Systems Security
OpenVPN

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1. Introdution
   - What is OpenVPN
   - Install required software
2. Configure
   - Client to site
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Introduction

What is OpenVPN?

- is an open-source software application that implements Virtual Private Network (VPN);
- creates secure **client-to-site** or **site-to-site** connections in routed or bridged configurations and remote access facilities;
- it uses a custom security protocol that utilizes SSL/TLS for key exchange;
- it is capable of traversing network address translators (NATs) and firewalls (if properly configured);
- it is available for all major Operating Systems: Windows, MacOS, Linux, Android, iOS;

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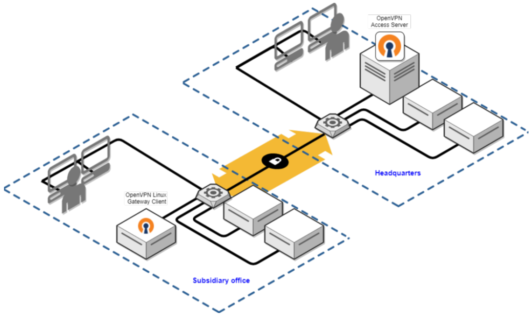
- it is available for all major Operating Systems: Windows, MacOS, Linux, Android, iOS;

Main disadvantage:

- lack of good GUI, most of the configuration must be done in the command line and configuration files;
  - but there are compatible alternatives (out of scope for this class): SoftEther

Authentication Methods



OpenVPN has several ways to authenticate peers with each other:

- **pre-shared keys** – the easiest setup, but also the less secure;
- **username / password** – can be enabled, both with or without certificates;
- **digital certificates** – the most robust solution and feature-rich;

Setup test scenario

Recommended setup to test OpenVPN with the instructions available on the next slides:

1. **server** – setup a virtual machine with Ubuntu 18.04: server
   - with 2 network interfaces, one "NAT" and the other as "Host Only";
2. **client** – setup a virtual machine with (k)ubuntu 18.04 desktop;
   - with 2 network interfaces, one "NAT" and the other as "Host Only";
   - later the "NAT" interface must be shutdown:
     - with only the "Host Only" interface this setup will prevent the virtual to have access to the Internet, but should be able to access it through the server after the VPN is properly setup;
     - shutdown "NAT" interface: `sudo ifdown enp3s0    # replace enp3s0 with the name of your NAT interface`
     - activate "NAT" interface: `sudo ifup enp3s0`
3. configure OpenVPN on both server and client virtual machines accordingly to these slides;

Server and Client – Install required software

Software requirements for Linux:

- **server and client: OpenSSL** – already installed in most Linux distributions;
- **server and client: OpenVPN** – install the latest stable version on both client and server. The instructions are for Ubuntu 18.04

```
sudo -i      # enter root mode

    # download and install GnuPG repository key
    wget -O - https://swupdate.openvpn.net/repos/repo-public.gpg|apt-key add -

    # add repository to the source lists
    echo "deb http://build.openvpn.net/debian/openvpn/release/2.4 bionic main" > /etc/apt/sources.list.d/openvpn-aptrepo.list

    # install OpenVPN
    apt update && apt install openvpn

exit         # exit root mode
```

  - **note**: on the **client** activate the client interface "NAT" temporarily to install the required software;

Generate digital certificates and secret key

Easy-RSA

- **server: Easy-RSA** – script to help setup the digital certificates, available here. No installation required just uncompress the downloaded file: `unzip EasyRSA-3.0.6.zip`
- create a copy of the sample configuration file

```
cd EasyRSA-3.0.6          # change directory
cp vars.example vars      # create a copy of the sample configuration file
```

- edit configuration file

```
nano vars                 # you may use your favorite editor (i.e. kate, gedit, vim)

    # Change the folloing parameters in the configuration file:
    set_var EASYRSA_REQ_COUNTRY     "PT"
    set_var EASYRSA_REQ_PROVINCE    "Leiria"
    set_var EASYRSA_REQ_CITY        "Leiria"
    set_var EASYRSA_REQ_ORG         "IPLeiria"
    set_var EASYRSA_REQ_EMAIL       "xxxx@ipleiria.pt"   # choose your email address
    set_var EASYRSA_REQ_OU          "Systems Security"

    set_var EASYRSA_ALGO            ec           # change to Elliptic Curve algorithm. Warning: not supported by all clients
    set_var EASYRSA_CURVE           secp521r1    # setup the curve name, to list all supported curves: openssl ecparam -list_curves
    set_var EASYRSA_DIGEST          "sha512"     # setup hash algorithm

    set_var EASYRSA_NS_SUPPORT       "yes"
```

