# 1. Intro

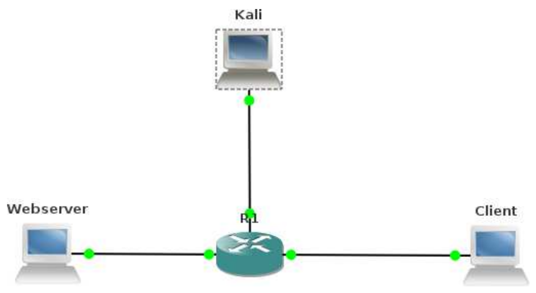
When I did the ISC2 course on DoS, I felt that the information on some parts was insufficient and sometimes too optimistic.

I tried to re-create the network that was used by the training on VirtualBox and GNS3. For VirtualBox, I use Vagrant to create the virtual machines and provision them. GNS3 is used for easy access to network interfaces. GNS3 makes it possible to use wireshark on those interfaces.

Being a different network, some of the behaviour might also be different.

# 2. Syn-flood

## 2.1 The network



The test for syn-flood uses 3 systems, a web server, a client and an attacker. These are created with Vagrant:

```
# -*- mode: ruby -*-
# vi: set ft=ruby :

# Vagrantfile API/syntax version. Don’t touch unless you know what you’re doing!
VAGRANTFILE_API_VERSION = "2"

Vagrant.configure(VAGRANTFILE_API_VERSION) do |config|

          config.vm.define :kali do |t|
                    t.vm.box = "kalilinux/rolling"
                    t.vm.box_version = "2019.2.0"
                    t.vm.provider "virtualbox" do |prov|
                              prov.customize ["modifyvm", :id, "--nic2", "hostonly", "--hostonlyadapter2", "vboxnet1" ]
                    end
                    t.vm.provision "shell", path: "./setup.kali.sh"
          end

          config.vm.define :webserver do |t|
                    t.vm.box = "ubuntu/trusty64"
                    t.vm.provider "virtualbox" do |prov|
                              prov.customize ["modifyvm", :id, "--nic2", "hostonly", "--hostonlyadapter2", "vboxnet2" ]
                    end
                    t.vm.provision "shell", path: "./setup.webserver.sh"
          end

          config.vm.define :client do |t|
                    t.vm.box = "ubuntu/trusty64"
                    t.vm.provider "virtualbox" do |prov|
                              prov.customize ["modifyvm", :id, "--nic2", "hostonly", "--hostonlyadapter2", "vboxnet3" ]
                    end
                    t.vm.provision "shell", path: "./setup.client.sh"
          end

end
```

For the web server, a simple out-of-the-box Apache2 is used. Contrary to the ISC2 test, I did not bother to make a nice image. That means that the Apache welcome-page is displayed.

```
#!/bin/bash
cat <<EOF
#                _
# __      _____| |__  ___  ___ _ ____   _____ _ __
# \ \ /\ / / _ \ ’_ \/ __|/ _ \ ’__\ \ / / _ \ ’__|
#  \ V  V /  __/ |_) \__ \  __/ |   \ V /  __/ |
#   \_/\_/ \___|_.__/|___/\___|_|    \_/ \___|_|
#
EOF


ifconfig eth1 10.128.2.100 netmask 255.255.255.0
route add -net 10.128.0.0 netmask 255.255.0.0 gw 10.128.2.1


apt-get update
apt-get -y  install apache2
```

For the client, a  graphical environment is needed. There is no need for an extensive environment and a simple browser will do.

```
#!/bin/bash

cat <<EOF
#       _ _            _
#   ___| (_) ___ _ __ | |_
#  / __| | |/ _ \ ’_ \| __|
# | (__| | |  __/ | | | |_
#  \___|_|_|\___|_| |_|\__|
#
EOF


ifconfig eth1 10.128.3.100 netmask 255.255.255.0
route add -net 10.128.0.0 netmask 255.255.0.0 gw 10.128.3.1


apt-get update
apt-get -y install xinit
apt-get -y install gdm
apt-get -y install fvwm
apt-get -y install midori
apt-get -y install imagemagick
apt-get -y install gnuplot

cp /vagrant/TrackRTT* ~vagrant
```

The router is a simple 3640 with NM-4E card in it. The router is in this test not important, so almost any (even very old) image will do.  Router configuration is kept simple.

```
enable
config t
int e0/1
ip addr 10.128.1.1 255.255.255.0
int e0/2
ip addr 10.128.2.1 255.255.255.0
int e0/3
ip addr 10.128.3.1 255.255.255.0
no shut
```

## 2.2 Reproducing the first syn-flood test

For both the client and Kali, a graphical interface is needed. This is done through the VirtualBox GUI by double-clicking on the machine.

