

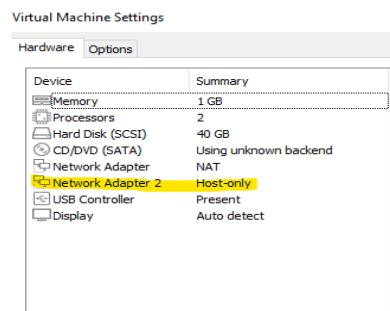
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SPD P01 – VPN

1. Creamos el entorno

Empezamos descargando todo lo necesario de cada maquina, para esto tiene que estar las redes en modo NAT. (OpenVPN en PC1 y el Server VPN, easy-rsa en el Server y Apache en todas porque no)

Apagamos el Gateway y le metemos otra interfaz de red en Host-Only



Despues encendemos y levantamos eth1 con '`sudo ip link set eth1 up`'

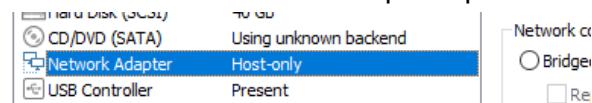
Y configuramos el direccionamiento del Gateway para eth1 ('`vim /etc/netplan/00-installer-config.yaml`'):

```
network:
  version: 2
  ethernets:
    eth0:
      dhcp4: true
    eth1:
      dhcp4: no
      addresses:
        - 172.22.0.10/24
      # dhcp4: no
```

Aplicamos con '`sudo netplan apply`' y haciendo un ipconfig ya sale la direccion para eth1:

```
eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
      inet 172.22.0.10  netmask 255.255.255.0  broadcast 172.22.0.255
      inet6 fe80::20c:29ff:fe3f:85da  prefixlen 64  scopeid 0x20<link>
        ether 00:0c:29:3f:85:da  txqueuelen 1000  (Ethernet)
          RX packets 0  bytes 0 (0.0 B)
          RX errors 0  dropped 0  overruns 0  frame 0
          TX packets 15  bytes 1146 (1.1 KB)
          TX errors 0  dropped 0  overruns 0  carrier 0  collisions 0
```

Cambiamos la NIC de PC1 para que este en Host-Only (se puede hacer en caliente):



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Una vez tenemos todo descargado correctamente, ajustamos las tarjetas de red de la siguiente manera:

PC1 al estar en la red externa lo dejamos en modo NAT:

| | |
|-----------------|------------------------------------|
| CD/DVD (SATA) | Using file C:\Users\giuli\Downl... |
| Network Adapter | NAT |
| USB Controller | Present |

El **gateway** estará a su vez en la red externa y la red interna, por tanto, la tarjeta que esté en la red externa se configurará en modo NAT y la otra interna en modo H.O:

| | |
|-------------------|------------------------------------|
| CD/DVD (SATA) | Using file C:\Users\giuli\Downl... |
| Network Adapter | NAT |
| Network Adapter 2 | Host-only |

El **server**:

| | |
|-----------------|------------------------------------|
| CD/DVD (SATA) | Using file C:\Users\giuli\Downl... |
| Network Adapter | Host-only |
| USB Controller | Present |

El **PC2**:

| | |
|-----------------|-----------|
| Network Adapter | Host-only |
| USB Controller | Present |

Y ponemos el direccionamiento correcto de PC1 y en todas las máquinas correspondientes como se muestra a continuación, todo esto siempre manipulando el fichero que se encuentra en (</etc/netplan/00-cloud-init.yaml>) o como se llame el fichero en su máquina correspondiente:

PC1 (por favor, comentar el default gateway para simular que está en red externa):

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```
network:
  version: 2
  ethernets:
    ens33:
      addresses: [40.40.40.30/24]

      routes:
        - to: default
          via: 40.40.40.10
    nameservers:
      addresses: [8.8.8.8]

~
```

Ejecutar (**netplan apply**) para guardar los cambios en la configuración. Ahora seguimos la misma lógica en función el esquema de la práctica para el resto de las máquinas.

Gateway:

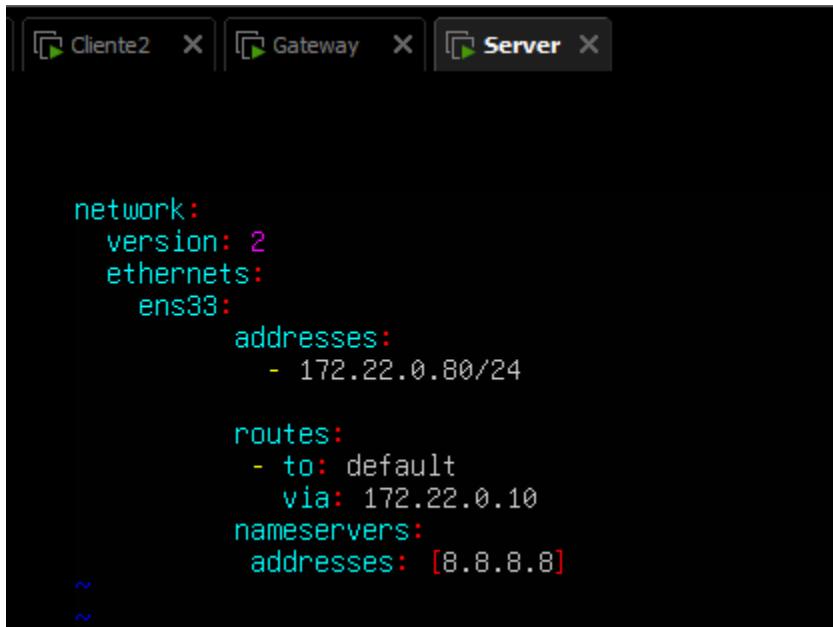


```
network:
  version: 2
  ethernets:
    ens33:
      addresses:
        - 40.40.40.10/24

    ens37:
      addresses:
        - 172.22.0.10/24
    nameservers:
      addresses: [8.8.8.8]
```

Server:

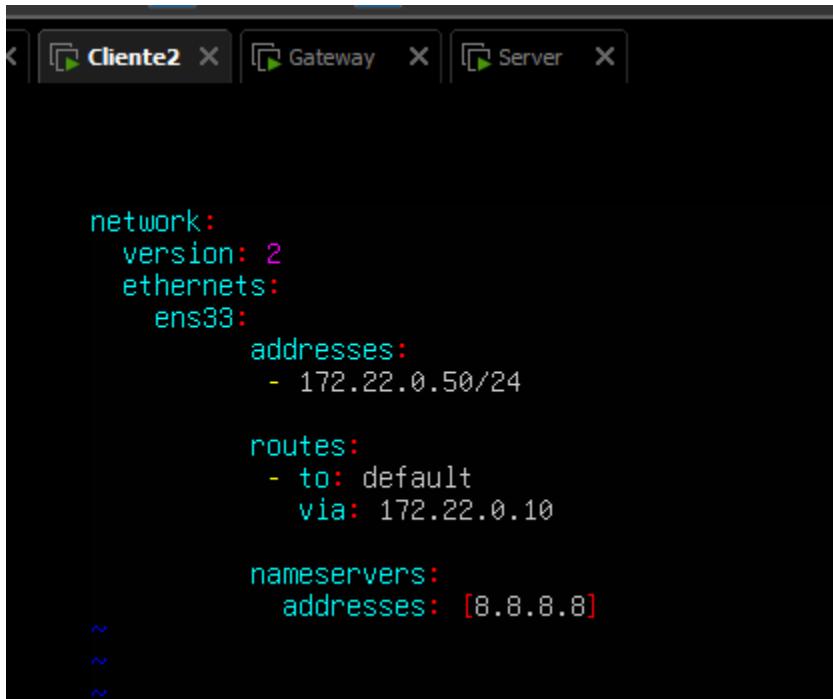
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A terminal window titled "Server" showing a snippet of a network configuration file. The configuration includes a network version 2, an ens33 interface with an IP address of 172.22.0.80/24, a default route via 172.22.0.10, and nameservers at 8.8.8.8.