Generate digital certificates and secret key

Easy-RSA

- generate digital certificates

```
./easyrsa init-pki                      # create PKI directories
./easyrsa build-ca                      # create CA key pair and self-signed certificate

# repeat for each server:
    ./easyrsa gen-req SERVER_x nopass       # create a key pair for server SERVERx
    ./easyrsa sign-req server SERVER_x      # sign public key of SERVERx and create the digital certificate
    ./easyrsa gen-dh                        # generate DH parameters for key exchange

# repeat for each client:
    ./easyrsa gen-req CLIENT_x nopass       # create a key pair for client CLIENTx
    ./easyrsa sign-req client CLIENT_x      # sign public key of CLIENTx and create the digital certificate
```

OpenVPN

- generate secret key (optional, but recommended)

```
    openvpn --genkey --secret ta.key        # create a static key
```

Filenames and their purpose

Important files generated by Easy-RSA (running in the CA computer):

Filename	Needed by	Description	Secret
`pki/private/ca.key`	only CA computer	root CA private key	YES
`pki/ca.crt`	servers and clients	root CA certificate	no
`pki/ta.key`	servers and clients	HMAC authentication key	YES
`pki/dh_x.pem`	only server *x*	Diffie Hellman parameters	no
`pki/issued/SERVER_x.crt`	only server *x*	server *x* certificate	no
`pki/private/SERVER_x.key`	only server *x*	server *x* private key	YES
`pki/issued/CLIENT_x.crt`	only client *x*	client *x* certificate	no
`pki/private/CLIENT_x.key`	only client *x*	client *x* private key	YES

Use `cp`, `scp` or `WinSCP` to copy files to servers and clients

Where to place the files

Create destination folders inside each server and client:

Server x	**Client** x
`sudo mkdir -p /etc/openvpn/keys`	`mkdir -p ~/.openvpn/keys`
`sudo chmod 700 /etc/openvpn/keys`	`chmod 700 ~/.openvpn/keys`

Copy the files created by Easy-RSA to the following folders:

Server x	**Client** x
`/etc/openvpn/ca.crt`	`~/.openvpn/ca.crt`
`/etc/openvpn/keys/ta.key`	`~/.openvpn/keys/ta.key`
`/etc/openvpn/SERVER_x.crt`	`~/.openvpn/CLIENT_x.crt`
`/etc/openvpn/keys/SERVER_x.key`	`~/.openvpn/keys/CLIENT_x.key`
`/etc/openvpn/dh_x.pem`	

Create the SERVER configuration file

For each Linux server:

```
sudo -i              # enter root mode
cd /etc/openvpn
# copy sample configuration file and uncompress it
cp /usr/share/doc/openvpn/examples/sample-config-files/server.conf.gz .
gunzip -c server.conf.gz > server_x.conf
nano server_x.conf   # edit server.conf and check the following parameters (add them if needed):
    # ...
    ca ca.crt
    cert SERVER_x.crt
    key keys/SERVER_x.key
    dh dh_x.pem
    # ...
    server 10.8.0.0 255.255.255.0              # DHCP pool for clients, cannot conflict with existing subnets
    # ...
    push "redirect-gateway def1 bypass-dhcp"    # to avoid DNS leaking
    # ...
    push "dhcp-option DNS 9.9.9.9"              # instruct clients to use QUAD9 DNS service (or other service you wish)
    # ...
    tls-auth keys/ta.key 0                      # HMAC authentication key, 0 for servers
    auth SHA512                                 # HMAC algorithm
    # ...
    cipher AES-256-CBC                          # encryption algorithm for the communications
    # ...
    user nobody                                 # reduce OpenVPN privileges
    group nogroup
    # ..
exit                 # exit root mode
```

