FIT3031 - Network Security: Assignment I (2024 S2)
Total Marks 100
Due date: September 20, Friday, 11:55:00 PM (Melbourne time)

1 Overview

The learning objective of this assignment is for you to gain a first-hand experience on network attacks (i.e., TCP/UDP scanning techniques and DNS attacks) and get a deeper understanding on how to launch these attacks in practice. All tasks in this assignment can be done on the unit's virtual machine
`https://drive.google.com/file/d/1Jm5y1PXE_e_G-gsONg1aJ-aYB29B5bXN/view?usp=sharing`
as used in Lab Week 6-Network Attacks.
This is an **individual** assignment. You are **not** allowed to help or seek help from other people. You are **not** allowed to re-use any previous assessment submission materials (even if they were created by you).

2 Submission Policy

For this assignment, you need to submit two files using a single submission link on Moodle:

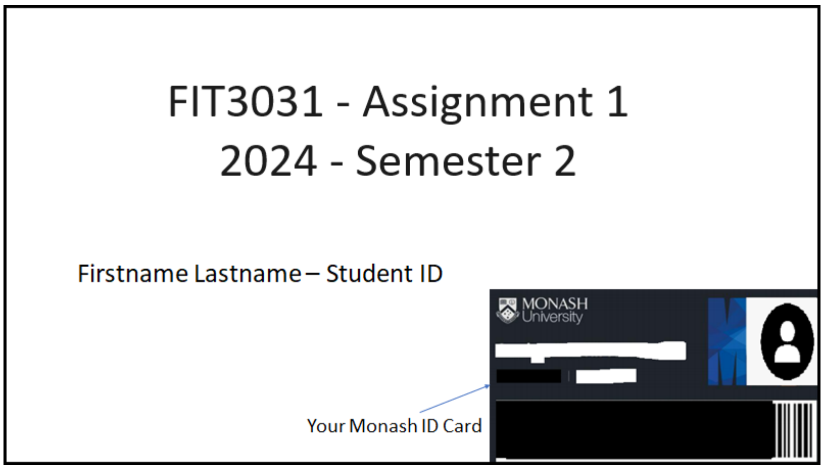
- a single **video file** containing the recording of you carrying out all tasks, and
- a single **scanner.py** file containing the final Python script from Section 4.

Name your submission files as the format: **[Your Name]-[Student ID]-FIT3031-Assignment1**, e.g., `HarryPotter-12345678-FIT3031-Assignment1.mp4`. The Python codes for Section 4 should be included in a separate `scanner.py` file.

Moodle allows a maximum submission size of 500 MB. Therefore, the total size of the above two submission files should not exceed 500 MB.

Important notes and penalties:

- It is the student's responsibility that the submitted video file can be opened on a standard Windows computer (without requiring specialised software), and that the images and texts shown in the video are understandable/readable (in English). If the video file cannot be opened, you will receive zero mark. After uploading **draft** files (**before** finalising the submission), we recommend you to download your uploaded files and check that they open and run properly and as intended. Once you finalise your submission, you will **not** be able to revise it.
- Note that draft files are **NOT** accepted and will not be marked. You must finalise your submission (with status shown as "submitted for grading") for your assignment to be considered as valid. Otherwise, you may receive late submission penalty or zero mark.
- Note that during your assignment submission, you may see a Turnitin warning for your **video file** stating something of the form "This file will not be submitted to Turnitin…". **This is completely fine**, and you can simply ignore this message. The video file is not scanned by Turnitin.
- At the beginning of your recording, you must clearly show your face and have your photo ID (preferably your Monash ID with photo) presented in the first slide as shown below (please update the slide contents as appropriate). Make sure the ID card details are clearly readable/visible.



FIT3031 - Assignment 1
2024 - Semester 2

Firstname Lastname – Student ID

Your Monash ID Card

MONASH University

[redacted]

[redacted]

Figure 1: Sample opening slide

- A part of the submitted video (at a corner) must clearly show your face at all times. The assignment will be deemed invalid and receive zero mark when that's not the case.