```
network:
  version: 2
  ethernets:
    ens33:
      addresses:
        - 172.22.0.80/24
      routes:
        - to: default
          via: 172.22.0.10
      nameservers:
        addresses: [8.8.8.8]
```

PC2:



A terminal window titled "Cliente2" showing a snippet of a network configuration file. The configuration includes a network version 2, an ens33 interface with an IP address of 172.22.0.50/24, a default route via 172.22.0.10, and nameservers at 8.8.8.8.

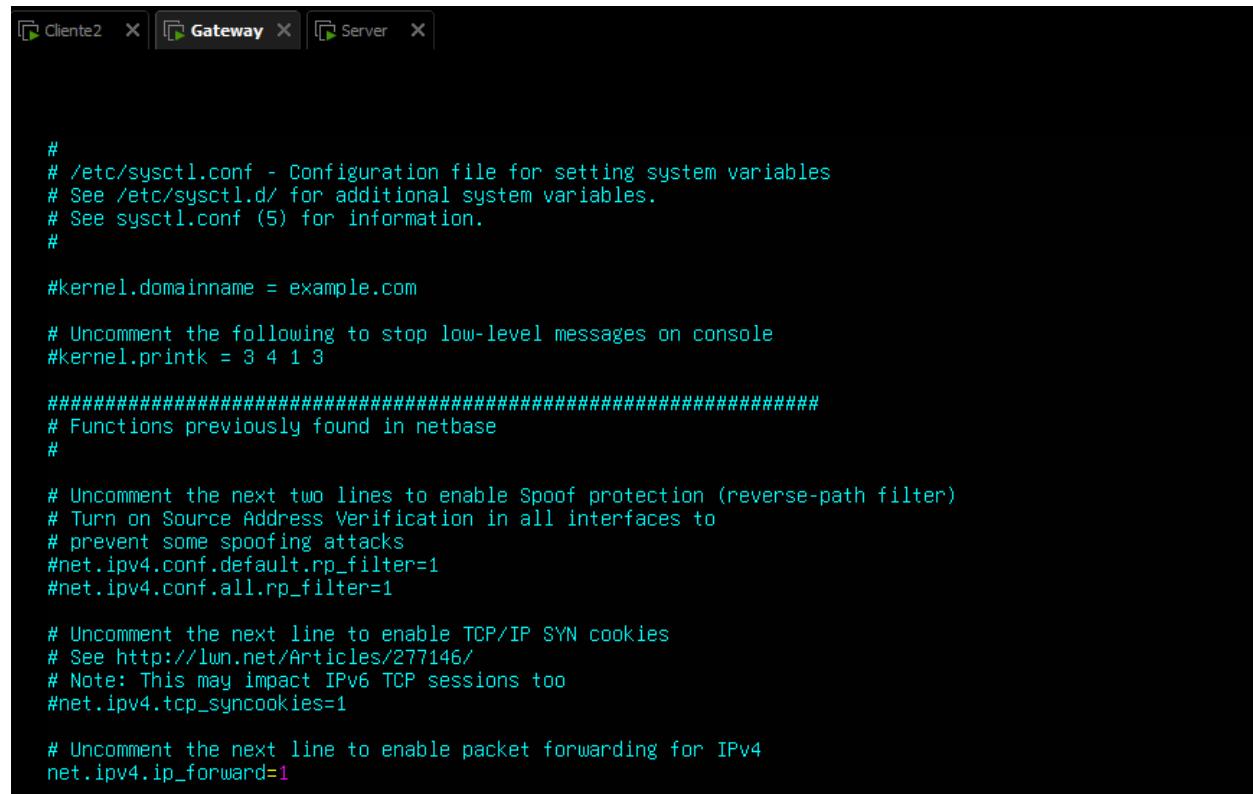
```
network:
  version: 2
  ethernets:
    ens33:
      addresses:
        - 172.22.0.50/24
      routes:
        - to: default
          via: 172.22.0.10
      nameservers:
        addresses: [8.8.8.8]
```

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Activar el forwarding en el gateway (ir al fichero /etc/sysctl.conf):



```
# /etc/sysctl.conf - Configuration file for setting system variables
# See /etc/sysctl.d/ for additional system variables.
# See sysctl.conf (5) for information.

#
#kernel.domainname = example.com

# Uncomment the following to stop low-level messages on console
#kernel.printk = 3 4 1 3

#####
# Functions previously found in netbase
#

# Uncomment the next two lines to enable Spoof protection (reverse-path filter)
# Turn on Source Address Verification in all interfaces to
# prevent some spoofing attacks
#net.ipv4.conf.default.rp_filter=1
#net.ipv4.conf.all.rp_filter=1

# Uncomment the next line to enable TCP/IP SYN cookies
# See http://lwn.net/Articles/277146/
# Note: This may impact IPv6 TCP sessions too
#net.ipv4.tcp_syncookies=1

# Uncomment the next line to enable packet forwarding for IPv4
net.ipv4.ip_forward=1
```

Descomentar el campo net.ipv4.ip_forward = 1. Para aplicar el cambio en la configuración con (**sudo sysctl -p**).

Ahora comprobamos la conectividad entre los equipos (naturalmente, sí que tendremos que ser capaces dentro de la red interna hacer ping a cualquier máquina dentro de la red interna).

Desde **PC2** al resto de máquinas:

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```
PING 172.22.0.80 (172.22.0.80) 56(84) bytes of data.  
64 bytes from 172.22.0.80: icmp_seq=1 ttl=64 time=1.36 ms  
64 bytes from 172.22.0.80: icmp_seq=2 ttl=64 time=0.567 ms  
64 bytes from 172.22.0.80: icmp_seq=3 ttl=64 time=0.576 ms  
64 bytes from 172.22.0.80: icmp_seq=4 ttl=64 time=0.519 ms  
  
--- 172.22.0.80 ping statistics ---  
4 packets transmitted, 4 received, 0% packet loss, time 3022ms  
rtt min/avg/max/mdev = 0.519/0.754/1.356/0.347 ms  
cliente2@cliente2:~$ ping -c 4 172.22.0.10  
PING 172.22.0.10 (172.22.0.10) 56(84) bytes of data.  
64 bytes from 172.22.0.10: icmp_seq=1 ttl=64 time=0.634 ms  
64 bytes from 172.22.0.10: icmp_seq=2 ttl=64 time=0.664 ms  
64 bytes from 172.22.0.10: icmp_seq=3 ttl=64 time=0.511 ms  
64 bytes from 172.22.0.10: icmp_seq=4 ttl=64 time=0.503 ms  
  
--- 172.22.0.10 ping statistics ---  
4 packets transmitted, 4 received, 0% packet loss, time 3032ms  
rtt min/avg/max/mdev = 0.503/0.578/0.664/0.071 ms  
cliente2@cliente2:~$ ping -c 4 40.40.40.10  
PING 40.40.40.10 (40.40.40.10) 56(84) bytes of data.  
64 bytes from 40.40.40.10: icmp_seq=1 ttl=64 time=0.682 ms  
64 bytes from 40.40.40.10: icmp_seq=2 ttl=64 time=0.592 ms  
64 bytes from 40.40.40.10: icmp_seq=3 ttl=64 time=0.568 ms  
64 bytes from 40.40.40.10: icmp_seq=4 ttl=64 time=0.528 ms  
  
--- 40.40.40.10 ping statistics ---  
4 packets transmitted, 4 received, 0% packet loss, time 3089ms  
rtt min/avg/max/mdev = 0.528/0.592/0.682/0.056 ms  
cliente2@cliente2:~$ ping 40.40.40.30  
PING 40.40.40.30 (40.40.40.30) 56(84) bytes of data.  
^C  
--- 40.40.40.30 ping statistics ---  
99 packets transmitted, 0 received, 100% packet loss, time 100293ms  
cliente2@cliente2:~$
```

Desde **PC1**:

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```
cliente1@cliente1:~$ ping -c 4 40.40.40.10
PING 40.40.40.10 (40.40.40.10) 56(84) bytes of data.
64 bytes from 40.40.40.10: icmp_seq=1 ttl=64 time=0.996 ms
64 bytes from 40.40.40.10: icmp_seq=2 ttl=64 time=0.603 ms
64 bytes from 40.40.40.10: icmp_seq=3 ttl=64 time=0.613 ms
64 bytes from 40.40.40.10: icmp_seq=4 ttl=64 time=0.581 ms

--- 40.40.40.10 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3054ms
rtt min/avg/max/mdev = 0.581/0.698/0.996/0.172 ms
cliente1@cliente1:~$ ping -c 4 172.22.0.10
ping: connect: Network is unreachable
cliente1@cliente1:~$ ping -c 4 172.22.0.80
ping: connect: Network is unreachable
cliente1@cliente1:~$ ping -c 4 172.22.0.50
ping: connect: Network is unreachable
cliente1@cliente1:~$ _
```

Desde **server:**

```
server@server:~$ ping -c 4 172.22.0.50
PING 172.22.0.50 (172.22.0.50) 56(84) bytes of data.
64 bytes from 172.22.0.50: icmp_seq=1 ttl=64 time=0.635 ms
64 bytes from 172.22.0.50: icmp_seq=2 ttl=64 time=0.467 ms
64 bytes from 172.22.0.50: icmp_seq=3 ttl=64 time=0.510 ms
64 bytes from 172.22.0.50: icmp_seq=4 ttl=64 time=0.599 ms

--- 172.22.0.50 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3066ms
rtt min/avg/max/mdev = 0.467/0.552/0.635/0.067 ms
server@server:~$ ping -c 4 172.22.0.10
PING 172.22.0.10 (172.22.0.10) 56(84) bytes of data.
64 bytes from 172.22.0.10: icmp_seq=1 ttl=64 time=0.809 ms
64 bytes from 172.22.0.10: icmp_seq=2 ttl=64 time=0.557 ms
64 bytes from 172.22.0.10: icmp_seq=3 ttl=64 time=0.533 ms
64 bytes from 172.22.0.10: icmp_seq=4 ttl=64 time=0.543 ms

