Cloud-based malware traffic analysis lab
Appendix

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Abstract

Initially designed for my paper project called “SSL/TLS INTERCEPTION FROM THE SHADOW TO THE LIGHT”, this document combines procedures for configuring the key components for malware traffic analysis lab in Amazon EC2. It describes the methodology to prepare Amazon Image (AMI) for infection phase with and without SSL/TLS interception. Moreover, this document provides a procedure for testing malware and capturing malicious network traffic. The main goal of this project is to contribute to the cybersecurity community.

Table of Contents

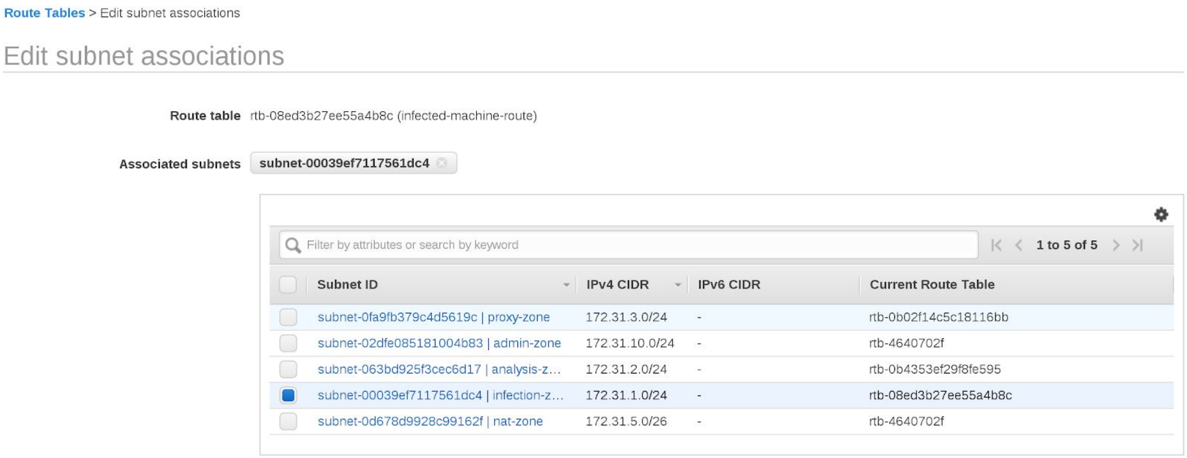
EC2 NAT instance configuration

The following Amazon procedure needs to be used to create a NAT instance. The NAT instance is the key component for capturing outgoing traffic to the Internet from the infected zone and proxy zone.

https://docs.aws.amazon.com/vpc/latest/userguide/VPC_NAT_Instance.html

Once the NAT instance is built, configure a specific routing table for the infected subnet to route the default route to the NAT instance.

Following our test, the infected machine cannot avoid this routing configuration by changing the local routing table of the operating system.



Route Tables > Edit subnet associations

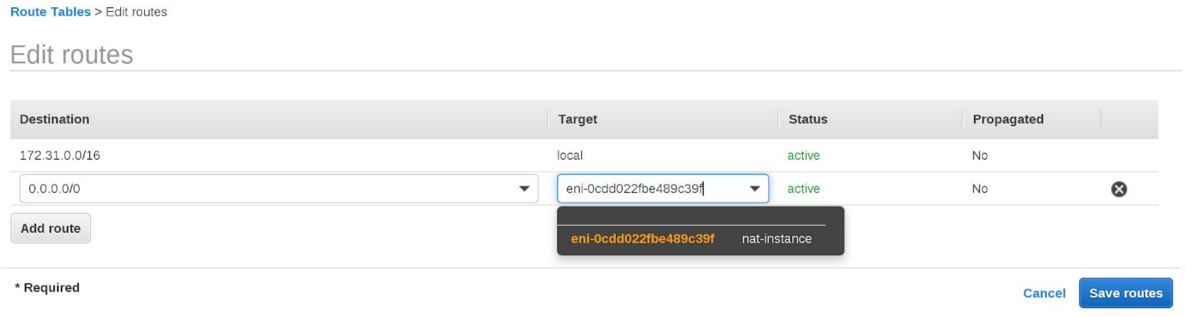
Edit subnet associations

Route table rtb-08ed3b27ee55a4b8c (infected-machine-route)

Associated subnets subnet-00039ef7117561dc4

Filter by attributes or search by keyword   1 to 5 of 5

	Subnet ID	IPv4 CIDR	IPv6 CIDR	Current Route Table
□	subnet-0fa9fb379c4d5619c | proxy-zone	172.31.3.0/24	-	rtb-0b02f14c5c18116bb
□	subnet-02dfe085181004b83 | admin-zone	172.31.10.0/24	-	rtb-4640702f
□	subnet-063bd925f3cec6d17 | analysis-z…	172.31.2.0/24	-	rtb-0b4353ef29f8fe595
☑	subnet-00039ef7117561dc4 | infection-z…	172.31.1.0/24	-	rtb-08ed3b27ee55a4b8c
□	subnet-0d678d9928c99162f | nat-zone	172.31.5.0/26	-	rtb-4640702f



Route Tables > Edit routes

Edit routes

Destination	Target	Status	Propagated
172.31.0.0/16	local	active	No
0.0.0.0/0	eni-0cdd022fbe489c39f	active	No

eni-0cdd022fbe489c39f nat-instance

Add route

* Required

Cancel Save routes

Squid Proxy SSL/TLS interception configuration

The squid proxy instance in our lab is a Linux Ubuntu. A second interface is added to the virtual machine to have a direct connectivity with the infected subnet. The following procedure helps the security analyst to add this second interface in Amazon EC2.

https://aws.amazon.com/premiumsupport/knowledge-center/ec2-ubuntu-secondary-network-interface/?nc1=h_ls

Once this second interface is fully functional, the following procedure needs to be used to create the squid proxy with SSL Bump feature.

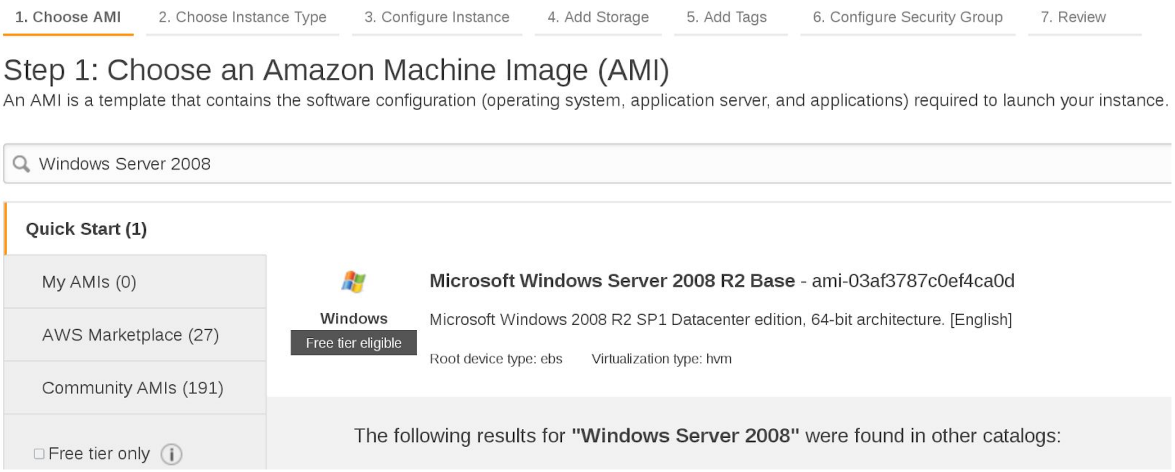
https://wiki.squid-cache.org/ConfigExamples/Intercept/SslBumpExplicit

Preparation template machine for infection

As a prerequisite, the security analyst needs to set up a machine template to test a malware sample. The following steps show how to build a machine template in Amazon EC2 for our experimentation. Amazon EC2 service provides several system images to deal with different operating systems and use cases. In the example below we will build two Microsoft Windows Server 2008 R2 images. The first image is built for direct Internet access without SSL/TLS interception. The second image is built for SSL/TLS interception.

To prepare the machine template, open the EC2 web console, go to the “Instances” panel and click on “Launch Instance”.

Step 1: Choose an Amazon Machine Image (AMI)
In the example, we used a Microsoft Windows Server 2008 R2 Base for AMI.



1. Choose AMI | 2. Choose Instance Type | 3. Configure Instance | 4. Add Storage | 5. Add Tags | 6. Configure Security Group | 7. Review

Step 1: Choose an Amazon Machine Image (AMI)

An AMI is a template that contains the software configuration (operating system, application server, and applications) required to launch your instance.

Windows Server 2008

Quick Start (1)

My AMIs (0)

AWS Marketplace (27)

Community AMIs (191)

□ Free tier only

Windows

Free tier eligible

Microsoft Windows Server 2008 R2 Base - ami-03af3787c0ef4ca0d

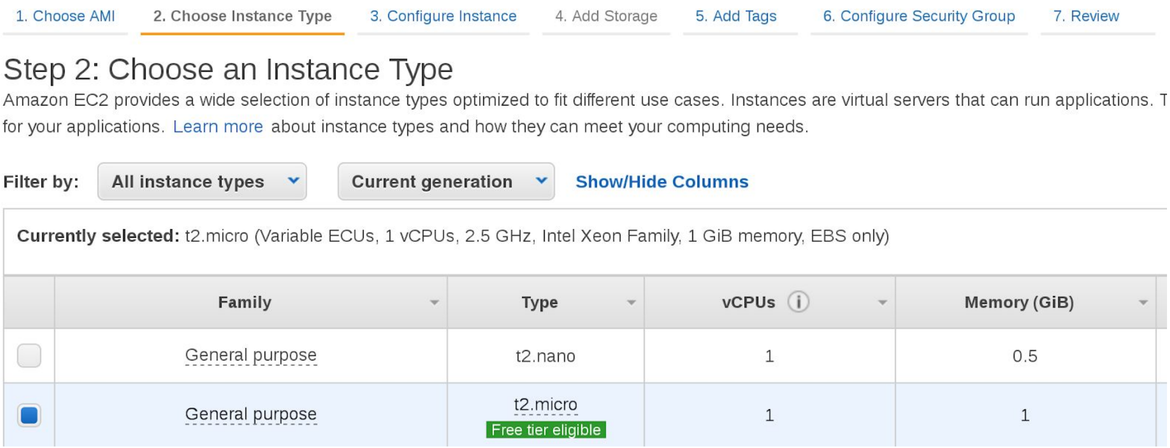
Microsoft Windows 2008 R2 SP1 Datacenter edition, 64-bit architecture. [English]

Root device type: ebs Virtualization type: hvm

The following results for **"Windows Server 2008"** were found in other catalogs:

Step 2: Choose an Instance Type

In this step, use a free tier eligible t2.micro instance type.