- Late submissions incur a 5-point deduction per calendar day. For example, if you submit 2 days and 1 hour late, that incurs 15-point deduction. Submissions more than 7 calendar days late will receive a zero mark.

- If you require extension or special consideration, refer to `https://www.monash.edu/students/admin/assessments/extensions-special-consideration`. No teaching team member is allowed to give you extension or special consideration, so please do not reach out to a teaching team member about this. Follow the guidelines in the aforementioned link. When requesting extension/special consideration via the central system, please select the correct assessment name from the provided drop-down menu, and **not manually type** an assessment name.

- **The maximum allowed duration for the recorded video is 15 mins**. Therefore, only the first 15:00 mins of your submitted video will be marked. Any exceeding video components will be ignored. Speeding up the video recording (e.g. using a software) is not allowed and such submissions will receive a zero mark.

- If your device does not have a camera (or for whatever reason you can't use your device), you can borrow a device from Monash Connect or Library. It's your responsibility to plan ahead for this. Monash Connect or Library not having available devices for loan at a particular point in time is not a valid excuse.

- You can create multiple video parts at different times, and combine and submit a single video at the end. Make sure that the final video is clear and understandable.

- All tasks must be live demonstrated instead of explaining an already completed task. You are **not** allowed to add voice-over later on. You are also **not** allowed to read from prepared scripts. At the beginning of each task, please clearly mention what task is being carried out in the video.

- If any task requires installing new software, you are allowed to do that in advance of recording your video. You do not need to demonstrate software installation in the video.

- You can do (online) research in advance, take brief notes[1] and make use of them during your video recording. You may also prepare Python codes in advance. But you cannot simply copy-paste commands to carry out the tasks without any explanations. Explanations (of what the code does) while completing the tasks are particularly important.

- In Section 5.2, you may need to run the attack for a long time (in the order of a few hours) due to brute forcing. In this case, you can record the parts until the time-consuming step, pause/stop the

[1]The notes cannot be full scripts that you just read in the video. They should only be brief reminders for you.

video recording, and then continue to record once the time-consuming step concludes. You may merge multiple recordings as mentioned before.

- Zero tolerance on plagiarism and academic integrity violations: If you are found not adhering to the Monash Academic Integrity Policies, penalties will apply, e.g., a zero grade for the unit. The demonstration video is also used to detect/avoid plagiarism. University policies can be found at `https://www.monash.edu/students/academic/policies/academic-integrity`.

3 Environment Setup

In this section, you need to double check whether you have configured GNS3 correctly. We will be using the Week06 lab configuration, i.e., your GNS3 configuration should look like below:

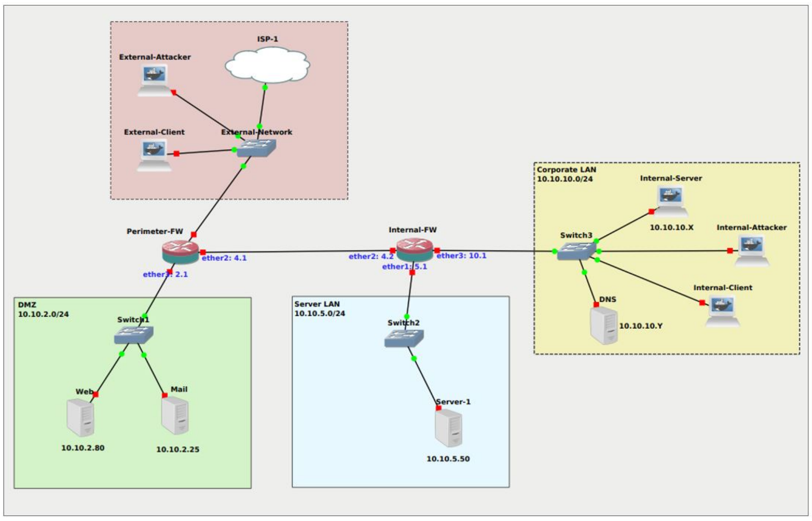


Figure 2: GNS3 Config

Otherwise, if you just downloaded the VM for the first time, we refer you to Environment Setup in Week 01 (`https://learning.monash.edu/course/view.php?id=19340&section=7`). It is recommended to perform lab tasks of Week06 before proceeding.