--- 172.22.0.10 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3081ms
rtt min/avg/max/mdev = 0.533/0.610/0.809/0.114 ms
server@server:~$ ping -c 4 40.40.40.10
PING 40.40.40.10 (40.40.40.10) 56(84) bytes of data.
64 bytes from 40.40.40.10: icmp_seq=1 ttl=64 time=0.756 ms
64 bytes from 40.40.40.10: icmp_seq=2 ttl=64 time=0.540 ms
64 bytes from 40.40.40.10: icmp_seq=3 ttl=64 time=0.621 ms
64 bytes from 40.40.40.10: icmp_seq=4 ttl=64 time=0.656 ms

--- 40.40.40.10 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3110ms
rtt min/avg/max/mdev = 0.540/0.643/0.756/0.077 ms
server@server:~$ ping -c 4 40.40.40.30
PING 40.40.40.30 (40.40.40.30) 56(84) bytes of data.
^C
--- 40.40.40.30 ping statistics ---
3 packets transmitted, 0 received, 100% packet loss, time 2027ms
```

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2. Crear CA y configurar valores DH y claves/certificados del servidor y cliente:

Para la creación de la CA, certificados y claves nos vamos al servidor y ejecutamos los siguientes comandos:

1. cd ~
2. /usr/share/easy-rsa/easyrsa init-pki
3. /usr/share/easy-rsa/easyrsa build-ca
4. /usr/share/easy-rsa/easyrsa gen-dh

Con esto generamos tres ficheros importantes:

- ca.crt: certificado raíz de la CA (se comparte con todos)
- ca.key: clave privada de la CA (se guarda en la CA)
- dh.pem: claves Diffie-Hellmann para el intercambio de claves seguro

Creamos certificados para el servidor, cliente PC1 y la lista de certificados revocados:

1. /usr/share/easy-rsa/easyrsa build-server-full servidor nopass
2. /usr/share/easy-rsa/easyrsa build-client-full cliente-01 nopass
3. /usr/share/easy-rsa/easyrsa gen-crl

Opcionalmente, se puede generar una clave compartida para aumentar la seguridad, yo no lo he hecho:

- openvpn --genkey secret ta.key

Luego, movemos los certificados correspondientes donde les corresponde usando la siguiente lógica:

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| Archivo | Contenido | Utilizado por | Secreto |
|----------------|---------------------------|--------------------------------------|---------|
| ca.key | Clave privada de la CA | Equipo de generación de certificados | Si |
| ca.crt | Certificado raíz de la CA | servidor y todos los clientes | No |
| dh.pem | Parámetros Diffie Hellman | Servidor | No |
| crl.pem | Certificados revocados | Servidor | No |
| servidor.crt | Certificado del servidor | Servidor | No |
| servidor.key | Clave priv. del servidor | Servidor | Si |
| cliente-01.crt | Certificado de cliente1 | Cliente1 | No |
| cliente-01.key | Clave priv. de Cliente1 | Cliente1 | Si |

Para transferir los certificados y claves de manera segura usaremos **SCP**:

Archivos que corresponden a PC1, para ello ejecutar los siguientes comandos:

- scp /usr/share/easy-rsa/pki/issued/cliente-01.crt cliente1@40.40.40.30:/home/cliente1/
- scp /usr/share/easy-rsa/pki/private/cliente-01.key cliente1@40.40.40.30:/home/cliente1/
- scp /usr/share/easy-rsa/pki/ca.crt cliente1@40.40.40.30:/home/cliente1/

Luego, dentro del servidor creamos el siguiente directorio:

sudo mkdir -p /etc/openvpn/pki y copiamos cada certificado y llave relacionado con el servidor al nuevo directorio **pki**.

-
- sudo cp ~/easy-rsa/pki/ca.crt /etc/openvpn/pki/
 - sudo cp ~/easy-rsa/pki/issued/servidor.crt /etc/openvpn/pki/
 - sudo cp ~/easy-rsa/pki/private/servidor.key /etc/openvpn/pki/
 - sudo cp ~/easy-rsa/pki/dh.pem /etc/openvpn/pki/
 - sudo cp ~/easy-rsa/pki/crl.pem /etc/openvpn/pki/

```
server@server:/etc/openvpn$ ls pki/
ca.crt  crl.pem  dh.pem  servidor.crt  servidor.key
```

Con esto concluimos el apartado 2.

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3) Configurar el servidor VPN en modo TUN, configurar su arranque automático y su servicio. Habilitar la función de forwarding en el servidor.

Antes de realizar la configuración del servidor en modo TUN, vamos a crear un directorio donde guardaremos todos los archivos esenciales para el openvpn-server. Por tanto, dentro del directorio (/etc/openvpn) creamos un directorio **server**:

```
~ver:~$ ls /etc/openvpn/  
ci server update-resolv-conf
```

Dentro del directorio server creamos un fichero llamado **server.conf** en el que configuraremos el lado del servidor para openvpn tal que así:

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```
# Puerto donde se activa el servicio openvpn:  
port 1194  
  
# Protocolo que se usará para la comunicación  
proto udp  
  
# Modo de configuración de la VPN (TUN /TAP)  
dev tun  
  
# Rutas para encontrar los certificados del servidor:  
ca /etc/openvpn/pki/ca.crt  
cert /etc/openvpn/pki/servidor.crt  
key /etc/openvpn/pki/servidor.key  
dh /etc/openvpn/pki/dh.pem  
crl-verify /etc/openvpn/pki/crl.pem  
  
# Red que OpenVpn usará para asignar IPs a los clientes:  
server 172.16.0.0 255.255.255.0  
  
# Fichero donde se guardan las IPs asociadas a clientes que ya se conectaron  
ifconfig-pool-persist ipp.txt  
  
# Anunciar/mostrar a los clientes la red interna real detrás del servidor VPN (LAN 172.22.0.0/24)  
push "route 172.22.0.0 255.255.255.0"  
  
# Configuración de sesión:  
  
# manda un ping cada 10 segundos, cierra la sesión si tras 120 seg no hay respuesta  
keepalive 10 120  
  
# Clave TLS para proteger contra escaneos y ataques Dos:  
#tls-auth /etc/openvpn/server/ta.key 0  
  
# Algoritmo de cifrado simétrico usado en el tunel:  
data-ciphers AES-256-CBC  
  
# Mantener claves y tunel si el servicio se reinicia:  
persist-key  
persist-tun  
  
~
```

Activamos también el modo forward en el servidor, arrancar el servicio y dejarlo en enable para que se encienda solo cada vez que se encienda la máquina:

```
# Uncomment the next line to  
net.ipv4.ip_forward=1
```

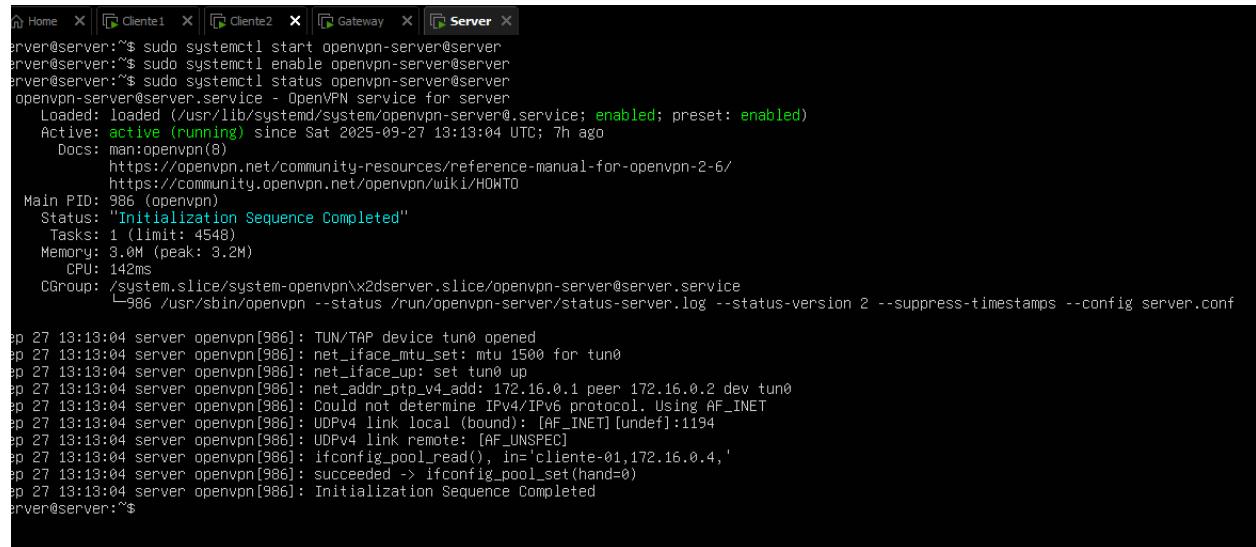
y guardar los cambios con sudo sysctl -p