Create the CLIENT configuration file

For each Linux client:

```
cd ~/.openvpn
# copy sample configuration file
cp /usr/share/doc/openvpn/examples/sample-config-files/client.conf ./client_x.conf
nano client_x.conf  # edit client_x.conf and check the following parameters (add them if needed):
    # ...
    client                             # VPN client mode
    # ...
    remote  SERVER_x_ip_address 1194   # replace with the IP address of the server
    # ...
    ca ca.crt
    cert CLIENT_x.crt
    key keys/CLIENT_x.key
    # ...
    tls-auth keys/ta.key 1             # HMAC authentication key, 1 for clients
    auth SHA512                        # HMAC algorithm
    # ...
    cipher AES-256-CBC                 # encryption algorithm for the communications
    # ...
    user nobody                        # reduce OpenVPN privileges
    group nogroup
    # ..
```

Server – Enable packet forwarding on Linux

For each server:

- read the current state of IP forwarding

```
$ sysctl net.ipv4.ip_forward
net.ipv4.ip_forward = 0
```

- enable forwarding
  - temporarily (lost after a reboot)

    ```
    $ sudo sysctl -w net.ipv4.ip_forward=1
    net.ipv4.ip_forward = 1
    ```

  - persistently (remains after a reboot)

    ```
    $ sudo nano /etc/sysctl.conf
        # change value to "1":
        net.ipv4.ip_forward = 1

        # if IPv6 is required change also:
        net.ipv6.conf.all.forwarding = 1
    ```

Server – setup IPTables to allow OpenVPN traffic

Add the following rules to your IPTables firewall:

```
IPT=/sbin/iptables
$IPT -F && $IPT -t nat -F   # delete any previous configurations
$IPT -P INPUT ACCEPT        # change to DROP after
$IPT -P OUTPUT ACCEPT       # successful test of your
$IPT -P FORWARD ACCEPT      # OpenVPN configuration
# (...)
DYN=1024:65535
echo "OpenVPN: server on port 1194 UDP"
$IPT -A INPUT -p udp -m state --state NEW --sport $DYN --dport 1194 -j ACCEPT

echo "OpenVPN: allow interface TUN"
$IPT -A INPUT -i tun+ -j ACCEPT

IFNAME=enp3s0                 # change to the name of your server NAT interface
echo "OpenVPN: route TUN <-> $IFNAME"
$IPT -A FORWARD -i tun+ -j ACCEPT
$IPT -A FORWARD -i tun+ -o $IFNAME -m state --state RELATED,ESTABLISHED -j ACCEPT
$IPT -A FORWARD -i $IFNAME -o tun+ -m state --state RELATED,ESTABLISHED -j ACCEPT

# This part is mandatory even if you don't want to use a firewall
echo "OpenVPN: ativar NAT"
SOURCE_NET=10.8.0.0/8       # source network from DHCP pool
$IPT -t nat -A POSTROUTING -s $SOURCE_NET -o $IFNAME -j MASQUERADE
```

Apply the IPTables rules and then perform the tests on the next slide.

First test – Linux OS on both client and server

1. **client**:
   - make sure the "NAT" interface is shutdown;
   - on the "Host only" interface configure the default gateway with the IP of the server;
   - disable any firewall you might have configured;
2. **server** – stop OpenVPN service and execute OpenVPN on the command line:

```
$ sudo service openvpn stop     # for debugging purposes
$ cd /etc/openvpn
$ sudo openvpn SERVER_x.conf    # the terminal will stay locked after this command, press CTRL+C to terminate
# ...
Thu Nov 23 14:56:14 2017 Initialization Sequence Completed
```

3. **client** – execute OpenVPN on the command line:

```
$ cd ~./openvpn
$ sudo openvpn CLIENT_x.conf    # the terminal will stay locked after this command, press CTRL+C to terminate
# ...
Thu Nov 23 15:03:24 2017 Initialization Sequence Completed
```

4. **client** – check if VPN is working:

```
$ tracepath 9.9.9.9
1?: [LOCALHOST]                                        pmtu 1500
1:  10.8.0.1                                           125.908ms    # IP from OpenVPN DHCP pool
1:  10.8.0.1                                           139.983ms    # this IP doesn't show up if the VPN is not connected
# ...
6:  dns.quad9.net                                      138.106ms !H
```

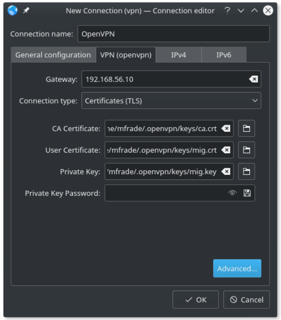
Second test – Linux OS on both client and server

