

Introduction to Cloud Computing Report

Lab 2: Nebula VPN Configuration and Connectivity

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Introduction to Cloud Computing
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I. Objective

The objective of this lab is to configure and verify a Nebula VPN, ensuring secure communication between multiple client nodes through a Lighthouse node. By completing this lab, students will achieve proficiency in:

- Configuring a Lighthouse node using a server provided by the instructor, setting its IP address, and generating the necessary certificates.
- Configuring multiple client nodes located behind NAT, enabling them to establish secure connections through the Lighthouse node.
- Ensuring secure node identity authentication through encryption certificates and configuration files.
- Testing network connectivity, including performing ICMP ping tests and verifying application layer connectivity via SSH.

II. Lab Content

1. Cryptographic Assets Acquisition

- Obtain the necessary cryptographic assets provided by the instructor:
 - yinyuang.crt: Client certificate (public key) for identity verification.
 - yinyuang.key: Private key for decrypting data and signing outgoing messages.
 - ca.crt: Root certificate to establish the trust domain in the network.

2. Configuration and Deployment

- Customize the configuration files using YAML format to define each node's role, IP address, and point to the cryptographic assets. The configuration should include the following:

- ‘pki.cert’: Path to the client certificate (e.g., **‘yinyuang.crt’**).
 - ‘pki.key’: Path to the private key (e.g., **‘yinyuang.key’**).
 - ‘pki.ca’: Path to the root certificate (e.g., **‘ca.crt’**).
 - ‘static_{host_map}’: Public IP address of the Lighthouse node (provided by the instructor).
 - ‘firewall’: Rules to allow traffic such as ICMP/Ping and SSH.

- Configure the Lighthouse Node:

- Use the server provided by the instructor as the Lighthouse node, setting the IP address and generating necessary certificates.
 - Install Nebula and generate the certificates using the following commands:

- * ‘nebula-cert ca –name ”LeiNetwork”’
 - * ‘nebula-cert sign -name ”lighthouse” -ip ”192.168.100.1/24”’
 - * ‘nebula-cert sign -name ”MBP15” -ip ”192.168.100.15/24”’
 - * ‘nebula-cert sign -name ”mini” -ip ”192.168.100.10/24”’

- Configure the ‘config.yaml’ file for the Lighthouse node, ensuring it points to the correct certificate paths and IP addresses.
 - Start the Nebula Daemon to enable the Lighthouse node to accept connections from client nodes:
 - * ‘sudo nebula -config ./nebula/config.yaml’

- Configure Client Nodes:

- Similar to the Lighthouse node, each client node needs to configure the certificate paths and the Lighthouse IP address in the ‘config.yaml’ file. The ‘static_{host_map}’ should point to the Lighthouse node's IP address ‘192.168.100.1’ * *).

3. Connectivity Verification

- ICMP Connectivity Test (Ping Test):

- Use the ‘ping’ command to test if the client node can establish basic network connectivity to the Lighthouse node:

- * ‘ping 192.168.100.1‘
- Application Layer Connectivity Test (SSH Login):
 - Use SSH to confirm that the secure tunnel established by Nebula VPN can reliably pass application layer traffic, verifying node identity:
 - * ‘ssh user@192.168.100.1‘

III. Results

1.Cryptographic Assets Received

The security and identity of the node rely on three essential files provided by the lecturer (Certificate Authority).

File Name	Role & Type	Core Function in Nebula	Security Requirement
yinyuang.crt	Client Certificate (Public Key)	Proves your identity to the network peers and Lighthouse. It contains the public key necessary for others to encrypt data for you.	Publicly shareable (but used internally for identity).
yinyuang.key	Private Key	Used to decrypt data sent to your node and to create digital signatures to authenticate your outgoing messages.	MUST be kept absolutely confidential.
ca.crt	Root CA Certificate	Establishes the network's trust domain. It verifies that your 'yourname.crt' (and all other peer certificates) were issued by the trusted CA.	Publicly shareable, needed by all nodes.