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```
display all the possibilities (y or n)
server@server:~$ sudo cat /proc/sys/net/ipv4/ip_forward
1
server@server:~$
```



The screenshot shows a terminal window with several tabs at the top: Home, Cliente1, Cliente2, Gateway, and Server. The Server tab is active. The terminal output shows the following:

```
server@server:~$ sudo systemctl start openvpn-server@server
server@server:~$ sudo systemctl enable openvpn-server@server
server@server:~$ sudo systemctl status openvpn-server@server
openvpn-server@server.service - OpenVPN service for server
  Loaded: loaded (/usr/lib/systemd/system/openvpn-server@.service; enabled; preset: enabled)
  Active: active (running) since Sat 2025-09-27 13:13:04 UTC; 7h ago
    Docs: man:openvpn(8)
          https://openvpn.net/community-resources/reference-manual-for-openvpn-2-6/
          https://community.openvpn.net/openvpn/wiki/HOWTO
  Main PID: 986 (openvpn)
    Status: "Initialization Sequence Completed"
      Tasks: 1 (limit: 4548)
     Memory: 3.0M (peak: 3.2M)
        CPU: 142ms
       CGroup: /system.slice/system-openvpn\x2dserver.slice/openvpn-server@server.service
               └─986 /usr/sbin/openvpn --status /run/openvpn/server/status-server.log --status-version 2 --suppress-timestamps --config server.conf

sep 27 13:13:04 server openvpn[986]: TUN/TAP device tun0 opened
sep 27 13:13:04 server openvpn[986]: net_iface_mtu_set: mtu 1500 for tun0
sep 27 13:13:04 server openvpn[986]: net_iface_up: set tun0 up
sep 27 13:13:04 server openvpn[986]: net_addr_ptp_v4_add: 172.16.0.1 peer 172.16.0.2 dev tun0
sep 27 13:13:04 server openvpn[986]: Could not determine IPv4/IPv6 protocol. Using AF_INET
sep 27 13:13:04 server openvpn[986]: UDPv4 link local (bound): [AF_INET][undef]:1194
sep 27 13:13:04 server openvpn[986]: UDPv4 link remote: ([AF_UNSPEC])
sep 27 13:13:04 server openvpn[986]: ifconfig_pool_read(), in='cliente-01.172.16.0.4.'
sep 27 13:13:04 server openvpn[986]: succeeded -> ifconfig_pool_set(hand=0)
sep 27 13:13:04 server openvpn[986]: Initialization Sequence Completed
server@server:~$
```

4. Configurar en el Gateway un port-forwarding para reenviar al servidor interno todo el tráfico recibido en el puerto udp/1194 de su interface externo (es necesaria una regla iptables nat en PREROUTING).

En el gateway:

```
gateway@gateway:~$ sudo iptables -t nat -A PREROUTING -p udp --dport 1194 -i ens33 -j DNAT --to-destination 172.22.0.80:1194
gateway@gateway:~$
```

5. Configurar en el Gateway el enmascaramiento para todo el tráfico saliente Comprobar que siguen pudiendo alcanzarse recursos externos desde la red interna (PC2 a PC1). Verificar que se realiza el enmascaramiento usando tcpdump.



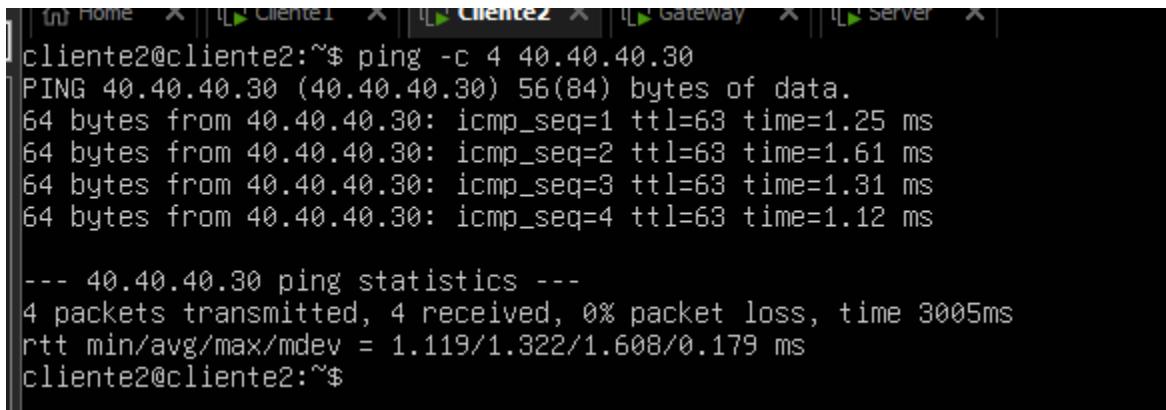
The screenshot shows a terminal window with several tabs at the top: Home, Cliente1, Cliente2, Gateway, and Server. The Gateway tab is active. The terminal output shows the following:

```
gateway@gateway:~$ sudo iptables -t nat -A POSTROUTING -o ens33 -j MASQUERADE
```

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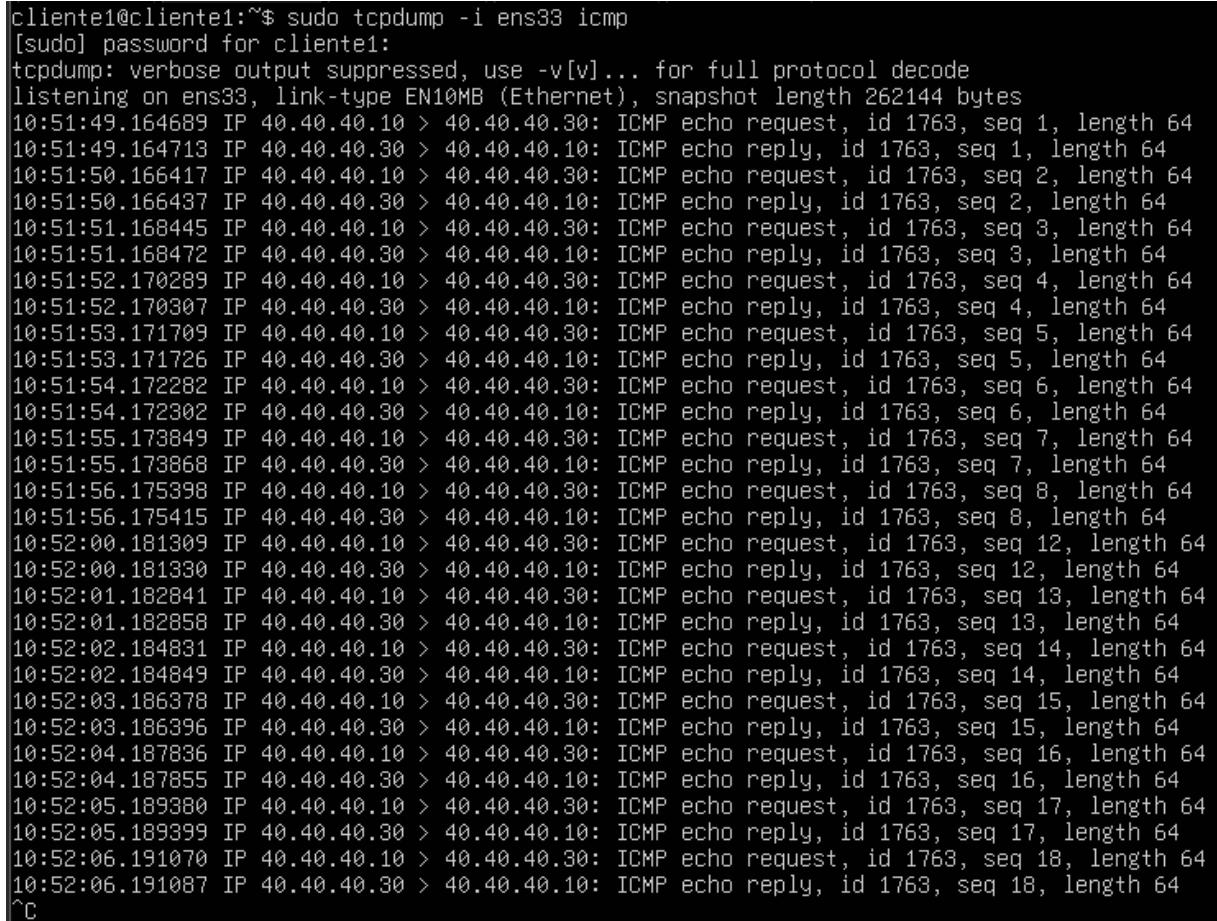
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```
cliente2@cliente2:~$ ping -c 4 40.40.40.30
PING 40.40.40.30 (40.40.40.30) 56(84) bytes of data.
64 bytes from 40.40.40.30: icmp_seq=1 ttl=63 time=1.25 ms
64 bytes from 40.40.40.30: icmp_seq=2 ttl=63 time=1.61 ms
64 bytes from 40.40.40.30: icmp_seq=3 ttl=63 time=1.31 ms
64 bytes from 40.40.40.30: icmp_seq=4 ttl=63 time=1.12 ms

--- 40.40.40.30 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3005ms
rtt min/avg/max/mdev = 1.119/1.322/1.608/0.179 ms
cliente2@cliente2:~$
```