4 Port Scanning Techniques [40 Marks]

A port scan is a common technique used by attackers to discover entry points in a system. The following task focuses on network traffic analysis and security measures related to port scanning techniques. By following the steps, students will analyse network interactions between a client and a server, identify and interpret the type of scan used, and explore countermeasures to enhance security. Additionally, students will gain practical experience by implementing evasive techniques in a scanner script and observing the effects. The goal is to deepen understanding of port scanning concepts and hands-on mitigation strategies.

Download and copy the `server.py` file on to the Internal-Server and `scanner.py` on to the Internal-Attacker. Run Wireshark on any link between the 2 nodes. Run `server.py` as below with **your student ID**.

IMPORTANT: If you don't use the correct student ID, your attempt will be deemed invalid and you will receive zero mark for this Section 4.

```
python3 server.py <Student ID>
```

Running the script with your student ID will always open the same unique set of ports on the server.

Now run `scanner.py` as below and observe the traffic in Wireshark.

```
python3 scanner.py <Server IP>
```

Q1: Identify and explain the type of TCP scan by observing the traffic seen in Wireshark. Explain how the scan works. **(2.5 marks)**

Q2: Detecting port scans is an important aspect of network security as port scans can be an early indication of malicious intent. There are several methods and tools to help detect port scanning activities. Identify 3 traffic patterns you observed which can be used to detect the above-mentioned type of TCP port scans. **(6 marks)**

Q3: Evading port scanning countermeasures is often a tactic used by attackers to avoid detection. While these techniques are illegal and unethical when used without permission, understanding them is critical for strengthening security defences. Identify and explain 3 ways the above TCP scan can be modified to evade the countermeasures identified in the previous step. **(6 marks)**

Q4: Improve the `scanner.py` script by implementing at least 2 evading mechanisms identified in the previous question. Run the scanner again and demonstrate the improvements using Wireshark. A part of the video must show and explain your Python code. **(8 marks)**

Now run `scanner.py` with UDP scan and observe the traffic in Wireshark.

```
python3 scanner.py <Server IP> --udp
```

Q5: Observe the traffic and explain how the UDP scan works **(2.5 marks)**.
Explain why UDP scan results of the above scan can be unreliable. Identify and explain a technique that you could use to make the scan results more reliable. **(10 marks)**

Q6: Implement the above-mentioned technique in your script and perform the attack again. Demonstrate using the traffic in Wireshark to confirm the correct implementation. A part of the video must show and explain your Python code. **(5 marks)**

Notes.

1. All questions (Q1 to Q6) in Section 4 require a live demonstration and must be included in the final submission video. All explanations should be provided during the demonstration.
2. Do not use Python scripts in your demonstration or explanations unless explicitly mentioned in the question.
3. You may use the `--start-port` and `--end-port` arguments with the scanner.py to scope the scan into a small port range for demonstration purposes.
4. You must submit the final `scanner.py` file on Moodle as part of your assignment submission.

5 DNS Attacks – Using Scapy [60 Marks]

Domain Name System (DNS) is an essential component of the Internet infrastructure. It serves as the phone book for the Internet, so computers can look up for a "telephone number" (i.e. an IP address) from domain names. Without knowing the IP address, computers will not be able to communicate with one another. Due to its importance, the DNS infrastructure faces frequent attacks. In this section, you will explore the most primary attack on DNS. That is DNS cache poisoning by investigating both Local and Remote DNS cache poisoning attacks.