Table 1: Cryptographic Assets in Nebula VPN

The screenshot below displays the core files required for Nebula VPN deployment: - nebula.exe and nebula-cert.exe: Nebula’s main executable program and certificate management utility. - ca.crt, yinyuang.crt, yinyuang.key: Cryptographic assets (root certificate, node-specific certificate, and private key) that correspond to the pki section in Table 1. - config.yaml: The configuration file to be edited, which maps to the parameters outlined in the above table.

dist	2025/9/16 15:05	文件夹
ca.crt	2025/9/16 14:08	安全证书
config.yaml	2025/9/16 15:48	Yaml 源文件
nebula.exe	2025/9/16 15:05	应用程序
nebula-cert.exe	2025/9/16 15:05	应用程序
yinyuang.crt	2025/9/16 14:17	安全证书
yinyuang.key	2025/9/16 14:17	KEY 文件

Figure 1: List of Nebula VPN Core Files

2.Configuration and Deployment

(1)Customizing the Configuration File

A YAML configuration file must be created or modified to define the node’s role, IP address, and point to the cryptographic assets.

Section	Parameter	Customization
pki	cert	Path to your <code>yourname.crt</code>
pki	key	Path to your <code>yinyuang.key</code>
pki	ca	Path to the root <code>ca.crt</code>
static_host_map	192.168.100.1	The Lighthouse's public IP/port for initial contact.
firewall	inbound/outbound	Custom rules to allow traffic (e.g., ICMP/Ping, SSH).

Table 2: Key Configuration Parameters for Nebula VPN

The screenshot below displays the core files required for Nebula VPN deployment: - `nebula.exe` and `nebula-cert.exe`: Nebula's main executable program and certificate management utility. - `ca.crt`, `yinyuang.crt`, `yinyuang.key`: Cryptographic assets (root certificate, node-specific certificate, and private key) that correspond to the `pki` section in Table 1. - `config.yaml`: The configuration file to be edited, which maps to the parameters outlined in the above table.

📁 dist	2025/9/16 15:05	文件夹
📅 ca.crt	2025/9/16 14:08	安全证书
📝 config.yaml	2025/9/16 15:48	Yaml 源文件
💻 nebula.exe	2025/9/16 15:05	应用程序
💻 nebula-cert.exe	2025/9/16 15:05	应用程序
📅 yinyuang.crt	2025/9/16 14:17	安全证书
📄 yinyuang.key	2025/9/16 14:17	KEY 文件