Enmascaramiento correcto en PC1:



```
cliente1@cliente1:~$ sudo tcpdump -i ens33 icmp
[sudo] password for cliente1:
tcpdump: verbose output suppressed, use -v[v]... for full protocol decode
listening on ens33, link-type EN10MB (Ethernet), snapshot length 262144 bytes
10:51:49.164689 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 1, length 64
10:51:49.164713 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 1, length 64
10:51:50.166417 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 2, length 64
10:51:50.166437 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 2, length 64
10:51:51.168445 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 3, length 64
10:51:51.168472 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 3, length 64
10:51:52.170289 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 4, length 64
10:51:52.170307 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 4, length 64
10:51:53.171709 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 5, length 64
10:51:53.171726 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 5, length 64
10:51:54.172282 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 6, length 64
10:51:54.172302 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 6, length 64
10:51:55.173849 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 7, length 64
10:51:55.173868 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 7, length 64
10:51:56.175398 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 8, length 64
10:51:56.175415 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 8, length 64
10:52:00.181309 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 12, length 64
10:52:00.181330 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 12, length 64
10:52:01.182841 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 13, length 64
10:52:01.182858 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 13, length 64
10:52:02.184831 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 14, length 64
10:52:02.184849 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 14, length 64
10:52:03.186378 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 15, length 64
10:52:03.186396 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 15, length 64
10:52:04.187836 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 16, length 64
10:52:04.187855 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 16, length 64
10:52:05.189380 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 17, length 64
10:52:05.189399 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 17, length 64
10:52:06.191070 IP 40.40.40.10 > 40.40.40.30: ICMP echo request, id 1763, seq 18, length 64
10:52:06.191087 IP 40.40.40.30 > 40.40.40.10: ICMP echo reply, id 1763, seq 18, length 64
^C
```

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6 . Configurar el cliente OpenVPN en PC1 (client.conf) para conectar al servidor (a través de la IP del Gateway). Para completar esta tarea será necesario copiar los archivos necesarios obtenidos en el apartado 2.

```
cliente1@cliente1:~$ ls /etc/openvpn
client  server  update-resolv-conf
cliente1@cliente1:~$ ls /etc/openvpn/server/
cliente1@cliente1:~$ ls /etc/openvpn/client
ca.crt  client.conf  cliente-01.crt  cliente-01.key
cliente1@cliente1:~$ _
```

Copiar las claves y certificados al directorio de cliente1 como se muestra en la captura de arriba. Luego, crear un fichero de configuración en el directorio (**/etc/openvpn/client**)

Y añadir la siguiente configuración:

```
# Dirección y puerto del servidor VPN:
client
dev tun
proto udp

# IP externa del gateway
remote 40.40.40.10 1194

# Certificados y claves:
ca /etc/openvpn/client/ca.crt
cert /etc/openvpn/client/cliente-01.crt
key /etc/openvpn/client/cliente-01.key

# Si se usa un HMAC para protección TLS:
#remote-cert-tls server
# tls-auth ta.key 1

# Algoritmo de cifrado:
data-ciphers AES-256-CBC

# Mantener la conexión:
resolv-retry infinite
persist-key
persist-tun
```

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7. Iniciar el cliente y comprobar que se conecta al servidor. Verificar la configuración que se establece en el interface virtual tun del cliente, su tabla de encaminamiento y que es posible alcanzar desde PC1 los recursos ofrecidos por el Servidor a través de la VPN (puede hacer una captura del tráfico intercambiado para verificar que los paquetes se transportan sobre tun0, que a su vez se envía encriptado sobre eth0). Desactivar el router por defecto en PC1 y comprobar que sigue siendo posible acceder al Servidor.

Iniciamos el cliente:

```
cliente1@cliente1:~$ sudo systemctl start openvpn-client@client
cliente1@cliente1:~$ sudo systemctl status openvpn-client@client
● openvpn-client@client.service - OpenVPN tunnel for client
   Loaded: loaded (/usr/lib/systemd/system/openvpn-client@.service; enabled; preset: enabled)
   Active: active (running) since Sun 2025-09-28 10:59:59 UTC; 36s ago
     Docs: man:openvpn(8)
           https://openvpn.net/community-resources/reference-manual-for-openvpn-2-6/
           https://community.openvpn.net/openvpn/wiki/HOWTO
   Main PID: 1802 (openvpn)
      Status: "Initialization Sequence Completed"
        Tasks: 1 (limit: 7564)
       Memory: 2.8M (peak: 3.1M)
         CPU: 31ms
        CGroup: /system.slice/system-openvpn\x2dclient.slice/openvpn-client@client.service
                  └─1802 /usr/sbin/openvpn --suppress-timestamps --nobind --config client.conf

sep 28 10:59:59 cliente1 systemd[1]: Started openvpn-client@client.service - OpenVPN tunnel for
sep 28 10:59:59 cliente1 openvpn[1802]: TCP/UDP: Preserving recently used remote address: [AF_]
sep 28 10:59:59 cliente1 openvpn[1802]: UDPv4 link local: (not bound)
sep 28 10:59:59 cliente1 openvpn[1802]: UDPv4 link remote: [AF_INET]40.40.40.10:1194
sep 28 10:59:59 cliente1 openvpn[1802]: [servidor] Peer Connection Initiated with [AF_INET]40.4
sep 28 10:59:59 cliente1 openvpn[1802]: TUN/TAP device tun0 opened
sep 28 10:59:59 cliente1 openvpn[1802]: net_iface_mtu_set: mtu 1500 for tun0
sep 28 10:59:59 cliente1 openvpn[1802]: net_iface_up: set tun0 up
sep 28 10:59:59 cliente1 openvpn[1802]: net_addr_ptp_v4_add: 172.16.0.6 peer 172.16.0.5 dev tun0
sep 28 10:59:59 cliente1 openvpn[1802]: Initialization Sequence Completed
cliente1@cliente1:~$ s
```

Verificar configuración interfaz virtual:

```
cliente1@cliente1:~$ ip addr show tun0
3: tun0: <POINTOPOINT,MULTICAST,NOARP,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UNKNOWN group default qlen 500
  link/none
    inet 172.16.0.6 peer 172.16.0.5/32 scope global tun0
      valid_lft forever preferred_lft forever
    inet6 fe80::8f52:dfef:2bff:6760/64 scope link stable-privacy
      valid_lft forever preferred_lft forever
cliente1@cliente1:~$
```

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Verificar tabla de encaminamiento:

```
cliente1@cliente1:~$ ip route
40.40.40.0/24 dev ens33 proto kernel scope link src 40.40.40.30
172.16.0.1 via 172.16.0.5 dev tun0
172.16.0.5 dev tun0 proto kernel scope link src 172.16.0.6
172.22.0.0/24 via 172.16.0.5 dev tun0
cliente1@cliente1:~$
```