Due to the large number of computers and networks on the Internet, the domain namespace is organised in a hierarchical tree-like structure. Each node on the tree is called a domain, or sub-domain when referencing to its child node. The following figure depicts a part of the domain hierarchy.

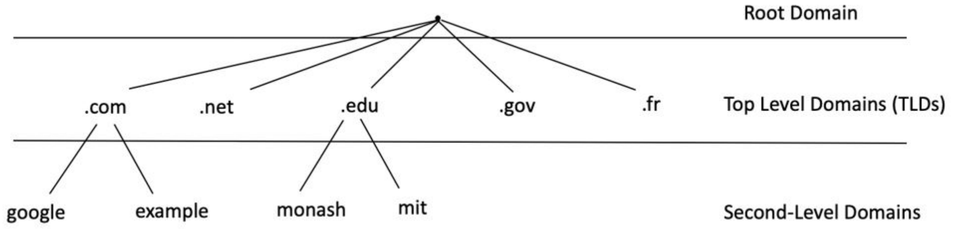


Figure 3: Domain hierarchy

The domain hierarchy tree structure describes how the domain namespace is organised, but that is not exactly how the domain name systems are organised. Domain name systems are organised according to zones. A DNS zone basically groups contiguous domains and sub-domains on the domain tree, and assign the management authority to an entity. Each zone is managed by an authority, while a domain does not indicate any authority information. The following figure depicts an example of the `example.com` domain.

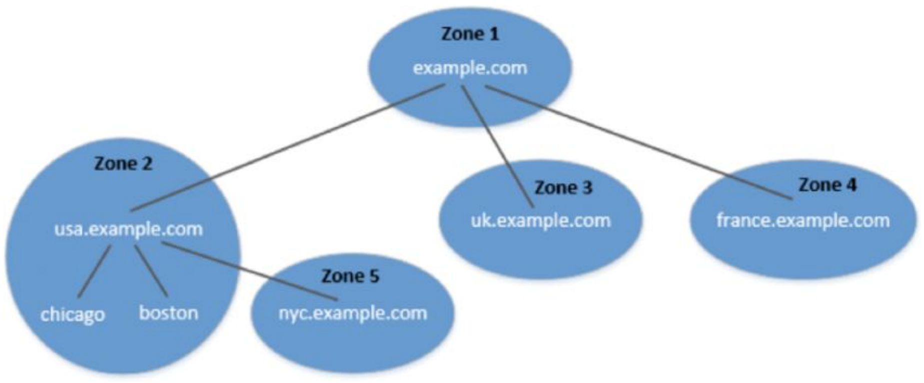
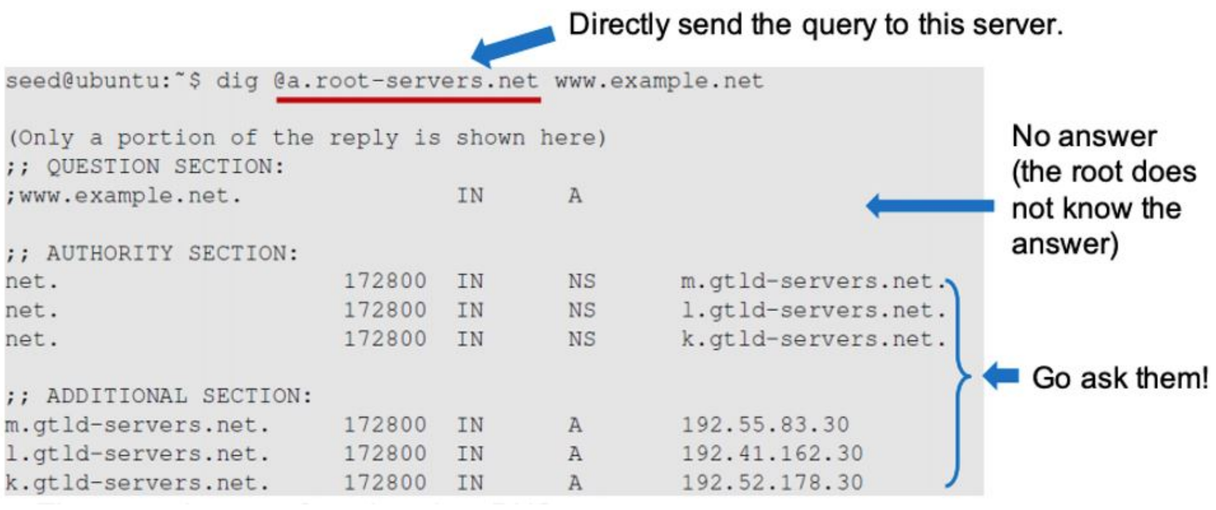