1. Choose AMI | 2. Choose Instance Type | 3. Configure Instance | 4. Add Storage | 5. Add Tags | 6. Configure Security Group | 7. Review

Step 2: Choose an Instance Type

Amazon EC2 provides a wide selection of instance types optimized to fit different use cases. Instances are virtual servers that can run applications. T
for your applications. Learn more about instance types and how they can meet your computing needs.

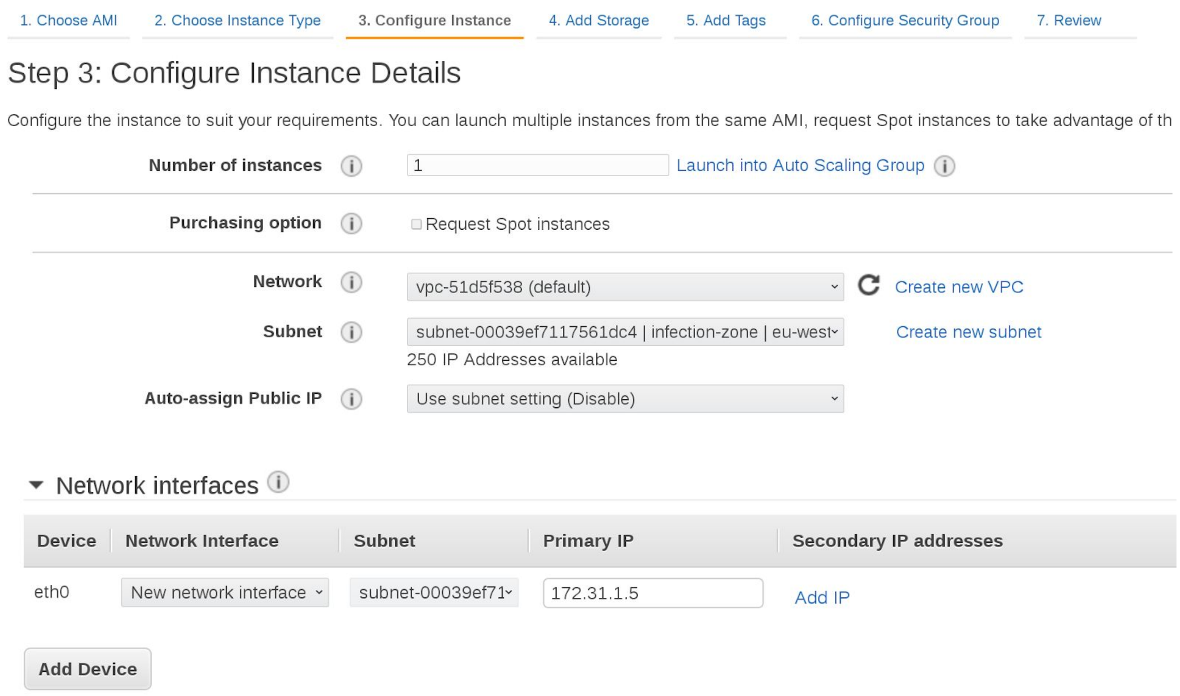
Filter by: All instance types | Current generation | Show/Hide Columns

Currently selected: t2.micro (Variable ECUs, 1 vCPUs, 2.5 GHz, Intel Xeon Family, 1 GiB memory, EBS only)

	Family	Type	vCPUs	Memory (GiB)
□	General purpose	t2.nano	1	0.5
■	General purpose	t2.micro Free tier eligible	1	1

Step 3: Configure Instance Details

Assign the machine in the infection subnet, then assign the IP address of the machine in the subnet (optional).



Step 3: Configure Instance Details

Configure the instance to suit your requirements. You can launch multiple instances from the same AMI, request Spot instances to take advantage of th

Number of instances: 1 — Launch into Auto Scaling Group

Purchasing option: □ Request Spot instances

Network: vpc-51d5f538 (default) — Create new VPC

Subnet: subnet-00039ef7117561dc4 | infection-zone | eu-west — Create new subnet

250 IP Addresses available

Auto-assign Public IP: Use subnet setting (Disable)

Network interfaces

Device	Network Interface	Subnet	Primary IP	Secondary IP addresses
eth0	New network interface	subnet-00039ef71	172.31.1.5	Add IP

Step 4: Add Storage

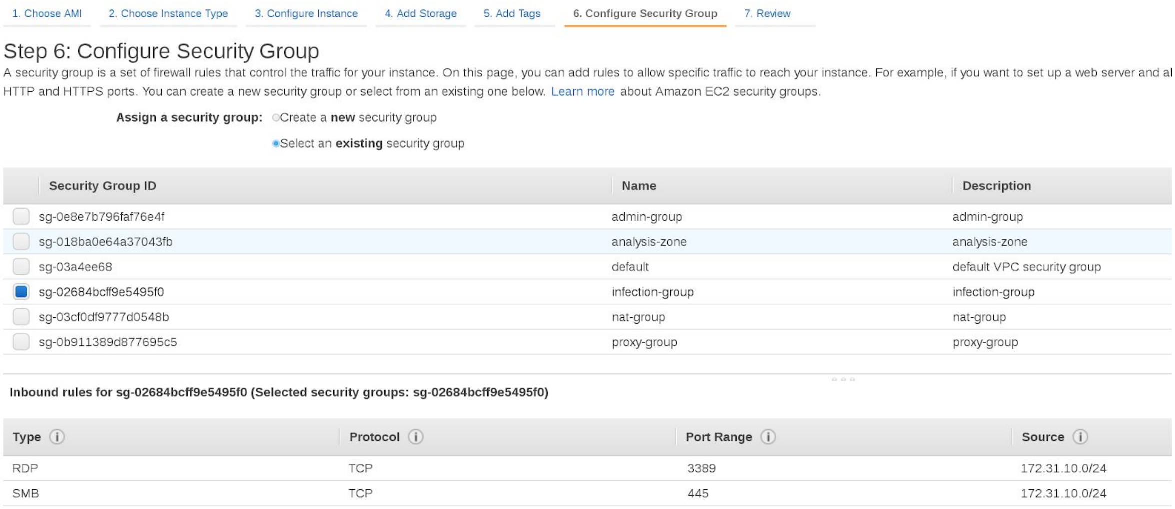
Adjust the size of the machine storage for your needs. Use the default value if there is no specific requirement.

Step 5: Add tags

Add tags if needed (optional). Tags are useful for categorizing a group of objects.

Step 6: Configure Security Group

Select the security group “infection group” The admin zone in the subnet 172.31.10.0/24 could access the infected zone for administration purposes.



Step 6: Configure Security Group

A security group is a set of firewall rules that control the traffic for your instance. On this page, you can add rules to allow specific traffic to reach your instance. For example, if you want to set up a web server and al HTTP and HTTPS ports. You can create a new security group or select from an existing one below. Learn more about Amazon EC2 security groups.

Assign a security group: ○Create a **new** security group
●Select an **existing** security group

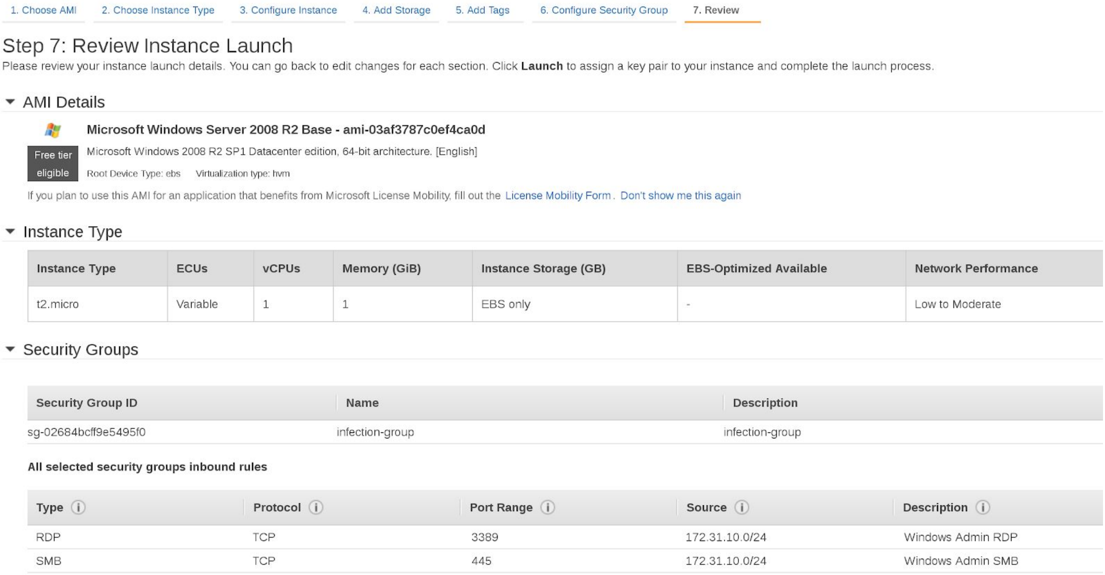
	Security Group ID	Name	Description
□	sg-0e8e7b796faf76e4f	admin-group	admin-group
□	sg-018ba0e64a37043fb	analysis-zone	analysis-zone
□	sg-03a4ee68	default	default VPC security group
☑	sg-02684bcff9e5495f0	infection-group	infection-group
□	sg-03cf0df9777d0548b	nat-group	nat-group
□	sg-0b911389d877695c5	proxy-group	proxy-group

Inbound rules for sg-02684bcff9e5495f0 (Selected security groups: sg-02684bcff9e5495f0)

Type	Protocol	Port Range	Source
RDP	TCP	3389	172.31.10.0/24
SMB	TCP	445	172.31.10.0/24

Step 7: Review Instance Launch

In this step, review your configuration and click on Launch if all parameters are correct.