Figure 2: List of Nebula VPN Core Files

(2) Running the Nebula Daemon

The screenshot below presents the startup log of the Nebula VPN client on Windows systems, which records the full process: *Loading configuration* → *Starting firewall* → *Creating virtual network adapter* → *Listening on port* → *Connecting to the Lighthouse node*. Eventually, a handshake connection with the Lighthouse node (VPN IP: 192.168.100.1, public address: 104.243.20.247:554) is successfully established.

```
C:\Windows\System32>cd C:\Users\21534\Desktop\nebula
C:\Users\21534\Desktop\nebula>nebula.exe --config '\config.yaml'
time="2025-09-16T16:43:05+08:00" level=info msg="Firewall rule added" firewallRule="map[caName: caSha; direction:outgoing endPort:0 groups:[]; host:any ip; localIp; proto:0 startPort:0]"
time="2025-09-16T16:43:05+08:00" level=info msg="Firewall rule added" firewallRule="map[caName: caSha; direction:incoming endPort:0 groups:[]; host:any ip; localIp; proto:0 startPort:0]"
time="2025-09-16T16:43:05+08:00" level=info msg="Firewall started" firewallHashes="SHA:498215dec4e568fa233f51c10838c113bdaf35er7258c8c97536986ada8417, FNV:2782948616"
2025/09/16 16:43:04 Using existing driver 0.14
2025/09/16 16:43:04 Creating adapter
time="2025-09-16T16:43:05+08:00" level=info msg="listening on 0.0.0.0:554"
time="2025-09-16T16:43:05+08:00" level=error msg="Falling back to standard udp sockets" error="bind: The attempted operation is not supported for the type of object referenced."
time="2025-09-16T16:43:05+08:00" level=info msg="Main HostMap created" network="192.168.100.143/24 preferredRanges=[ ]"
time="2025-09-16T16:43:05+08:00" level=info msg="punchy enabled"
time="2025-09-16T16:43:05+08:00" level=info msg="Loaded send_recv_error config" sendRecvError=always
time="2025-09-16T16:43:05+08:00" level=info msg="Nebula interface is active" boringcrypto=false build=d1.9.6 interface=nebulal network=192.168.100.143/24 udpAddr="[:]:554"
time="2025-09-16T16:43:05+08:00" level=info msg="Handshake message sent" initiatorIndex=623518446 responderIndex=623518446 remoteIndex=0 udpAddr="[:104.243.20.247:554]" vpnIp="192.168.100.1"
time="2025-09-16T16:43:05+08:00" level=info msg="Handshake message received" certName=lighthouse durationNs=177676800 fingerprint="fb998b866e8275810bdb0c0175cd7cb31be03d0adec2a831ae16f9669a517 handshake=map[stage:2 style:ix_psk0] initiatorIndex=623518446 issuer=e430f526e15e22fd11db26e9482945865f17aa42c800481e56f68d087c892e0 remoteIndex=623518446 responderIndex=648598222 se
cachedPackets=1 udpAddr="104.243.20.247:554" vpnIp="192.168.100.1"
```

Figure 3: Nebula VPN Client Launch Log (Command-Line Output)

3. Connectivity Verification

(1) Testing ICMP Connectivity (Ping Test)

From a separate terminal window, the connectivity to the Lighthouse (IP 192.168.100.1) is tested using the ICMP protocol (Ping). ping 192.168.100.1

The screenshot below shows the result of the Ping test: it successfully receives 4 replies from the Lighthouse node (192.168.100.1) with 0

```
C:\Users\21534>ping 192.168.100.1

正在 Ping 192.168.100.1 具有 32 字节的数据:
来自 192.168.100.1 的回复: 字节=32 时间=183ms TTL=64
来自 192.168.100.1 的回复: 字节=32 时间=253ms TTL=64
来自 192.168.100.1 的回复: 字节=32 时间=235ms TTL=64
来自 192.168.100.1 的回复: 字节=32 时间=193ms TTL=64

192.168.100.1 的 Ping 统计信息:
    数据包: 已发送 = 4, 已接收 = 4, 丢失 = 0 (0% 丢失),
往返行程的估计时间(以毫秒为单位):
    最短 = 183ms, 最长 = 253ms, 平均 = 216ms
```

Figure 4: ICMP Connectivity Test (Ping Result to Lighthouse Node)

(2) Testing Application Layer Connectivity (SSH Login) To confirm that the secure tunnel can reliably pass application traffic and that the identity is fully verified, an SSH login attempt is made.

The screenshot below shows the successful SSH login result: after entering the password, the client connects to the Ubuntu 22.04 system of the Lighthouse node, and subsequent commands (e.g., ls, pwd) execute normally. This confirms that the application-layer connectivity of the Nebula VPN is fully functional.

```
C:\Users\21534>ssh nuist@192.168.100.1
nuist@192.168.100.1's password:
Welcome to Ubuntu 22.04.5 LTS (GNU/Linux 5.15.0-151-generic x86_64)

 * Documentation:  https://help.ubuntu.com
 * Management:    https://landscape.canonical.com
 * Support:       https://ubuntu.com/pro

This system has been minimized by removing packages and content that are
not required on a system that users do not log into.

To restore this content, you can run the 'unminimize' command.
New release '24.04.3 LTS' available.
Run 'do-release-upgrade' to upgrade to it.

Last login: Tue Sep 16 08:42:53 2025 from 192.168.100.134
$ ls
$ pwd
/home/nuist
```

Figure 5: Application-Layer Connectivity Test (SSH Login to Lighthouse Node)