After the previous test is successful:

- **client** – install OpenVPN integration with the desktop interface

```
$ sudo apt install  network-manager-openvpn
```

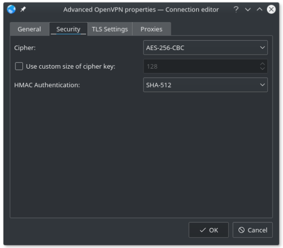
  - configure and test again;


New Connection (vpn) — Connection editor

Connection name: OpenVPN

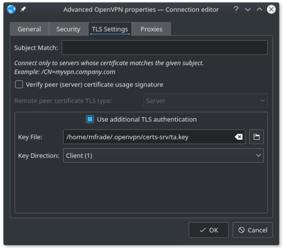
General configuration | VPN (openvpn) | IPv4 | IPv6

Gateway: 192.168.56.10
Connection type: Certificates (TLS)
CA Certificate: ıe/mfrade/.openvpn/keys/ca.crt
User Certificate: ı/mfrade/.openvpn/keys/mig.crt
Private Key: 'mfrade/.openvpn/keys/mig.key
Private Key Password:


Advanced OpenVPN properties — Connection editor

General | Security | TLS Settings | Proxies

Cipher: AES-256-CBC
☐ Use custom size of cipher key: 128
HMAC Authentication: SHA-512


Advanced OpenVPN properties — Connection editor

General | Security | TLS Settings | Proxies

Subject Match:
Connect only to servers whose certificate matches the given subject.
Example: /CN=myvpn.company.com
☐ Verify peer (server) certificate usage signature
Remote peer certificate TLS type: Server
☑ Use additional TLS authentication
Key File: /home/mfrade/.openvpn/certs-srv/ta.key
Key Direction: Client (1)

- **server** – after successful test with the GUI, enable OpenVPN service:

```
$ sudo service openvpn start
```

OpenVPN for other OS

OpenVPN is available for many OS:

- **Windows** – check OpenVPN ▸ downloads page
- **MAC** – a popular OpenVPN client for MacOSX is ▸ Tunnelblick
- **Android** – there are many clients:
  - ▸ OpenVPN Connect – from the OpenVPN authors, last time I tried didn't worked well with Elliptic Curve algorithms and contains ads;
  - ▸ OpenVPN for Android – from Arne Schwabe, works well with Elliptic Curve algorithms and doesn't have ads;
- **iOS** – ▸ OpenVPN Connect from the OpenVPN authors;
- **pfSense** – this firewall OS has built-in support for OpenVPN, check this ▸ tutorial

All these OpenVPN clients require a single .ovpn configuration file, with all keys embedded

How to build a .ovpn file

- the `.ovpn` file is very similar to the `.conf` file
- but the `.ovpn` file has all keys and certs embeded, including the private key
- the conversion from `.conf` to `.ovpn` can be automated
  - download the script `conf2ovpn.sh` from Moodle
  - or copy/past it from the slides:

```
cd ~/.openvpn              # go to the directory with the .conf file

touch conf2ovpn.sh         # create an empty script file

# give execution permissions
chmod +x conf2ovpn.sh

# edit the script file
nano conf2opvpn.sh
    # then copy/past the script on the next slide

# execute the script
./conf2ovpn.sh CLIENT_x.conf
```

- then copy the `.ovpn` to the expected location for your OpenVPN client software;

Script conf2ovpn.sh (available for download on Moodle)

```
#!/bin/bash
# based on https://goo.gl/DjkX39
src=$1
dst="$(basename $src .ovpn)_unified.ovpn"

gawk -f - $src > $dst << 'AWK'

BEGIN {
    RS="\n|\r\n"
}

function readcert(file) {
    while ((getline < file) > 0) {
        contents = contents RT $0
        if ($1 == "-----BEGIN")
            contents = $0
        if ($1 == "-----END")
            break
    }

    close(file)
    return contents
}

$1 ~ /^(ca|key|cert|tls-auth)$/ {
    tag = $1
    print "#" $0

    if (tag == "tls-auth"){
        print "# for servers: key-direction 0"
        print "key-direction 1"
    }

    print "<" tag ">"
    print readcert($2)
    print "</" tag ">"

    next
}

{
    print
}

AWK
```