Step 7: Review Instance Launch

Please review your instance launch details. You can go back to edit changes for each section. Click **Launch** to assign a key pair to your instance and complete the launch process.

AMI Details

Microsoft Windows Server 2008 R2 Base - ami-03af3787c0ef4ca0d

Free tier eligible

Microsoft Windows 2008 R2 SP1 Datacenter edition, 64-bit architecture. [English]

Root Device Type: ebs Virtualization type: hvm

If you plan to use this AMI for an application that benefits from Microsoft License Mobility, fill out the License Mobility Form. Don't show me this again

Instance Type

Instance Type	ECUs	vCPUs	Memory (GiB)	Instance Storage (GB)	EBS-Optimized Available	Network Performance
t2.micro	Variable	1	1	EBS only	-	Low to Moderate

Security Groups

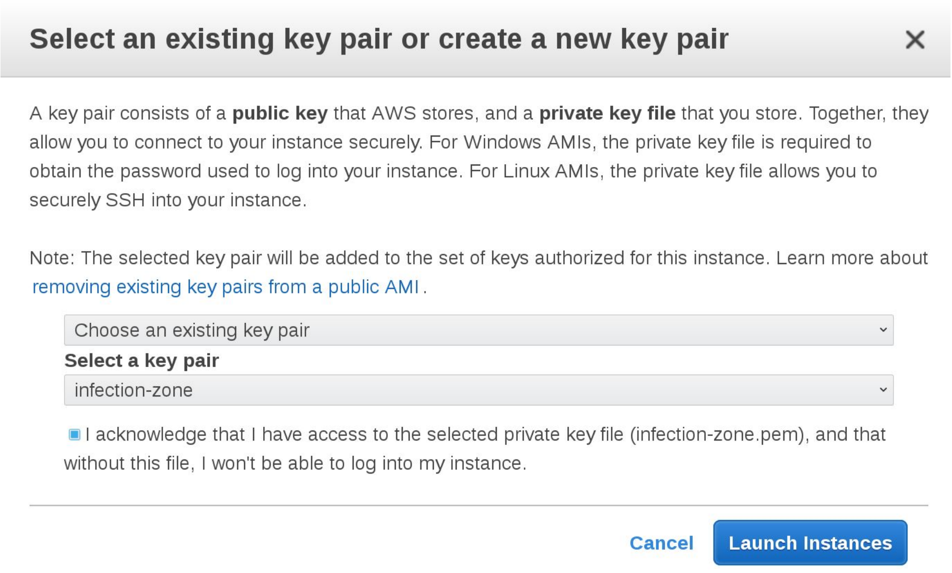
Security Group ID	Name	Description
sg-02684bcff9e5495f0	infection-group	infection-group

All selected security groups inbound rules

Type	Protocol	Port Range	Source	Description
RDP	TCP	3389	172.31.10.0/24	Windows Admin RDP
SMB	TCP	445	172.31.10.0/24	Windows Admin SMB

Step 8: Select an existing key pair or create a new key pair

In this step create or use a existing key pair to get to your Windows Administrator password.



Select an existing key pair or create a new key pair

A key pair consists of a **public key** that AWS stores, and a **private key file** that you store. Together, they allow you to connect to your instance securely. For Windows AMIs, the private key file is required to obtain the password used to log into your instance. For Linux AMIs, the private key file allows you to securely SSH into your instance.

Note: The selected key pair will be added to the set of keys authorized for this instance. Learn more about removing existing key pairs from a public AMI .

Choose an existing key pair

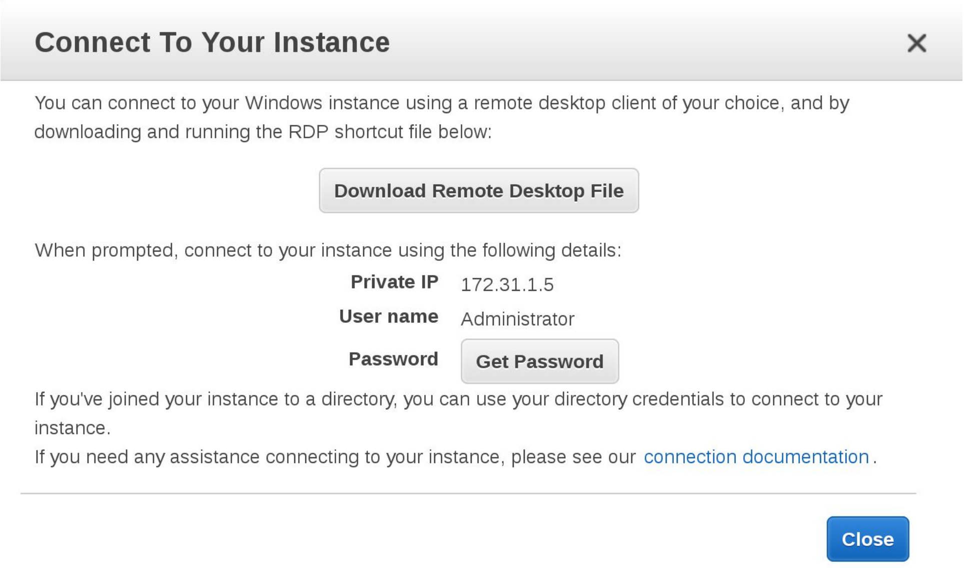
Select a key pair

infection-zone

☑ I acknowledge that I have access to the selected private key file (infection-zone.pem), and that without this file, I won't be able to log into my instance.

Step 9: Retrieve the Administrator password

On the instance panel, select the Windows instance and click on Connect to retrieve the Administrator password. The key pair created needs to be used to display in clear text the password in the web console.



Connect To Your Instance

You can connect to your Windows instance using a remote desktop client of your choice, and by downloading and running the RDP shortcut file below:

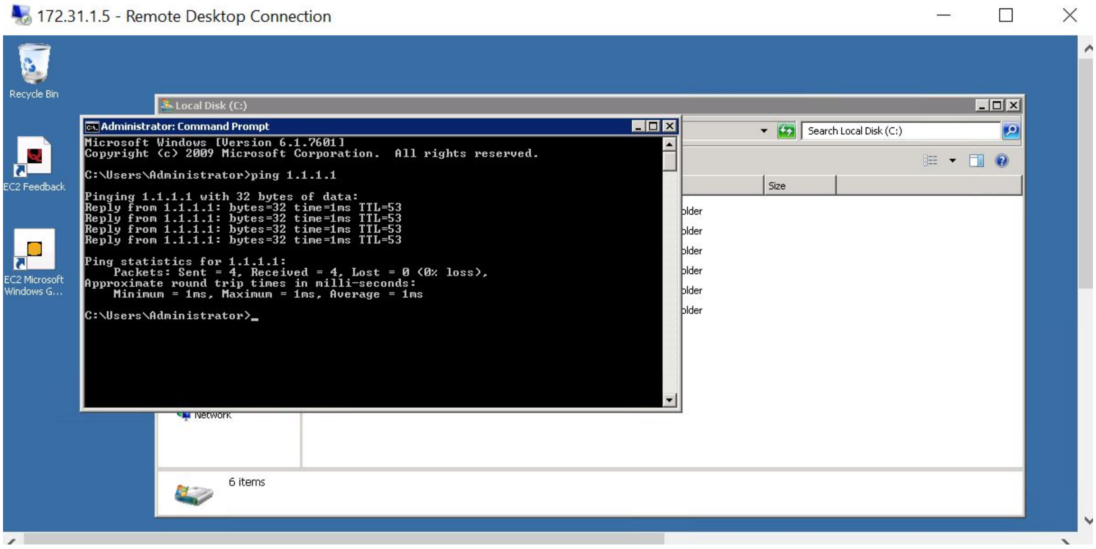
When prompted, connect to your instance using the following details:

Private IP	172.31.1.5
User name	Administrator
Password	Get Password

If you've joined your instance to a directory, you can use your directory credentials to connect to your instance.
If you need any assistance connecting to your instance, please see our connection documentation .

Step 10: Verify the connectivity to Internet

From the Windows instance in the admin zone, connect to the Windows template machine with remote desktop console. Open a terminal ms-dos and test your Internet connectivity.

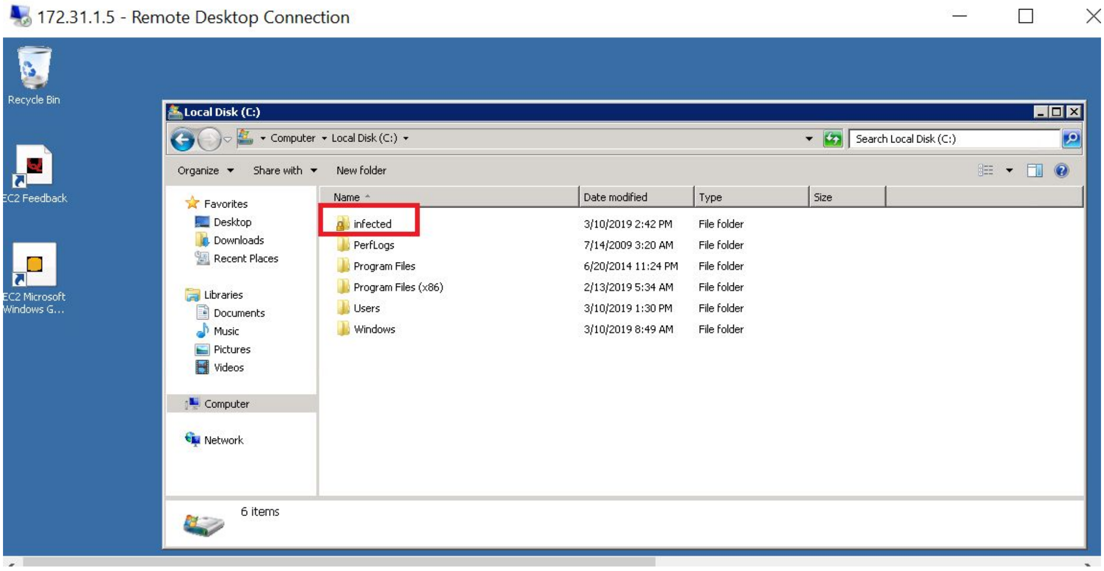

172.31.1.5 - Remote Desktop Connection
Recycle Bin
EC2 Feedback
EC2 Microsoft Windows G...
Local Disk (C:)
Search Local Disk (C:)
Size
6 items
Administrator: Command Prompt

```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\Administrator>ping 1.1.1.1

Pinging 1.1.1.1 with 32 bytes of data:
Reply from 1.1.1.1: bytes=32 time=1ms TTL=53
Reply from 1.1.1.1: bytes=32 time=1ms TTL=53
Reply from 1.1.1.1: bytes=32 time=1ms TTL=53
Reply from 1.1.1.1: bytes=32 time=1ms TTL=53

Ping statistics for 1.1.1.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 1ms, Maximum = 1ms, Average = 1ms

C:\Users\Administrator>_
```

NOTE : If problem, check Security group policies and Network Access Control lists.