So, first, `Midori` is used to fetch the home-page on the web server, 10.128.2.100. As expected this works as normal.  Next, the `hping3 -S --flood -p 80 10.128.2.100` from Kali is started. And sure enough, the web server takes a lot of extra time to respond.  Running `netstat | grep SYN_RECV` on the web server reveals a lot of sessions in this state, mostly ticking towards the 256 lines.  And that is odd. Because I have a low-memory virtual machine, the value in `/proc/sys/net/ipv4/tcp_max_syn_backlog is 128` and it the number of SYN_RECV sessions should be below that. I have not found an explanation for this.

Because we have gns3 with a router, we can also see the traffic on the web server with wireshark. First we see the syn-request:

```
Frame 24859: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: cc:00:26:af:00:02 (cc:00:26:af:00:02), Dst: CadmusCo_3e:03:b7 (08:00:27:3e:03:b7)
Internet Protocol Version 4, Src: 10.128.1.100, Dst: 10.128.2.100
Transmission Control Protocol, Src Port: 6566 (6566), Dst Port: 80 (80), Seq: 0, Len: 0
    Source Port: 6566
    Destination Port: 80
    [Stream index: 12281]
    [TCP Segment Len: 0]
    Sequence number: 0    (relative sequence number)
    Acknowledgment number: 293437713
        [Expert Info (Note/Protocol): The acknowledgment number field is nonzero while the ACK flag is not set]
    Header Length: 20 bytes
    Flags: 0x002 (SYN)
        000. .... .... = Reserved: Not set
        ...0 .... .... = Nonce: Not set
        .... 0... .... = Congestion Window Reduced (CWR): Not set
        .... .0.. .... = ECN-Echo: Not set
        .... ..0. .... = Urgent: Not set
        .... ...0 .... = Acknowledgment: Not set
        .... .... 0... = Push: Not set
        .... .... .0.. = Reset: Not set
        .... .... ..1. = Syn: Set
        .... .... ...0 = Fin: Not set
        [TCP Flags: **********S*]
    Window size value: 512
    [Calculated window size: 512]
    Checksum: 0xeabf [validation disabled]
        [Good Checksum: False]
        [Bad Checksum: False]
    Urgent pointer: 0
```

And we see the reply from the web server:

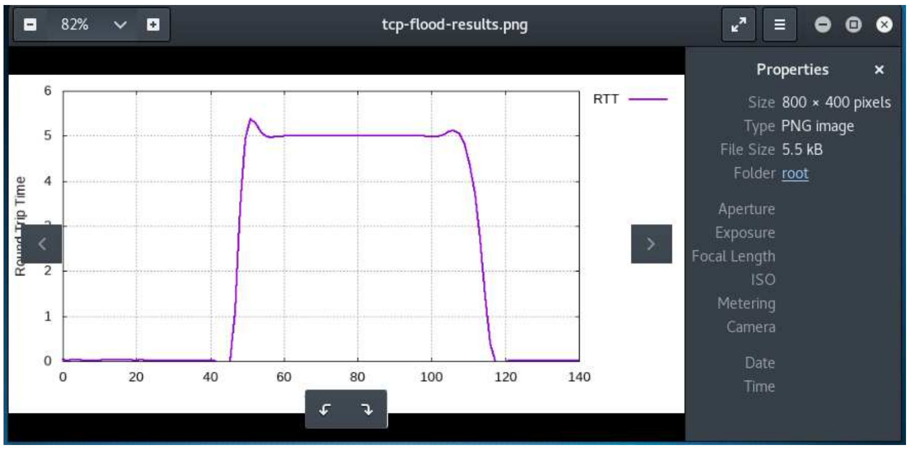
```
Frame 24875: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: CadmusCo_3e:03:b7 (08:00:27:3e:03:b7), Dst: cc:00:26:af:00:02 (cc:00:26:af:00:02)
Internet Protocol Version 4, Src: 10.128.2.100, Dst: 10.128.1.100
Transmission Control Protocol, Src Port: 80 (80), Dst Port: 6566 (6566), Seq: 0, Ack: 1, Len: 0
    Source Port: 80
    Destination Port: 6566
    [Stream index: 12281]
    [TCP Segment Len: 0]
    Sequence number: 0    (relative sequence number)
    Acknowledgment number: 1    (relative ack number)
    Header Length: 24 bytes
    Flags: 0x012 (SYN, ACK)
        000. .... .... = Reserved: Not set
        ...0 .... .... = Nonce: Not set
        .... 0... .... = Congestion Window Reduced (CWR): Not set
        .... .0.. .... = ECN-Echo: Not set
        .... ..0. .... = Urgent: Not set
        .... ...1 .... = Acknowledgment: Set
        .... .... 0... = Push: Not set
        .... .... .0.. = Reset: Not set
        .... .... ..1. = Syn: Set
            [Expert Info (Chat/Sequence): Connection establish acknowledge (SYN+ACK): server port 80]
        .... .... ...0 = Fin: Not set
        [TCP Flags: *******A**S*]
    Window size value: 29200
    [Calculated window size: 29200]
    Checksum: 0x01a6 [validation disabled]
        [Good Checksum: False]
        [Bad Checksum: False]
    Urgent pointer: 0
    Options: (4 bytes), Maximum segment size
        Maximum segment size: 1460 bytes
    [SEQ/ACK analysis]
        [This is an ACK to the segment in frame: 24859]
        [The RTT to ACK the segment was: 0.000620000 seconds]
```

Hint: by right-clicking on a syn-request, you can choose 'Follow' and 'TCP stream' in wireshark. And of course, the `hping3` does not answer anymore.

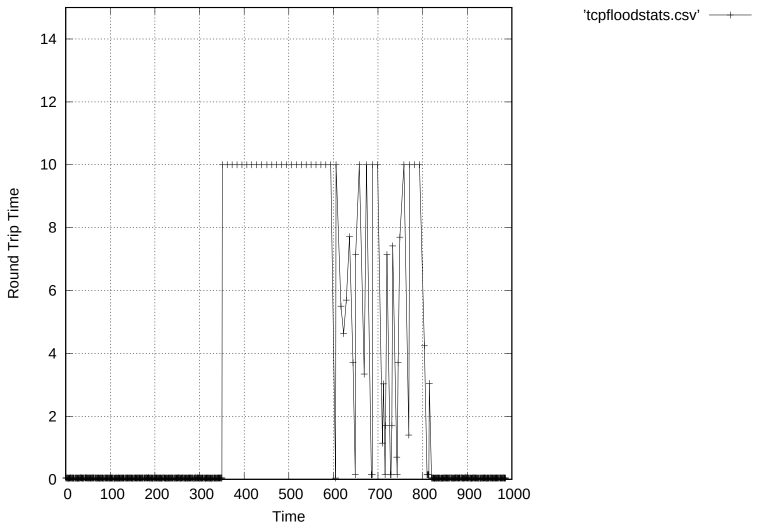
It is also nice to see that `hping3` runs out of source ports. Wireshark will mark packets with "TCP Port numbers reused" if there is yet another SYN from this port number.

## 2.3 Syn cookies

The second exercise was to enable syn-cookies during a SYN attack. In the ISC2 lab environment, that works like charm. When syn cookies are enabled everything is fine and dandy.



Of course, in reality it is not. This exercise promotes a false sense of security: I've enabled syn cookies, so I am safe. That simply is not true. In a more realistic scenario, it would come-out as follows.



Attack starts at 350, `sysctl` at 600 and end the attack at 800.

Why is that?

That is because ISC2 uses a rather simplistic network. Everything is connected together in one single subnet. But that is not realistic. If your attacker manages to get access to the VLAN or physical switch where your web server is connected, then DoS attacks are the least of your worries.

I had to modify the `Tracrtt.sh` script to match the difference in network. I also polished away some of the more clumsy stuff. Below is my version of the script.