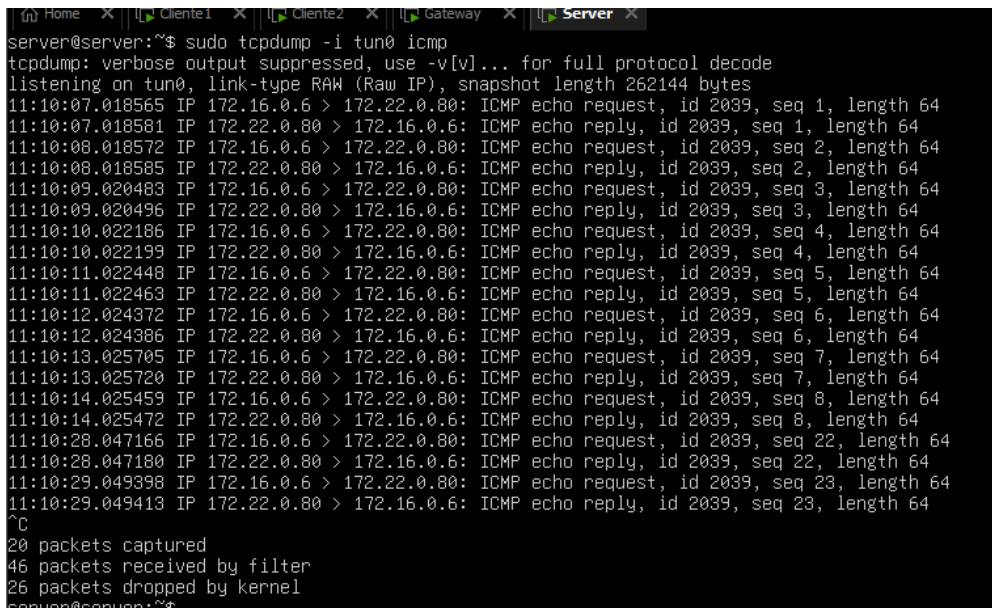
Alcanzando recursos red privada desde PC1 (PC1 – Server):

```
Home  X  Cliente1  X  Cliente2  X  Gateway  X  Server  X
cliente1@cliente1:~$ ping 172.22.0.80
PING 172.22.0.80 (172.22.0.80) 56(84) bytes of data.
64 bytes from 172.22.0.80: icmp_seq=1 ttl=64 time=1.79 ms
64 bytes from 172.22.0.80: icmp_seq=2 ttl=64 time=2.07 ms
64 bytes from 172.22.0.80: icmp_seq=3 ttl=64 time=2.12 ms
64 bytes from 172.22.0.80: icmp_seq=4 ttl=64 time=2.02 ms
64 bytes from 172.22.0.80: icmp_seq=5 ttl=64 time=1.89 ms
64 bytes from 172.22.0.80: icmp_seq=6 ttl=64 time=1.59 ms
64 bytes from 172.22.0.80: icmp_seq=7 ttl=64 time=1.68 ms
64 bytes from 172.22.0.80: icmp_seq=8 ttl=64 time=1.99 ms
64 bytes from 172.22.0.80: icmp_seq=9 ttl=64 time=1.58 ms
64 bytes from 172.22.0.80: icmp_seq=10 ttl=64 time=1.50 ms
64 bytes from 172.22.0.80: icmp_seq=11 ttl=64 time=1.53 ms
64 bytes from 172.22.0.80: icmp_seq=12 ttl=64 time=1.74 ms
64 bytes from 172.22.0.80: icmp_seq=13 ttl=64 time=1.63 ms
64 bytes from 172.22.0.80: icmp_seq=14 ttl=64 time=1.60 ms
64 bytes from 172.22.0.80: icmp_seq=15 ttl=64 time=1.78 ms
64 bytes from 172.22.0.80: icmp_seq=16 ttl=64 time=1.68 ms
64 bytes from 172.22.0.80: icmp_seq=17 ttl=64 time=1.60 ms
64 bytes from 172.22.0.80: icmp_seq=18 ttl=64 time=1.72 ms
64 bytes from 172.22.0.80: icmp_seq=19 ttl=64 time=1.82 ms
64 bytes from 172.22.0.80: icmp_seq=20 ttl=64 time=1.68 ms
64 bytes from 172.22.0.80: icmp_seq=21 ttl=64 time=1.62 ms
64 bytes from 172.22.0.80: icmp_seq=22 ttl=64 time=1.69 ms
64 bytes from 172.22.0.80: icmp_seq=23 ttl=64 time=1.79 ms
64 bytes from 172.22.0.80: icmp_seq=24 ttl=64 time=1.76 ms
^C
--- 172.22.0.80 ping statistics ---
24 packets transmitted, 24 received, 0% packet loss, time 23031ms
rtt min/avg/max/mdev = 1.495/1.744/2.124/0.165 ms
cliente1@cliente1:~$ _
```

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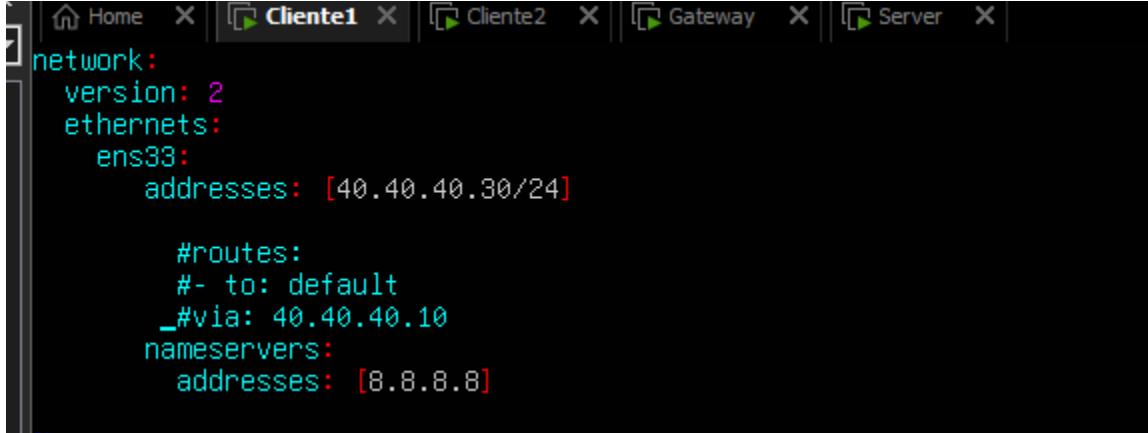
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```
server@server:~$ sudo tcpdump -i tun0 icmp
tcpdump: verbose output suppressed, use -v[v]... for full protocol decode
listening on tun0, link-type RAW (Raw IP), snapshot length 262144 bytes
11:10:07.018565 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 1, length 64
11:10:07.018581 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 1, length 64
11:10:08.018572 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 2, length 64
11:10:08.018585 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 2, length 64
11:10:09.020483 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 3, length 64
11:10:09.020496 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 3, length 64
11:10:10.022186 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 4, length 64
11:10:10.022199 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 4, length 64
11:10:11.022448 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 5, length 64
11:10:11.022463 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 5, length 64
11:10:12.024372 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 6, length 64
11:10:12.024386 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 6, length 64
11:10:13.025705 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 7, length 64
11:10:13.025720 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 7, length 64
11:10:14.025459 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 8, length 64
11:10:14.025472 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 8, length 64
11:10:28.047166 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 22, length 64
11:10:28.047180 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 22, length 64
11:10:29.049398 IP 172.16.0.6 > 172.22.0.80: ICMP echo request, id 2039, seq 23, length 64
11:10:29.049413 IP 172.22.0.80 > 172.16.0.6: ICMP echo reply, id 2039, seq 23, length 64
^C
20 packets captured
46 packets received by filter
26 packets dropped by kernel
benyam@benyam:~$
```

Desde el comienzo de la práctica tenemos el router por defecto desactivado en PC1:



```
network:
  version: 2
  ethernets:
    ens38:
      addresses: [40.40.40.30/24]

      #routes:
      #- to: default
      #via: 40.40.40.10
      nameservers:
        addresses: [8.8.8.8]
```

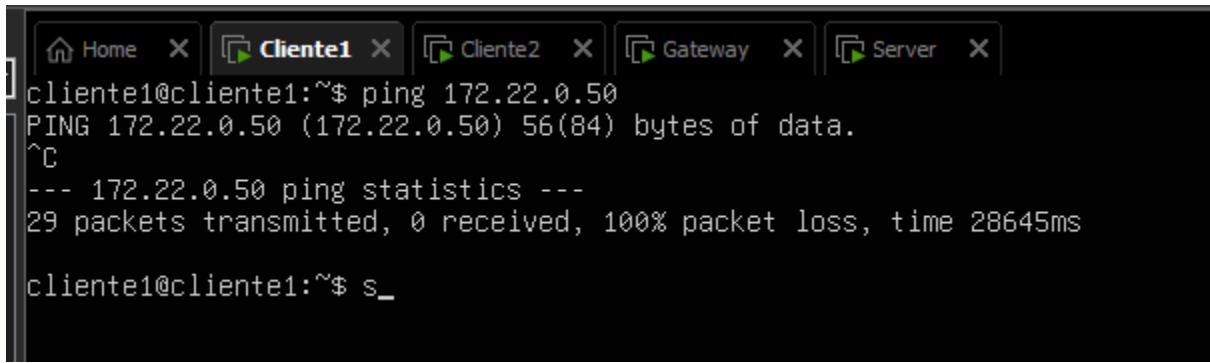
8. Compruebe si es posible alcanzar el equipo PC2 desde PC1 a través de la conexión VPN. ¿Qué está sucediendo?

Cuando se hace un ping desde PC1 – PC2 se puede ver claramente que no se obtiene una respuesta:

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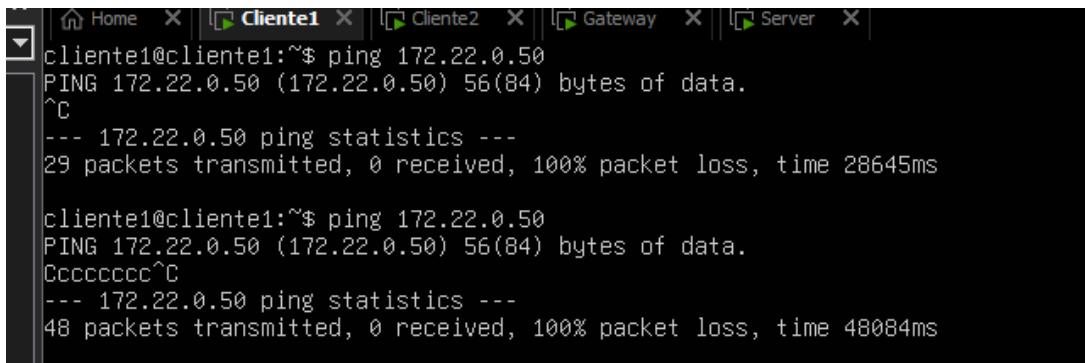


A screenshot of a terminal window titled "Cliente1". The window contains the following text:

```
cliente1@cliente1:~$ ping 172.22.0.50
PING 172.22.0.50 (172.22.0.50) 56(84) bytes of data.
^C
--- 172.22.0.50 ping statistics ---
29 packets transmitted, 0 received, 100% packet loss, time 28645ms

cliente1@cliente1:~$ s_
```

Esto NO es porque PC1 no llegue al PC2 a través de la conexión VPN, sino más bien que PC2 no sabe como llegar a PC1 y por tanto no hay respuesta. Eso se puede contrastar con lo siguiente:



A screenshot of a terminal window titled "Cliente1". The window contains the following text:

```
cliente1@cliente1:~$ ping 172.22.0.50
PING 172.22.0.50 (172.22.0.50) 56(84) bytes of data.
^C
--- 172.22.0.50 ping statistics ---
29 packets transmitted, 0 received, 100% packet loss, time 28645ms

cliente1@cliente1:~$ ping 172.22.0.50
PING 172.22.0.50 (172.22.0.50) 56(84) bytes of data.
Cccccccc^C
--- 172.22.0.50 ping statistics ---
48 packets transmitted, 0 received, 100% packet loss, time 48084ms
```

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```
cliente2@cliente2:~$ sudo tcpdump -i ens33 icmp
[sudo] password for cliente2:
tcpdump: verbose output suppressed, use -v[v]... for full protocol decode
listening on ens33, link-type EN10MB (Ethernet), snapshot length 262144 bytes
11:24:40.515628 IP 172.22.0.10 > 172.22.0.80: ICMP net 8.8.8.8 unreachable, length 68
11:24:40.515628 IP 172.22.0.10 > 172.22.0.80: ICMP net 8.8.8.8 unreachable, length 68
11:24:44.540377 IP 172.22.0.10 > 172.22.0.50: ICMP net 8.8.8.8 unreachable, length 68
11:24:47.225257 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 1, length 64
11:24:47.225273 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 1, length 64
11:24:47.225778 IP 172.22.0.10 > 172.22.0.50: ICMP net 172.16.0.6 unreachable, length 92
11:24:47.662247 IP 172.22.0.10 > 172.22.0.80: ICMP net 8.8.8.8 unreachable, length 68
11:24:48.228512 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 2, length 64
11:24:48.228528 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 2, length 64
11:24:48.229028 IP 172.22.0.10 > 172.22.0.50: ICMP net 172.16.0.6 unreachable, length 92
11:24:49.229419 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 3, length 64
11:24:49.229435 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 3, length 64
11:24:50.276153 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 4, length 64
11:24:50.276171 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 4, length 64
11:24:51.300238 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 5, length 64
11:24:51.300298 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 5, length 64
11:25:10.732191 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 24, length 64
11:25:10.732208 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 24, length 64
11:25:20.996227 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 34, length 64
11:25:20.996242 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 34, length 64
11:25:31.236471 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 44, length 64
11:25:31.236487 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 44, length 64
11:25:32.238151 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 45, length 64
11:25:32.238168 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 45, length 64
11:25:33.284140 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 46, length 64
11:25:33.284157 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 46, length 64
11:25:33.765892 IP 172.22.0.10 > 172.22.0.80: ICMP net 8.8.8.8 unreachable, length 68
11:25:33.765892 IP 172.22.0.10 > 172.22.0.80: ICMP net 8.8.8.8 unreachable, length 68
11:25:34.3008702 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 47, length 64
11:25:34.3008722 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 47, length 64
11:25:35.3009397 IP 172.16.0.6 > 172.22.0.50: ICMP echo request, id 2089, seq 48, length 64
11:25:35.3009412 IP 172.22.0.50 > 172.16.0.6: ICMP echo reply, id 2089, seq 48, length 64
11:25:40.974374 IP 172.22.0.10 > 172.22.0.80: ICMP net 8.8.8.8 unreachable, length 68
11:25:42.908724 IP 172.22.0.10 > 172.22.0.50: ICMP net 8.8.8.8 unreachable, length 68
^C
34 packets captured
```

9. Modificar la configuración de PC2 para que pueda comunicar con PC1 a través de la VPN. Nota: también es posible configurar el Gateway para el retorno de los paquetes a través de la VPN, sin modificar el encaminamiento en PC2. Compruebe ambas opciones.

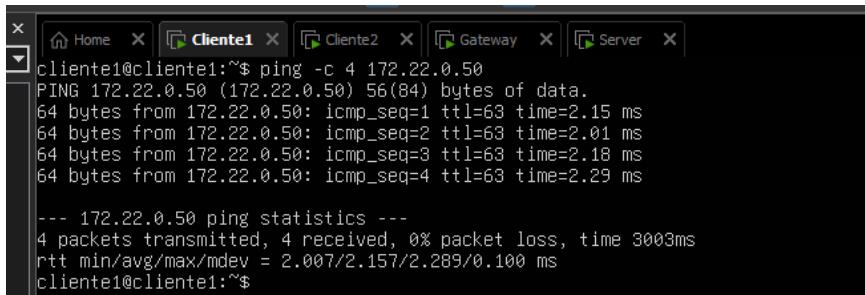
Lo que podemos hacer para PC2 es ponerle una ruta estática para que reenvíe el tráfico hacia la conexión VPN redirigiéndolo hacia el servidor:

```
Home Cliente1 Cliente2 Gateway Server
cliente2@cliente2:~$ sudo ip route add 172.16.0.0/24 via 172.22.0.80
cli Home cliente2:~$
```

O también se puede hacer poniendo una ruta en el Gateway (más cómodo si hay mas dispositivos en la red y no se quiere tener que configurar todos, o no los quieres tocar)

```
Last login: Sun Sep 28 10:50:46 2025 from 172.22.0.1
root@GW:~# sudo ip route add 172.16.0.0/24 via 172.22.0.80 dev eth0
```

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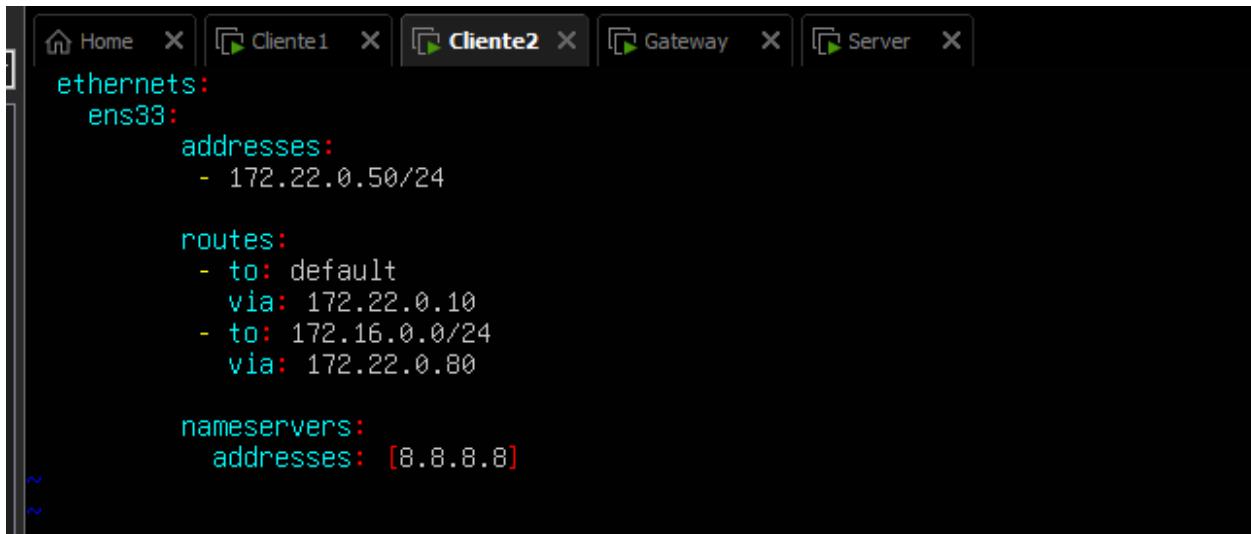


A screenshot of a terminal window titled "Cliente1". The terminal shows the output of a ping command to an IP address. The output includes four successful ICMP echo requests and their round-trip times, followed by statistics showing 4 packets transmitted, 4 received, 0% packet loss, and an average round-trip time of 2.15 ms.

```
cliente1@cliente1:~$ ping -c 4 172.22.0.50
PING 172.22.0.50 (172.22.0.50) 56(84) bytes of data.
64 bytes from 172.22.0.50: icmp_seq=1 ttl=63 time=2.15 ms
64 bytes from 172.22.0.50: icmp_seq=2 ttl=63 time=2.01 ms
64 bytes from 172.22.0.50: icmp_seq=3 ttl=63 time=2.18 ms
64 bytes from 172.22.0.50: icmp_seq=4 ttl=63 time=2.29 ms

--- 172.22.0.50 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3003ms
rtt min/avg/max/mdev = 2.007/2.157/2.289/0.100 ms
cliente1@cliente1:~$
```

Ahora sí que funciona, pero esta solución no es persistente, por tanto:



A screenshot of a terminal window titled "Cliente2". It displays a netplan configuration file. The configuration includes an interface "ens33" with an IP address of 172.22.0.50/24, a default route via 172.22.0.10, a route to 172.16.0.0/24 via 172.22.0.80, and nameservers set to 8.8.8.8.

```
ethernets:
  ens33:
    addresses:
      - 172.22.0.50/24
    routes:
      - to: default
        via: 172.22.0.10
      - to: 172.16.0.0/24
        via: 172.22.0.80
    nameservers:
      addresses: [8.8.8.8]
```

Añadimos la ruta estática a (**etc/netplan/50-cloud-init.yml**) y aplicamos los cambios netplan apply para que sea persistente.