Step 11: Create a shared folder for infected file repository

Open Windows Explorer and create a shared folder called “infected” with read/write permission in the C: disk drive.



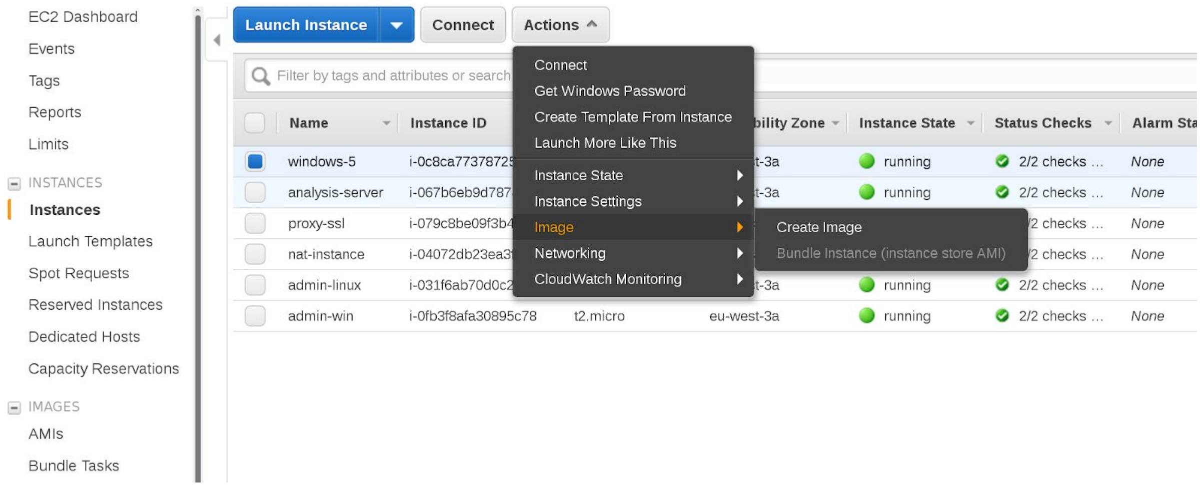
Name	Date modified	Type	Size
infected	3/10/2019 2:42 PM	File folder	
PerfLogs	7/14/2009 3:20 AM	File folder	
Program Files	6/20/2014 11:24 PM	File folder	
Program Files (x86)	2/13/2019 5:34 AM	File folder	
Users	3/10/2019 1:30 PM	File folder	
Windows	3/10/2019 8:49 AM	File folder	

Step 12: Create the instance image

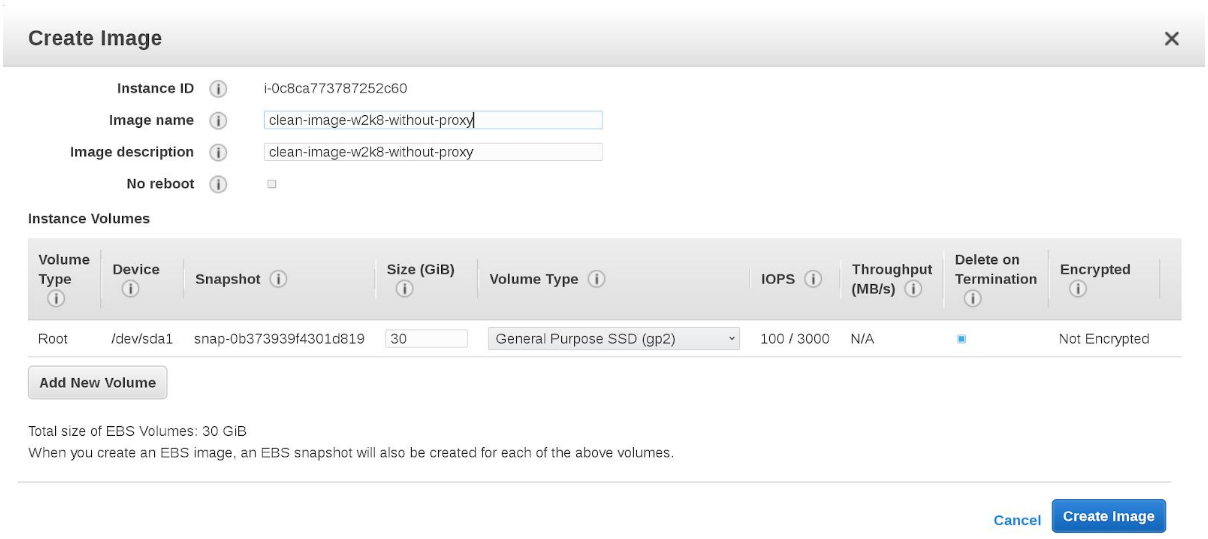
On the instance panel, create an image that could be reused for repetitive tests.

Select the Windows instance and click on Actions>Image>Create Image.

Assign a name for the image: clean-image-w2k8-without-proxy



☐	Name	Instance ID		bility Zone	Instance State	Status Checks	Alarm Sta
■	windows-5	i-0c8ca77378725		t-3a	● running	✓ 2/2 checks ...	None
☐	analysis-server	i-067b6eb9d787		t-3a	● running	✓ 2/2 checks ...	None
☐	proxy-ssl	i-079c8be09f3b4				2 checks ...	None
☐	nat-instance	i-04072db23ea3				2 checks ...	None
☐	admin-linux	i-031f6ab70d0c2		t-3a	● running	✓ 2/2 checks ...	None
☐	admin-win	i-0fb3f8afa30895c78	t2.micro	eu-west-3a	● running	✓ 2/2 checks ...	None



Instance ID: i-0c8ca773787252c60

Image name: clean-image-w2k8-without-proxy

Image description: clean-image-w2k8-without-proxy

No reboot: ☐

Instance Volumes

Volume Type	Device	Snapshot	Size (GiB)	Volume Type	IOPS	Throughput (MB/s)	Delete on Termination	Encrypted
Root	/dev/sda1	snap-0b373939f4301d819	30	General Purpose SSD (gp2)	100 / 3000	N/A	☑	Not Encrypted

Total size of EBS Volumes: 30 GiB

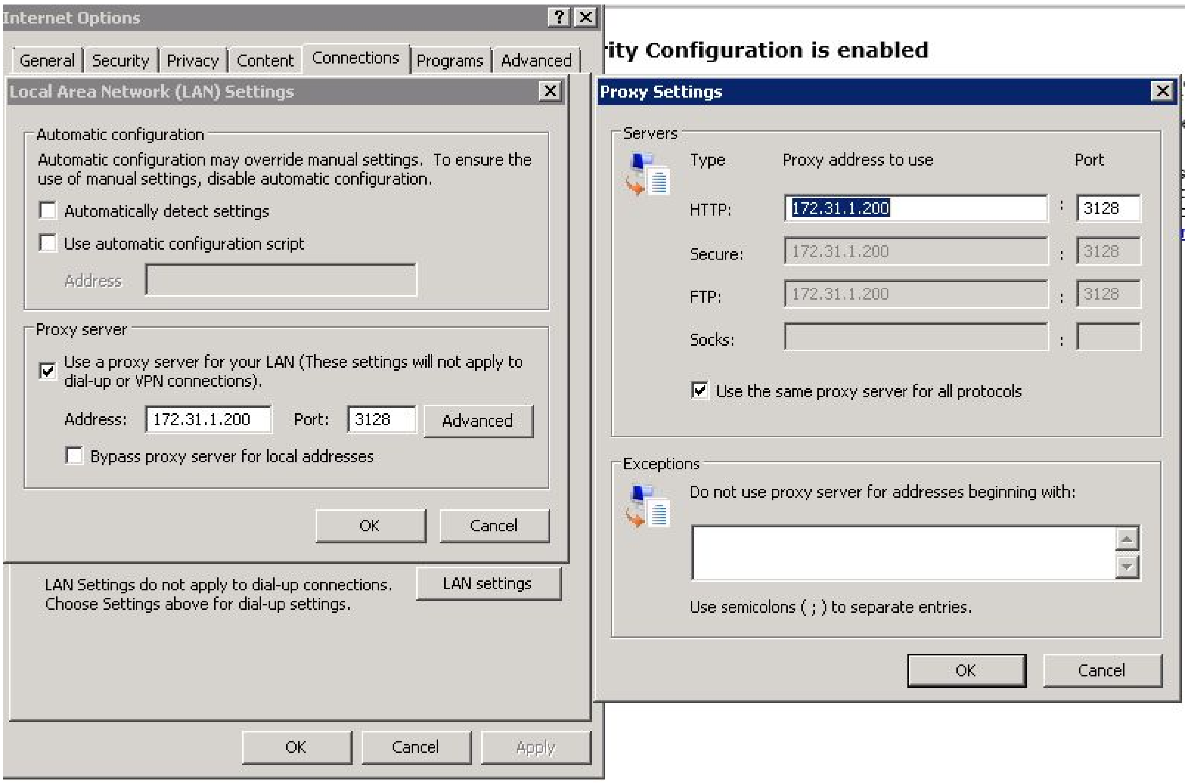
When you create an EBS image, an EBS snapshot will also be created for each of the above volumes.

Step 13: Configure the proxy

From the Windows instance in the admin zone, connect to the Windows template machine with remote desktop console and configure the proxy in Internet Explorer.