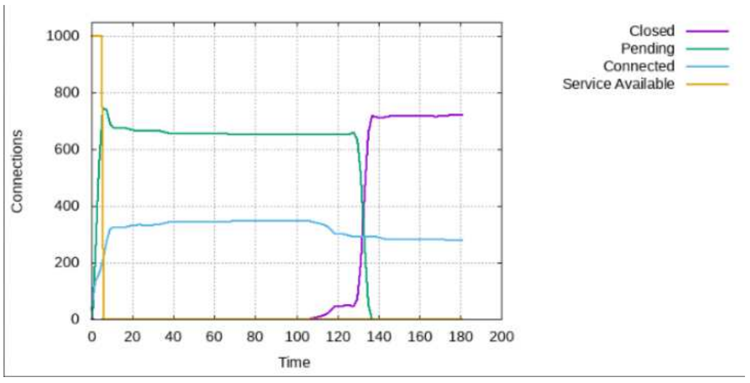
```
#!/bin/bash
trap ctrl_c INT
ctrl_c(){
gnuplot <<EOF
set terminal png
set term png size 800,400
set boxwidth 2 relative
set grid
set key outside
set datafile separator ","
set output 'TCP_flood_results.png'
set ylabel "Round Trip Time"
set xlabel "Time"
set yrange [0:15]
plot 'tcp-flood-stats.csv' with linespoints ls 1
EOF
cp tcp-flood-stats.csv /vagrant
cp TCP_flood_results.png /vagrant
display TCP_flood_results.png
exit
}

start=$(date +%s)
rm -f tcp-flood-sats.csv
sec=0
while : ; do
    now=$(date +%s)
    co=$(curl -s --max-time 10 -w '%{http_code}:%{time_total}' -o /dev/null http://10.128.2.100)
    response=${co%:*}
    if [ "$response" = 200 ] ; then
        rtt=${co#*:}
    else
        rtt=10
    fi
    sec=$((now - start))
    echo "$sec,$rtt">> tcp-flood-sats.csv
    sleep 1
done
```

So, do not be fooled by the fact that a simple kernel setting in Linux solved everything in the ISC2 lab environment.

## 3. Application level attacks

As an example of an application level attack, the course uses the example of slowloris; keeping sessions open by providing very slow requests. As a mitigation, two Apache modules are proposed.

The following image is the result of the reqtimeout module.



There are a number of parameters in the configuration file that can be set more aggressively.

It is also interesting to see what effect this attack and its moderation meas for the client. I used the same Trackrtt script on the client to see the effect of the attack.

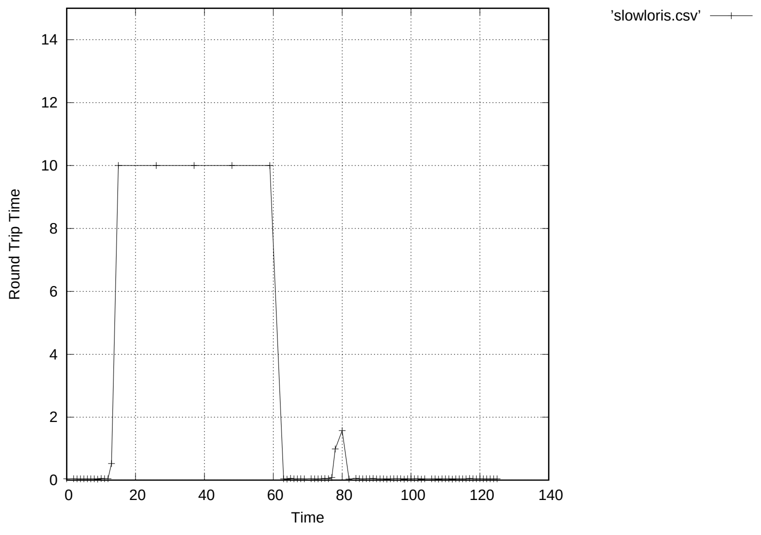
I adjusted the values in `reqtimeout.conf to the following values:`

```
RequestReadTimeout header=5-10,minrate=1000
RequestReadTimeout body=5,minrate=1000
```

Slowloris was started with

```
/opt/slowloris/slowloris.py 10.128.2.100 -s 200
```

Attack started at 15, Apache module enabled at 60 and attack ended around 110.



So, apart from a small spike, around 80, the attack seems sufficiently mitigated.