Figure 4: DNS Zones

Assume that `example.com` in the above figure is an international company, with branches all over the world, so the company's domain is further divided into multiple sub-domains, including `usa.example.com`, `uk.example.com`, and `france.example.com`. Inside US, the usa sub-domain is further divided into `chicago`, `boston`, and `nyc` subdomains.

Each DNS zone has at least one authoritative nameserver that publishes information about that zone. The goal of a DNS query is to eventually ask the authoritative DNS server for answers. That is why they are called authoritative because they provide the original and definitive answers to DNS queries, as opposed to obtaining the answers from other DNS servers.

With such arrangement, the root zone for example.com only needs to keep records of who the authority is for each of its subdomains. By doing this, it maintains the independence among the branches in different countries and enable the administrative right of those subdomains, so the branch in each country manages its own DNS information. For a given DNS query, if your local DNS server does not know the answer, it asks other DNS servers on the Internet for answer via hierarchical authority servers. The following example demonstrates a dig (DNS query) for the domain `www.example.net` when sending the query directly to one of the root servers (i.e. `a.root-servers.net`).



```
seed@ubuntu:~$ dig @a.root-servers.net www.example.net

(Only a portion of the reply is shown here)
;; QUESTION SECTION:
;www.example.net.                IN      A

;; AUTHORITY SECTION:
net.                    172800   IN      NS      m.gtld-servers.net.
net.                    172800   IN      NS      l.gtld-servers.net.
net.                    172800   IN      NS      k.gtld-servers.net.

;; ADDITIONAL SECTION:
m.gtld-servers.net.     172800   IN      A       192.55.83.30
l.gtld-servers.net.     172800   IN      A       192.41.162.30
k.gtld-servers.net.     172800   IN      A       192.52.178.30
```

Directly send the query to this server.
No answer (the root does not know the answer)
Go ask them!

Figure 5: DIG to the root server

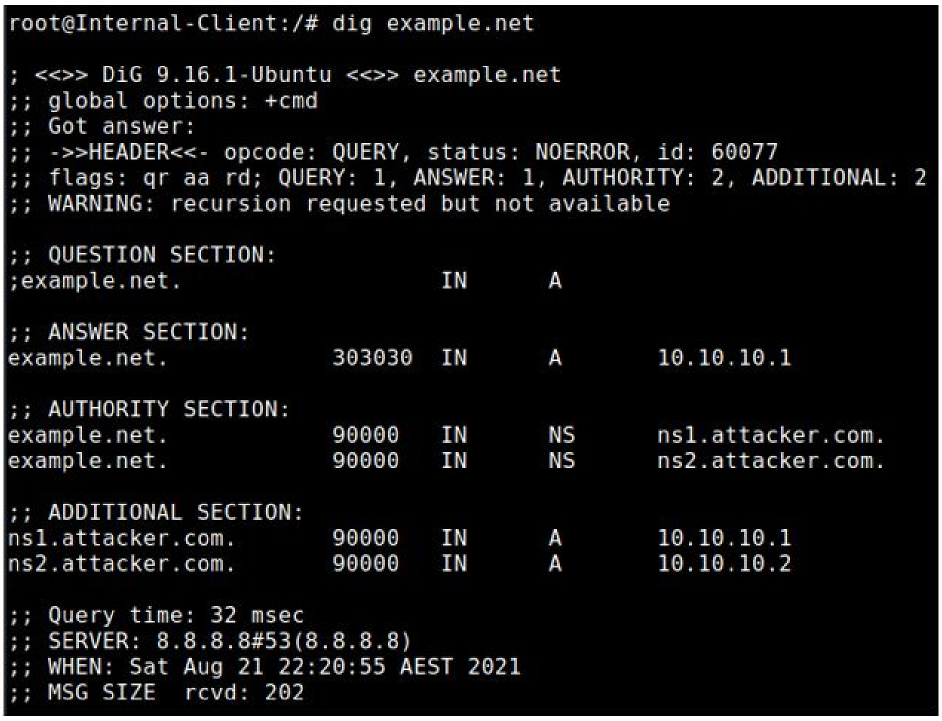
There are four types of sections in a DNS response: *question section*, *answer section*, *authority section*, and *additional section*. From the above result, we can see that the root server does not know the answer (because the reply does not include an answer section, but it tells several authoritative nameservers for the `net` zone (the NS records in the authority section), along with their IP address if possible in the *additional section*). If you continuously dig the domain `www.example.net` on one these authoritative nameservers, you will finally end up with the answer section showing the IP address of the machine hosting the website for `www.example.net`.