Go to Internet Options > Connections > LAN Settings

Select in the Proxy server zone the option “Use a proxy server for your LAN” and complete the field with the private IP address allocated in the infected subnet for the squid proxy server (172.31.1.200).



Local Area Network (LAN) Settings

Automatic configuration

Automatic configuration may override manual settings. To ensure the use of manual settings, disable automatic configuration.

□ Automatically detect settings

□ Use automatic configuration script

Address

Proxy server

☑ Use a proxy server for your LAN (These settings will not apply to dial-up or VPN connections).

Address: 172.31.1.200 Port: 3128

□ Bypass proxy server for local addresses

LAN Settings do not apply to dial-up connections. Choose Settings above for dial-up settings.

Proxy Settings

Servers

Type	Proxy address to use		Port
HTTP:	172.31.1.200	:	3128
Secure:	172.31.1.200	:	3128
FTP:	172.31.1.200	:	3128
Socks:		:	

☑ Use the same proxy server for all protocols

Exceptions

Do not use proxy server for addresses beginning with:

Use semicolons (;) to separate entries.

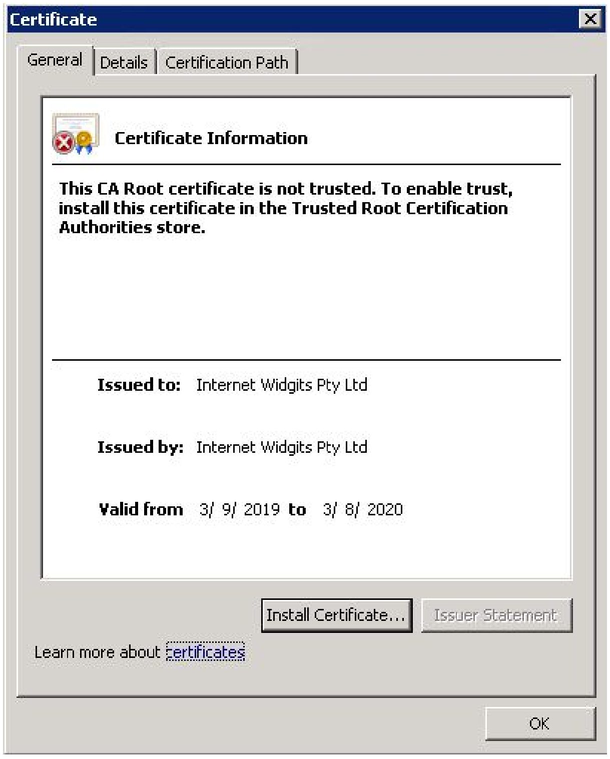
Step 14: Import the proxy CA root certificate

From the linux admin instance push the proxy squid CA root certificate file to the infected folder. The following command line transfers the file by SMB protocol.

```
smbclient '//172.31.1.[X]/Certificate' -U Administrator -c "put /[folder]/proxyCA.der proxyCA.der" -m SMB3
```

NOTE: The IP address of the machine template may vary according to your instance IP assignation in the infected subnet.

In the Windows template machine, go the the infected folder and double-click on proxyCA.der file to import the certificate into Windows Certificate Store. Select the Trusted Root Certification Authorities for the import.



Certificate Information

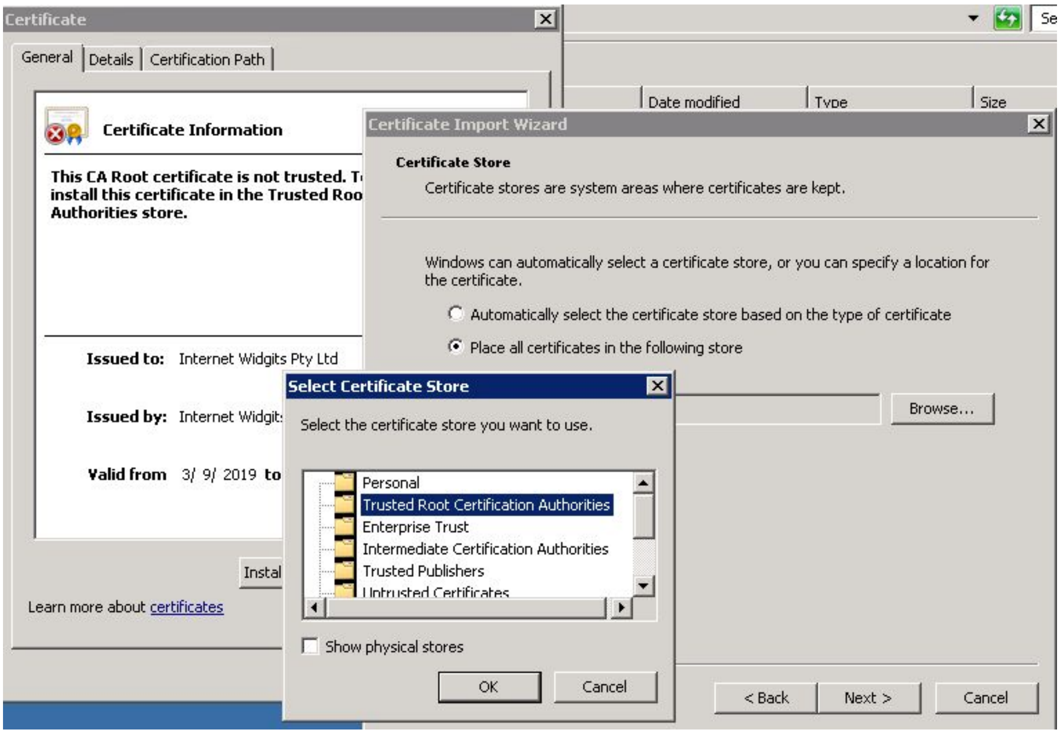
This CA Root certificate is not trusted. To enable trust, install this certificate in the Trusted Root Certification Authorities store.

Issued to: Internet Widgits Pty Ltd

Issued by: Internet Widgits Pty Ltd

Valid from 3/ 9/ 2019 to 3/ 8/ 2020

Learn more about certificates



Certificate Information

This CA Root certificate is not trusted. Ti install this certificate in the Trusted Roo Authorities store.

Issued to: Internet Widgits Pty Ltd

Issued by: Internet Widgit:

Valid from 3/ 9/ 2019 to

Learn more about certificates

Certificate Store

Certificate stores are system areas where certificates are kept.

Windows can automatically select a certificate store, or you can specify a location for the certificate.

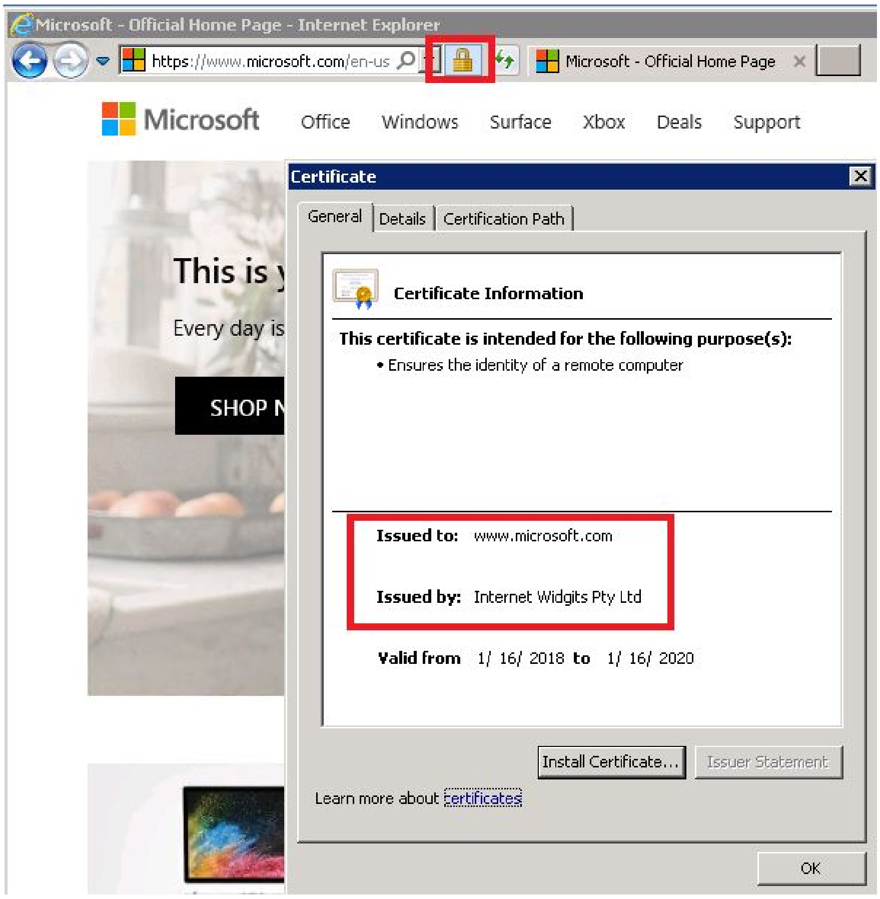
○ Automatically select the certificate store based on the type of certificate

● Place all certificates in the following store

Select the certificate store you want to use.

□ Show physical stores

Visit a website in HTTPS and verify that the website certificate is correctly signed by the proxy CA.



Certificate Information

This certificate is intended for the following purpose(s):

- Ensures the identity of a remote computer

Issued to: www.microsoft.com

Issued by: Internet Widgits Pty Ltd

Valid from 1/ 16/ 2018 to 1/ 16/ 2020

If the test is validated, delete the certificate from the infected shared folder.

Step 15: Save the instance image

On the instance panel, create an image that could be reused for repetitive tests.
Select the Windows instance and click on Actions>Image>Create Image.

Assign a name for the image: clean-image-w2k8-with-proxy

Malware traffic analysis testing procedure

Caution:

We recommend that the security analysts test their malware sample in a controlled, dedicated and isolated test environment. Do not perform this test in a production environment without written permission from your management. In case of misconfiguration the malware could escape the environment and cause severe damage to your production environment. If you perform this test for personal or research purposes, take precautions to protect your assets and stay in your legal framework.