También podríamos añadir la ruta estática en el gateway (temporal) o configurar la misma ruta estática en el propio netplan del gateway que es lo que vamos a realizar:

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```
network:
  version: 2
  ethernets:
    ens33:
      addresses:
        - 40.40.40.10/24

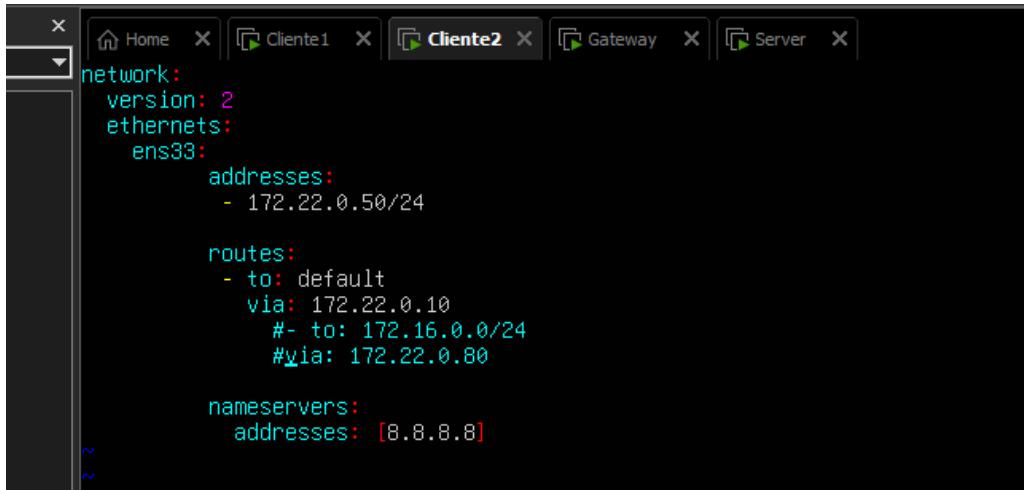
    ens37:
      addresses:
        - 172.22.0.10/24
  # Añadimos aquí la ruta estática en el gateway
  routes:
    - to: 172.16.0.0/24
      via: 172.22.0.80

  nameservers:
    addresses: [8.8.8.8]
```

(Utilizar netplan apply para guardar la configuración)

Ahora comprobamos que funcione, para ello eliminamos la ruta estática temporal y comentamos aquella configurada de forma persistente en el PC2:

```
cliente2@cliente2:~$ sudo ip route delete 172.16.0.0/24 via 172.22.0.80
cliente2@cliente2:~$ ip route
default via 172.22.0.10 dev ens33 proto static
172.22.0.0/24 dev ens33 proto kernel scope link src 172.22.0.50
cliente2@cliente2:~$ _
```



```
network:
  version: 2
  ethernets:
    ens33:
      addresses:
        - 172.22.0.50/24

      routes:
        - to: default
          via: 172.22.0.10
          #- to: 172.16.0.0/24
          #via: 172.22.0.80

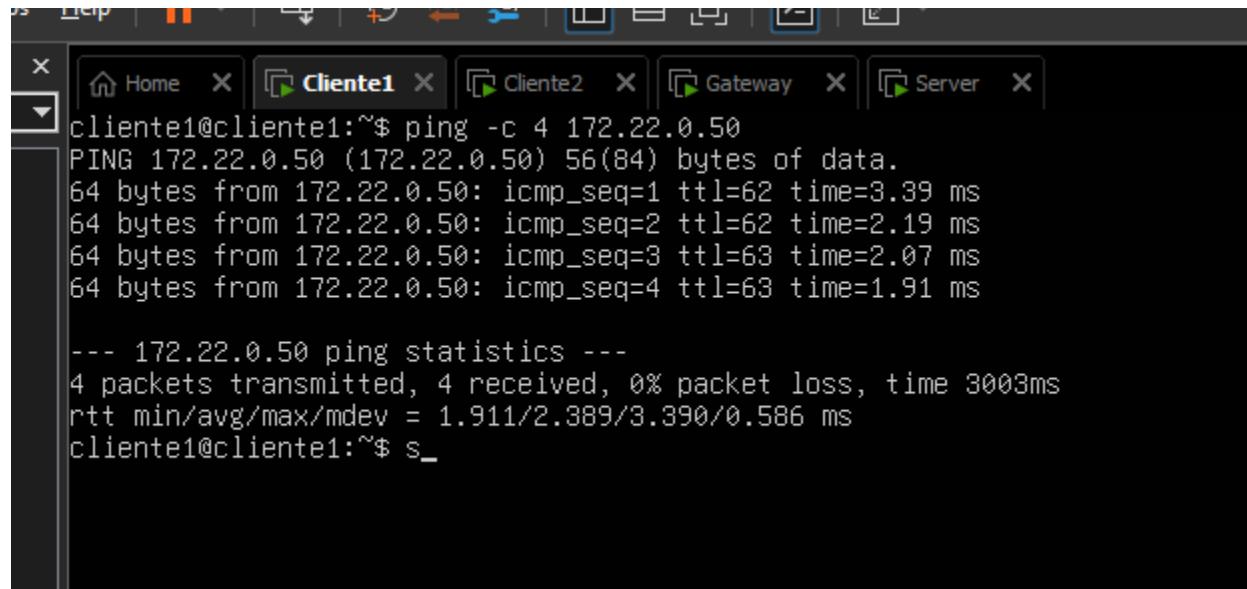
  nameservers:
    addresses: [8.8.8.8]
```

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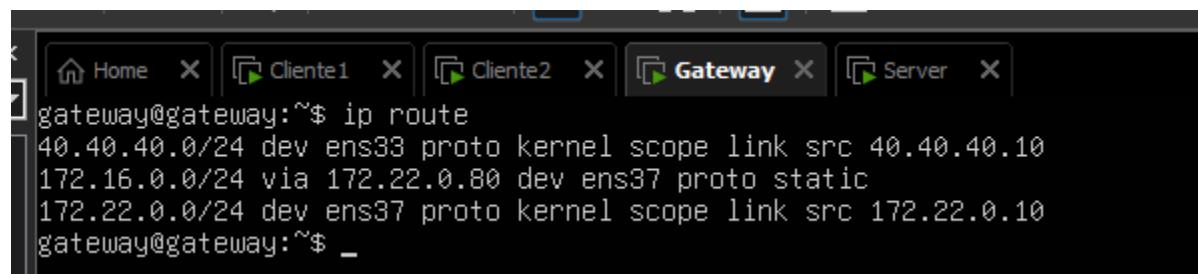
Comprobamos que funcione:



```
cliente1@cliente1:~$ ping -c 4 172.22.0.50
PING 172.22.0.50 (172.22.0.50) 56(84) bytes of data.
64 bytes from 172.22.0.50: icmp_seq=1 ttl=62 time=3.39 ms
64 bytes from 172.22.0.50: icmp_seq=2 ttl=62 time=2.19 ms
64 bytes from 172.22.0.50: icmp_seq=3 ttl=63 time=2.07 ms
64 bytes from 172.22.0.50: icmp_seq=4 ttl=63 time=1.91 ms

--- 172.22.0.50 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3003ms
rtt min/avg/max/mdev = 1.911/2.389/3.390/0.586 ms
cliente1@cliente1:~$ _
```

Tabla de encaminamiento para confirmarlo



```
gateway@gateway:~$ ip route
40.40.40.0/24 dev ens33 proto kernel scope link src 40.40.40.10
172.16.0.0/24 via 172.22.0.80 dev ens37 proto static
172.22.0.0/24 dev ens37 proto kernel scope link src 172.22.0.10
gateway@gateway:~$ _
```

Para hacer persistentes las reglas NAT (gateway):

- Persistencia de las reglas (iptables-save e iptables-restore)
Salvamos las reglas en un archivo de configuración

```
iptables-save > /etc/iptables-rules
iptables-restore < /etc/iptables-rules
```