ratio of successful versus failed authentication attempts for quick overview.



- Identified top accessed users through a leaderboard visualization to monitor user activity patterns.
- Developed a detailed table displaying recent MFA access logs for granular audit and troubleshooting purposes.



Recent MFA Access Logs

@timestamp per day	Top 5 values of user	Top 3 values of otp	Top 3 values of result	Count of records
2025-05-31	admin	155901	SUCCESS	1
2025-05-31	admin	243190	SUCCESS	1
2025-05-31	admin	345684	FAILURE	1
2025-05-31	admin	Other	SUCCESS	3
2025-05-31	admin	Other	FAILURE	1

6. Deliverables Review

The following key deliverables were produced and are available for review:

- **VPN Configuration Files:**
  server.conf and client.conf: OpenVPN configuration files enabling secure VPN tunnel setup and authentication integration.

- **MFA System Source Code:**
  login_server.py: Python script implementing the MFA gateway using TOTP, handling authentication requests and logging access attempts.

- **Access Logs:**
  /var/log/mfa_access.log: Log file capturing all MFA authentication attempts, detailing success and failure events.
- **Correlation Dashboard:**
  Kibana dashboard visualizing authentication data, including charts for login attempts over time, success versus failure ratios, top accessed users, and recent MFA access logs.

- **Testing Artifacts:**
  Recorded video demonstrating successful and failed VPN connection attempts with integrated MFA, validating the system's authentication and logging functionality.

7. Results and Findings

This section summarizes the outcomes of the implemented encrypted VPN tunnel with MFA gateway, focusing on authentication success rates, system responsiveness, and log accuracy. The findings demonstrate that the solution effectively enforces multi-factor authentication while providing reliable logging and monitoring capabilities.

- **Successful VPN Connections with Valid Credentials**
  Users with correct username, password, and valid OTP were able to establish VPN connections seamlessly, confirming that the MFA gateway properly authenticates legitimate users.

- **Rejection of Invalid Authentication Attempts**
  Attempts using incorrect passwords or invalid OTPs were consistently denied access, demonstrating robust enforcement of the multi-factor authentication mechanism.

- **Accurate Logging of Access Attempts**
  All authentication attempts, whether successful or failed, were recorded in the /var/log/mfa_access.log file with precise timestamps and status messages, ensuring comprehensive audit trails.

- **Effective Correlation and Visualization**
  The Kibana dashboard successfully aggregated and visualized login attempt data, enabling clear analysis of user access patterns and immediate identification of suspicious activities.

- **Stable System Performance Under Load**
  The VPN and MFA system maintained stable performance during repeated connection attempts, with no significant delays or failures, indicating reliability suitable for production deployment.

8. Recommendations for Ongoing Security Enhancement

To further strengthen the security and reliability of the VPN and MFA system, the following recommendations are proposed:

- **Implement Adaptive Authentication:**
  Incorporate risk-based authentication measures that adjust MFA requirements based on user behavior, location, or device trust levels to enhance security without impacting user experience.

- **Regularly Update and Rotate Secrets:**
  Establish policies for periodic rotation of TOTP secrets and VPN certificates to minimize the risk of credential compromise.

- **Enable Real-Time Alerting:**
  Integrate automated alerting mechanisms to notify administrators immediately of repeated failed login attempts or unusual access patterns detected via the correlation dashboard.

- **Harden Server Security:**
  Apply system hardening best practices on VPN and MFA servers, including firewall rules, intrusion detection, and timely patch management to reduce the attack surface.

- **Expand Logging and Monitoring:**
  Extend logging to capture additional metadata such as IP addresses and device information and perform ongoing log analysis to detect anomalies proactively.

- **User Training and Awareness:**
  Conduct regular user education on MFA importance and secure credential handling to reduce social engineering risks.

9. Conclusion

The project successfully established a secure, encrypted VPN tunnel integrated with a Python-based MFA gateway employing TOTP for enhanced authentication. This multi-layered security approach ensures that only authorized users with valid credentials and time-sensitive OTPs gain access, significantly reducing the risk of unauthorized entry. For secure credential management, the MFA system references passwords and secrets from an external configuration file, adhering to best security practices by avoiding hardcoded sensitive data. The comprehensive logging of all access attempts facilitates thorough auditing and accountability, while the centralized correlation dashboard provides valuable insights into user activity and potential security threats. Rigorous testing validated the system’s reliability and effectiveness in both granting legitimate access and preventing unauthorized attempts. Overall, this implementation delivers a robust, scalable, and easily maintainable solution that aligns with modern zero-trust security principles and can be further enhanced to address evolving security challenges.