Procedure:

Step 1: Collect the malware sample

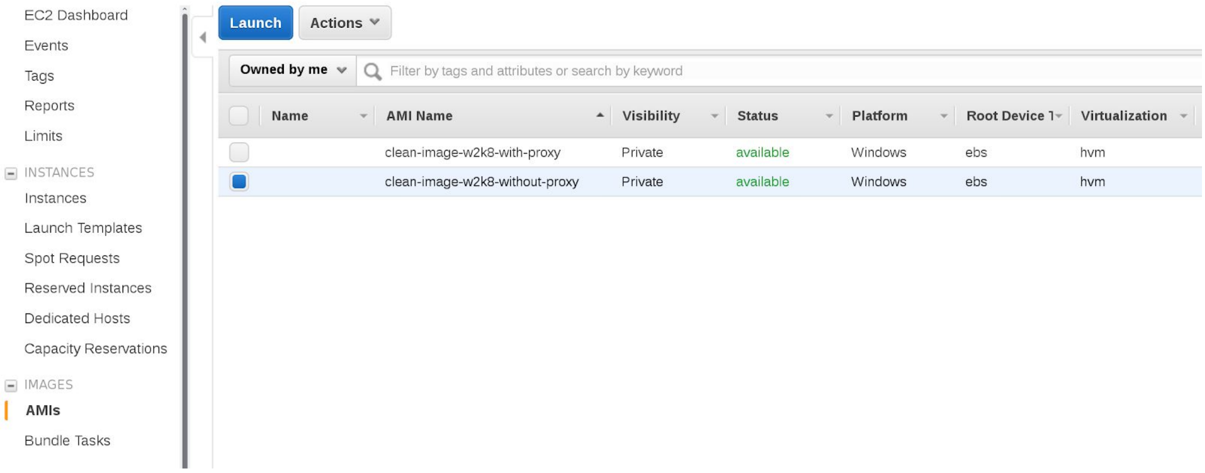
Connect to the admin linux instance and download the sample of malware in a specific folder for this usage. To avoid an execution mistake, the malware sample should be manipulated in a password protected archive. In the example we downloaded Emotet malware from malware-traffic-analysis.net website.

```
wget \
https://malware-traffic-analysis.net/2019/03/01/2019-03-01-malware-from-Emotet-infection.zip
```

Step 2: Launch Instance

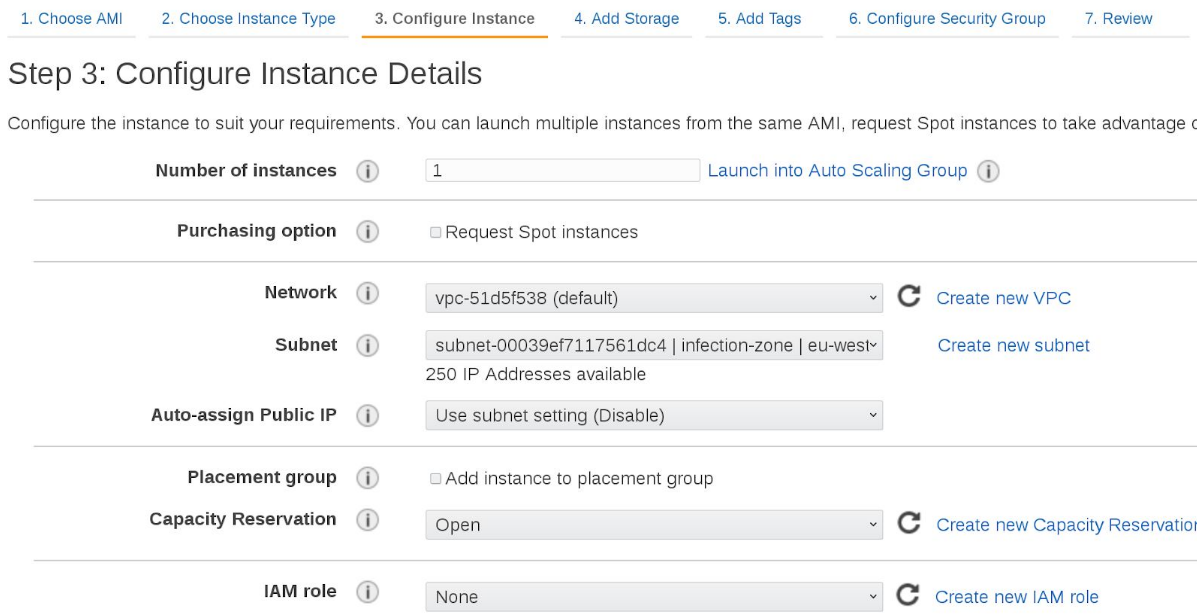
In our case we launched the Amazon Image clean-image-w2k8-without-proxy that we had created.

Go to the Images>AMIs, select the AMI clean-image-w2k8-without-proxy then click on Launch.



☐	Name	AMI Name	Visibility	Status	Platform	Root Device T	Virtualization
☐		clean-image-w2k8-with-proxy	Private	available	Windows	ebs	hvm
■		clean-image-w2k8-without-proxy	Private	available	Windows	ebs	hvm

In the configuration instance assign the subnet infection-zone to the machine.



Step 3: Configure Instance Details

Configure the instance to suit your requirements. You can launch multiple instances from the same AMI, request Spot instances to take advantage c

Number of instances: 1 — Launch into Auto Scaling Group

Purchasing option: □ Request Spot instances

Network: vpc-51d5f538 (default) — Create new VPC

Subnet: subnet-00039ef7117561dc4 | infection-zone | eu-west — Create new subnet
250 IP Addresses available

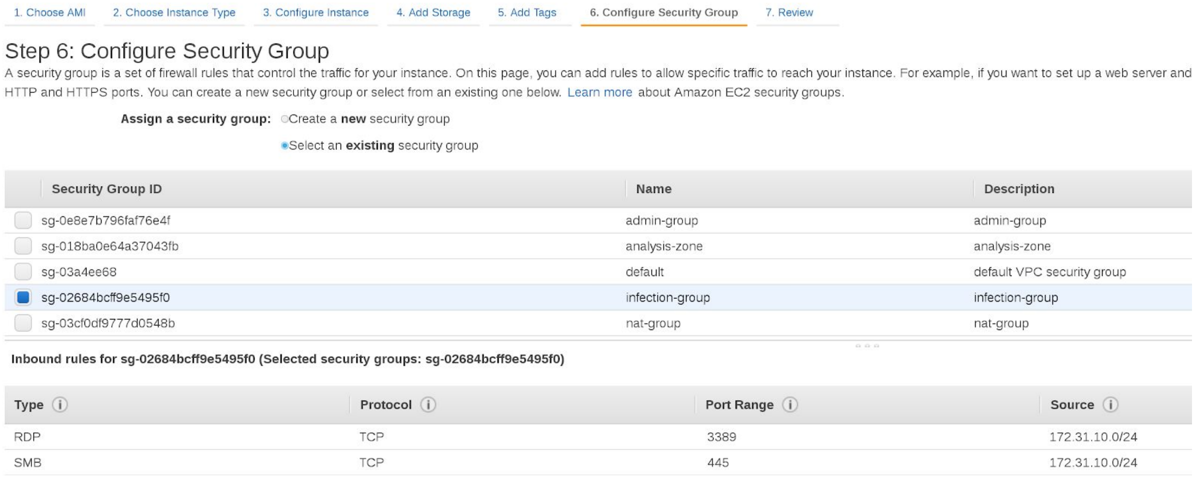
Auto-assign Public IP: Use subnet setting (Disable)

Placement group: □ Add instance to placement group

Capacity Reservation: Open — Create new Capacity Reservatio

IAM role: None — Create new IAM role

In the Security Group configuration select infection-group.



Step 6: Configure Security Group

A security group is a set of firewall rules that control the traffic for your instance. On this page, you can add rules to allow specific traffic to reach your instance. For example, if you want to set up a web server and HTTP and HTTPS ports. You can create a new security group or select from an existing one below. Learn more about Amazon EC2 security groups.

Assign a security group: ○ Create a **new** security group

● Select an **existing** security group

	Security Group ID	Name	Description
☐	sg-0e8e7b796faf76e4f	admin-group	admin-group
☐	sg-018ba0e64a37043fb	analysis-zone	analysis-zone
☐	sg-03a4ee68	default	default VPC security group
☑	sg-02684bcff9e5495f0	infection-group	infection-group
☐	sg-03cf0df9777d0548b	nat-group	nat-group

Inbound rules for sg-02684bcff9e5495f0 (Selected security groups: sg-02684bcff9e5495f0)

Type	Protocol	Port Range	Source
RDP	TCP	3389	172.31.10.0/24
SMB	TCP	445	172.31.10.0/24

Review the configuration and launch.

Step 3: Copy the malware into the virtual machine

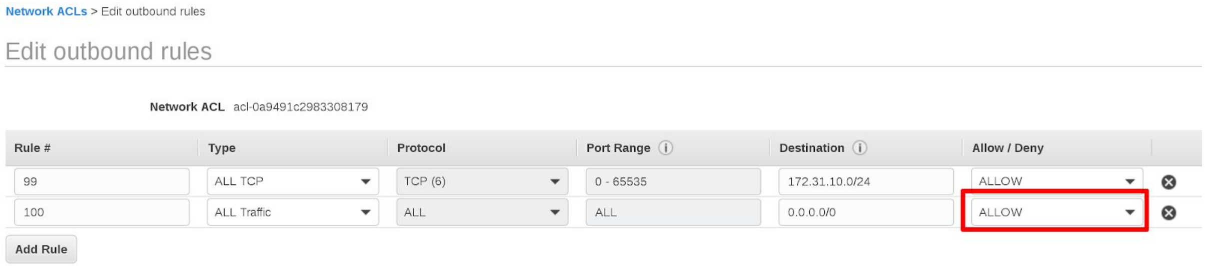
From the linux admin instance push the malware sample file to the infected folder. The following command line transfers the file by SMB protocol to the destination machine.

```
smbclient '//172.31.1.[N]/infected' -U Administrator -c "put [local folder] [destination file name]" -m SMB3
```

The Windows IP address depends on your configuration.

Step 4: Allow all outgoing traffic for infected zone

Edit the network ACL for the infected zone and allow all outbound traffic.



Edit outbound rules

Network ACL acl-0a9491c2983308179

Rule #	Type	Protocol	Port Range	Destination	Allow / Deny
99	ALL TCP	TCP (6)	0 - 65535	172.31.10.0/24	ALLOW
100	ALL Traffic	ALL	ALL	0.0.0.0/0	ALLOW

Note: Because the Network ACLs are stateless in Amazon EC2, rule 99 maintains the Remote Desktop connection initiated from the admin subnet when rule 100 is set to “deny” in step 5.

Step 5: Start capture on NAT instance

From the linux admin instance connect with ssh to the NAT instance and start the network capture.

```
sudo tcpdump -ni eth0 host 172.31.1.[N] -s0 -w [aaaammdd-malware-name-test].pcap -v
```

The option -s0 sets the snaplen to the default value of the system (262144 bytes).

The option -w writes captured data to a pcap file.

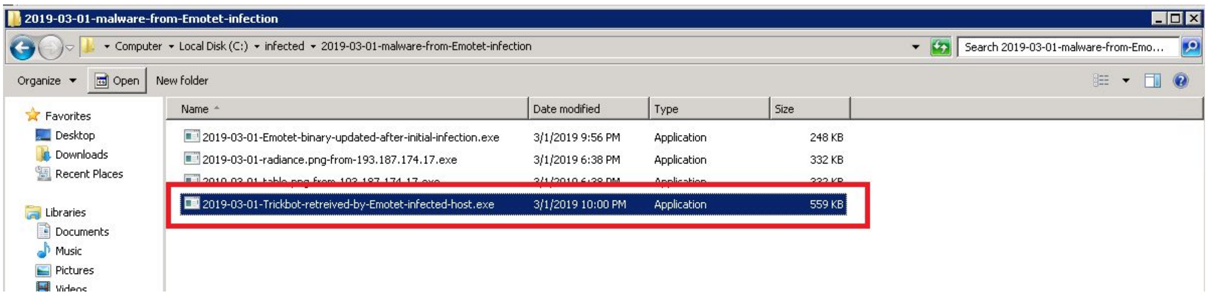
The option -v provides captured packets statistics

Step 6: Malware inoculation

From the Windows admin instance connect with remote desktop client to the test Windows machine.

On the Windows virtual machine stop the sharing of the folder “infected”.

Decompress the archive with the associated password and execute the malware binary.

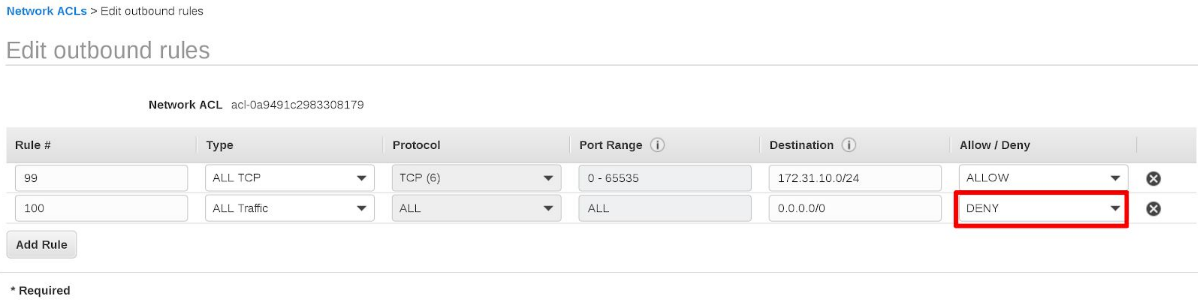


Name	Date modified	Type	Size
2019-03-01-Emotet-binary-updated-after-initial-infection.exe	3/1/2019 9:56 PM	Application	248 KB
2019-03-01-radiance.png-from-193.187.174.17.exe	3/1/2019 6:38 PM	Application	332 KB
2019-03-01-table.png-from-193.187.174.17.exe	3/1/2019 6:38 PM	Application	332 KB
2019-03-01-Trickbot-retreived-by-Emotet-infected-host.exe	3/1/2019 10:00 PM	Application	559 KB

Step 7: Deny all outgoing traffic for infected zone

When the capture is considered finished by the security analyst, block all outgoing traffic for the infected subnet.

Edit the network ACL for the infected zone and deny all outbound traffic.



Network ACLs > Edit outbound rules

Edit outbound rules

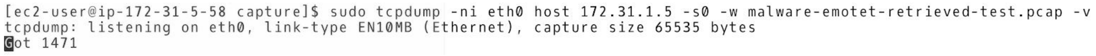
Network ACL acl-0a9491c2983308179

Rule #	Type	Protocol	Port Range	Destination	Allow / Deny
99	ALL TCP	TCP (6)	0 - 65535	172.31.10.0/24	ALLOW
100	ALL Traffic	ALL	ALL	0.0.0.0/0	DENY

* Required

Step 8: Stop the capture

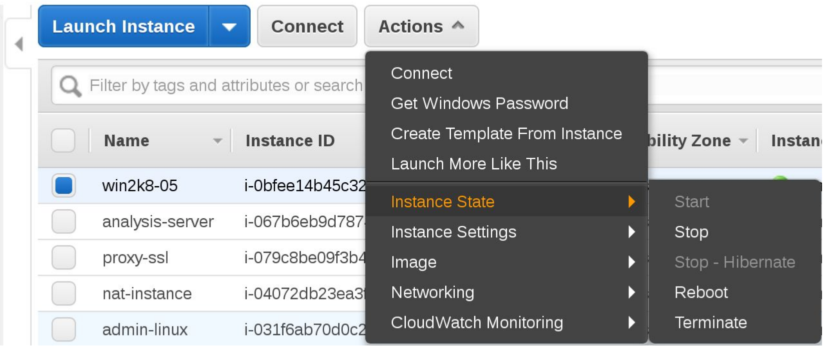
Stop the capture with CTRL+C keyboard touch combination to stop the capture tcpdump.



```
[ec2-user@ip-172-31-5-58 capture]$ sudo tcpdump -ni eth0 host 172.31.1.5 -s0 -w malware-emotet-retrieved-test.pcap -v
tcpdump: listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
Got 1471
```

Step 9: Stop the virtual machine

In the instance panel, select the Windows server instance, click Actions>Instance State>Stop.



☐	Name	Instance ID	bility Zone	Instan
☑	win2k8-05	i-0bfee14b45c32		
☐	analysis-server	i-067b6eb9d787		
☐	proxy-ssl	i-079c8be09f3b4		
☐	nat-instance	i-04072db23ea3		
☐	admin-linux	i-031f6ab70d0c2		

Step 10: Collect the malware traffic pcap file

From the linux analysis instance retrieve with scp command the pcap file from the NAT instance. The following command line transfers the file from the NAT instance to the local analysis instance.

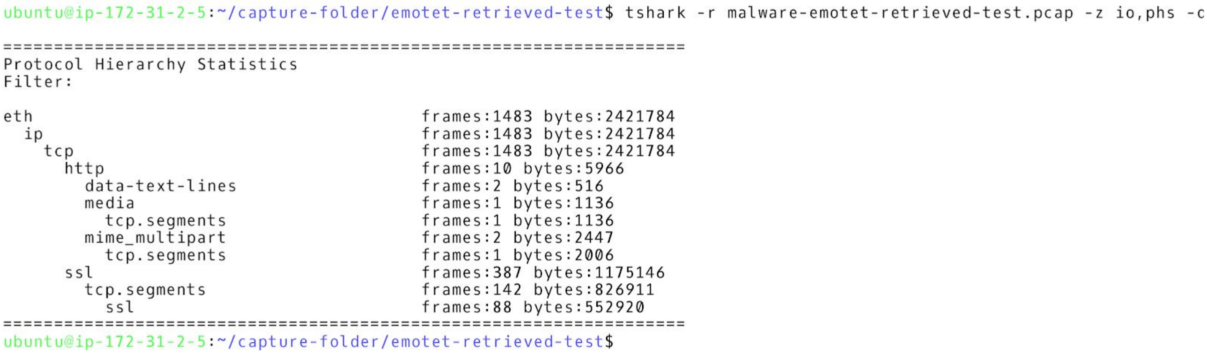
```
scp -i /[folder]/[amazon server key].pem ec2-user@172.31.5.58:/[location of the file captured]/[name_capture].pcap .
```

Step 11: Processing the files

We used this following tshark command line to have an overview of the traffic:

```
tshark -r [capture file].pcap -z io,phs -q
```

The traffic generated by the malware uses TCP protocol with HTTP and SSL on TCP/IP application layer. We can see 387 out of 1483 frames use SSL/TLS protocol.



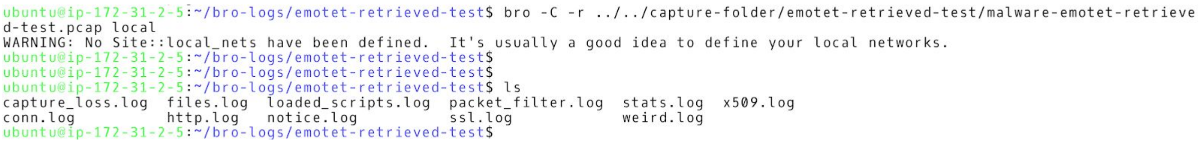
```
ubuntu@ip-172-31-2-5:~/capture-folder/emotet-retrieved-test$ tshark -r malware-emotet-retrieved-test.pcap -z io,phs -c

===================================================================
Protocol Hierarchy Statistics
Filter:

eth                                      frames:1483 bytes:2421784
  ip                                     frames:1483 bytes:2421784
    tcp                                  frames:1483 bytes:2421784
      http                               frames:10 bytes:5966
        data-text-lines                  frames:2 bytes:516
        media                            frames:1 bytes:1136
          tcp.segments                   frames:1 bytes:1136
        mime_multipart                   frames:2 bytes:2447
          tcp.segments                   frames:1 bytes:2006
      ssl                                frames:387 bytes:1175146
        tcp.segments                     frames:142 bytes:826911
          ssl                            frames:88 bytes:552920
===================================================================
ubuntu@ip-172-31-2-5:~/capture-folder/emotet-retrieved-test$
```

In this example we execute Zeek Bro analysis of the pcap file collected.

Create a folder for classifying the Zeek Bro logs, change directory into this folder and execute Bro command line as shown in the previous chapters:

```
Bro -C -r [capture file].pcap local
```

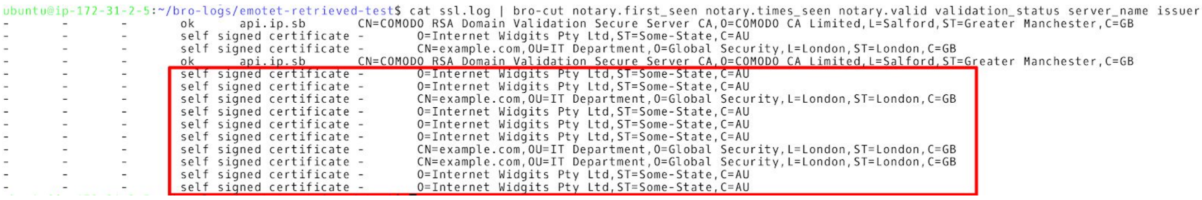
Zeek Bro execution provides ssl.log and x509.log confirming the presence of SSL/TLS exchanges between the malware and the C&C server. However, even though intelligence framework is activated for SSLabuse blacklist, there is no alert for certificates analyzed by Zeek Bro.



```
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$ bro -C -r ../../capture-folder/emotet-retrieved-test/malware-emotet-retrieve
d-test.pcap local
WARNING: No Site::local_nets have been defined.  It's usually a good idea to define your local networks.
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$ ls
capture_loss.log  files.log  loaded_scripts.log  packet_filter.log  stats.log  x509.log
conn.log          http.log   notice.log          ssl.log            weird.log
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$
```

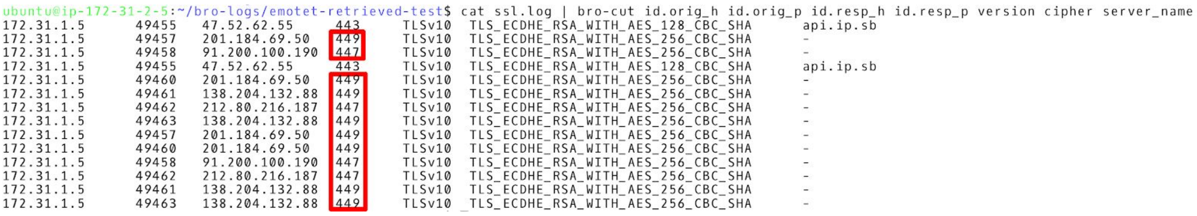
If we analyze the ssl.log we can see several usages of self-signed certificate. However, api.ip.sb access is done to a server providing a verified certificate. After some research we have discovered that the website api.ip.sb is a REST API service used to provide IPv4 information of the requester. Typically, the malware gathers information about the public IPv4 of the victim.

```
cat ssl.log | bro-cut notary.first_seen notary.times_seen notary.valid validation_status \
server_name issuer
```



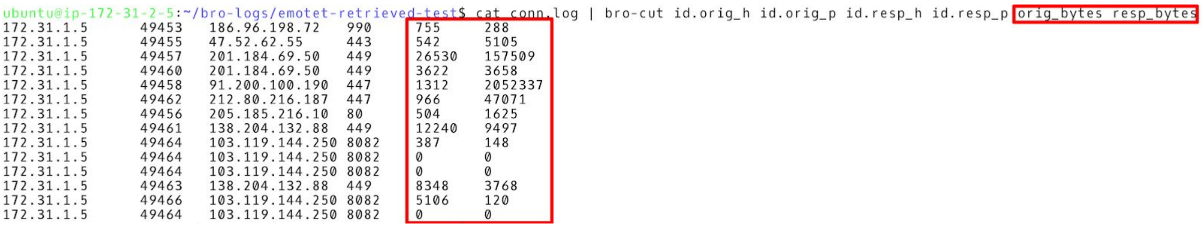
```
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$ cat ssl.log | bro-cut notary.first_seen notary.times_seen notary.valid validation_status server_name issuer
-       -       -       ok      api.ip.sb       CN=COMODO RSA Domain Validation Secure Server CA,O=COMODO CA Limited,L=Salford,ST=Greater Manchester,C=GB
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
-       -       -       self signed certificate -       CN=example.com,OU=IT Department,O=Global Security,L=London,ST=London,C=GB
-       -       -       ok      api.ip.sb       CN=COMODO RSA Domain Validation Secure Server CA,O=COMODO CA Limited,L=Salford,ST=Greater Manchester,C=GB
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
-       -       -       self signed certificate -       CN=example.com,OU=IT Department,O=Global Security,L=London,ST=London,C=GB
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
-       -       -       self signed certificate -       CN=example.com,OU=IT Department,O=Global Security,L=London,ST=London,C=GB
-       -       -       self signed certificate -       CN=example.com,OU=IT Department,O=Global Security,L=London,ST=London,C=GB
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
-       -       -       self signed certificate -       O=Internet Widgits Pty Ltd,ST=Some-State,C=AU
```

The malware uses unconventional TCP ports to communicate in TLS version 1.0 which is a suspicious behavior. The observed TLS ports are TCP/443, TCP/449, TCP/447. In our experimentation, we did not intercept the TLS traffic and can only make an assumption about the malware execution.



```
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$ cat ssl.log | bro-cut id.orig_h id.orig_p id.resp_h id.resp_p version cipher server_name
172.31.1.5      49455   47.52.62.55     443     TLSv10  TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA      api.ip.sb
172.31.1.5      49457   201.184.69.50   449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49458   91.200.100.190  447     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49455   47.52.62.55     443     TLSv10  TLS_ECDHE_RSA_WITH_AES_128_CBC_SHA      api.ip.sb
172.31.1.5      49460   201.184.69.50   449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49461   138.204.132.88  449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49462   212.80.216.187  447     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49463   138.204.132.88  449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49457   201.184.69.50   449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49460   201.184.69.50   449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49458   91.200.100.190  447     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49462   212.80.216.187  447     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49461   138.204.132.88  449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
172.31.1.5      49463   138.204.132.88  449     TLSv10  TLS_ECDHE_RSA_WITH_AES_256_CBC_SHA      -
```

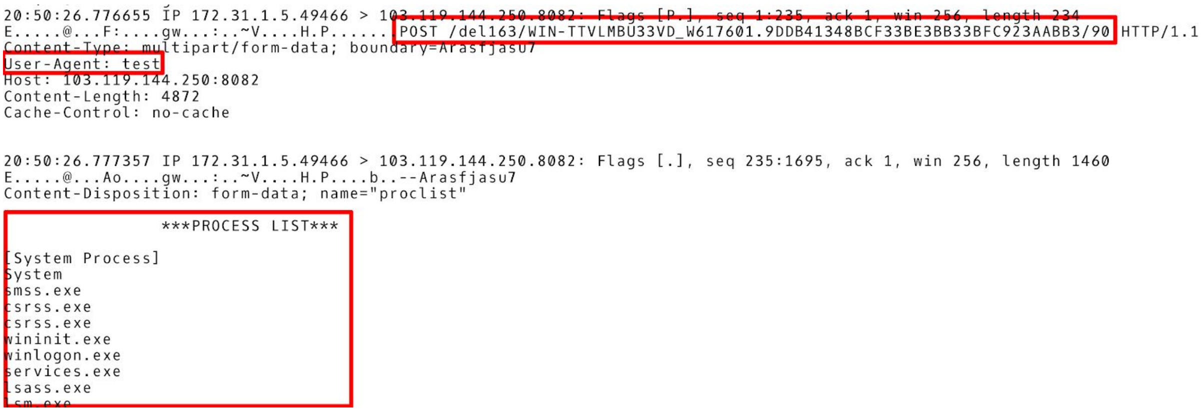
Based on the conn.log, we analyzed the total bytes exchanged in each connection. The results led us to the hypothesis of an additional download from the malware to perform the next actions which were not in TLS protocol in TCP/8082.



```
ubuntu@ip-172-31-2-5:~/bro-logs/emotet-retrieved-test$ cat conn.log | bro-cut id.orig_h id.orig_p id.resp_h id.resp_p orig_bytes resp_bytes
172.31.1.5      49453   186.96.198.72   990     755     288
172.31.1.5      49455   47.52.62.55     443     542     5105
172.31.1.5      49457   201.184.69.50   449     26530   157509
172.31.1.5      49460   201.184.69.50   449     3622    3658
172.31.1.5      49458   91.200.100.190  447     1312    2052337
172.31.1.5      49462   212.80.216.187  447     966     47071
172.31.1.5      49456   205.185.216.10  80      504     1625
172.31.1.5      49461   138.204.132.88  449     12240   9497
172.31.1.5      49464   103.119.144.250 8082    387     148
172.31.1.5      49464   103.119.144.250 8082    0       0
172.31.1.5      49464   103.119.144.250 8082    0       0
172.31.1.5      49463   138.204.132.88  449     8348    3768
172.31.1.5      49466   103.119.144.250 8082    5106    120
172.31.1.5      49464   103.119.144.250 8082    0       0
```

The analysis of the communication on TCP port 8082 shows the malware was sending the victim system information to the C&C server.

```
tcpdump -nn -r [capture file].pcap  tcp port 8082 -A
```



```
20:50:26.776655 IP 172.31.1.5.49466 > 103.119.144.250.8082: Flags [P.], seq 1:235, ack 1, win 256, length 234
E.....@...F:....gw...:..~V....H.P...... POST /del163/WIN-TTVLMBU33VD_W617601.9DDB41348BCF33BE3BB33BFC923AABB3/90 HTTP/1.1
Content-Type: multipart/form-data; boundary=Arasfjasu7
User-Agent: test
Host: 103.119.144.250:8082
Content-Length: 4872
Cache-Control: no-cache


20:50:26.777357 IP 172.31.1.5.49466 > 103.119.144.250.8082: Flags [.], seq 235:1695, ack 1, win 256, length 1460
E.....@...Ao....gw...:..~V....H.P....b..--Arasfjasu7
Content-Disposition: form-data; name="proclist"

                ***PROCESS LIST***

[System Process]
System
smss.exe
csrss.exe
csrss.exe
wininit.exe
winlogon.exe
services.exe
lsass.exe
lsm.exe
```