When your local DNS server gets information from other DNS servers, it caches the information, so if the same information is needed, it will not waste time to ask again.

5.1 Local DNS Attack targeting Authoritative Nameserver [20 Marks]

We recalled that a DNS response contains question section, *answer section*, *authority section*, and *additional section*. If we only target the *answer section*, the attack only affects one hostname (as we did in our Week06 lab "DNS Spoofing Attacks"). Real DNS attacks usually target the authority section by providing a fake NS record for the target domain in the authority section. If the fake NS record is cached, when a victim's local DNS server tries to find any IP address in the target domain, it will send a request to the malicious nameserver specified in the fake NS record. Such an attack can affect all the hostnames in the target domain. In this task, you will explore how to target the authoritative server of `example.net` and replace it with `ns1.attacker.com` and `ns2.attacker.com`.

Q6: Using `Internal-Client` as victim and `Internal-Attacker` as the attacker machine, perform a DNS spoofing attack that modifies the authoritative server of `example.net` to be `ns1.attacker.com` and `ns2.attacker.com`. Please record and submit a video showing **and** explaining how you performed the attack. A part of the video must show and explain your Python code. **(20 marks)**
Hint: If the attack works, you should see a result as in the following figures for which the malicious authoritative servers have taken place.



```
root@Internal-Client:/# dig example.net

; <<>> DiG 9.16.1-Ubuntu <<>> example.net
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 60077
;; flags: qr aa rd; QUERY: 1, ANSWER: 1, AUTHORITY: 2, ADDITIONAL: 2
;; WARNING: recursion requested but not available

;; QUESTION SECTION:
;example.net.                   IN      A

;; ANSWER SECTION:
example.net.            303030  IN      A       10.10.10.1

;; AUTHORITY SECTION:
example.net.            90000   IN      NS      ns1.attacker.com.
example.net.            90000   IN      NS      ns2.attacker.com.

;; ADDITIONAL SECTION:
ns1.attacker.com.       90000   IN      A       10.10.10.1
ns2.attacker.com.       90000   IN      A       10.10.10.2

;; Query time: 32 msec
;; SERVER: 8.8.8.8#53(8.8.8.8)
;; WHEN: Sat Aug 21 22:20:55 AEST 2021
;; MSG SIZE  rcvd: 202
```

Figure 6: Successful DNS spoofing attack

5.2 Remote DNS Attack targeting Authoritative Server [40 Marks]

For this task, the attacker (`Internal-Attacker`) and `DNS` server need to be in different LAN. We will move `DNS` server back to the Server LAN and configure its IP statically. The GNS3 configuration for this task should look like below:

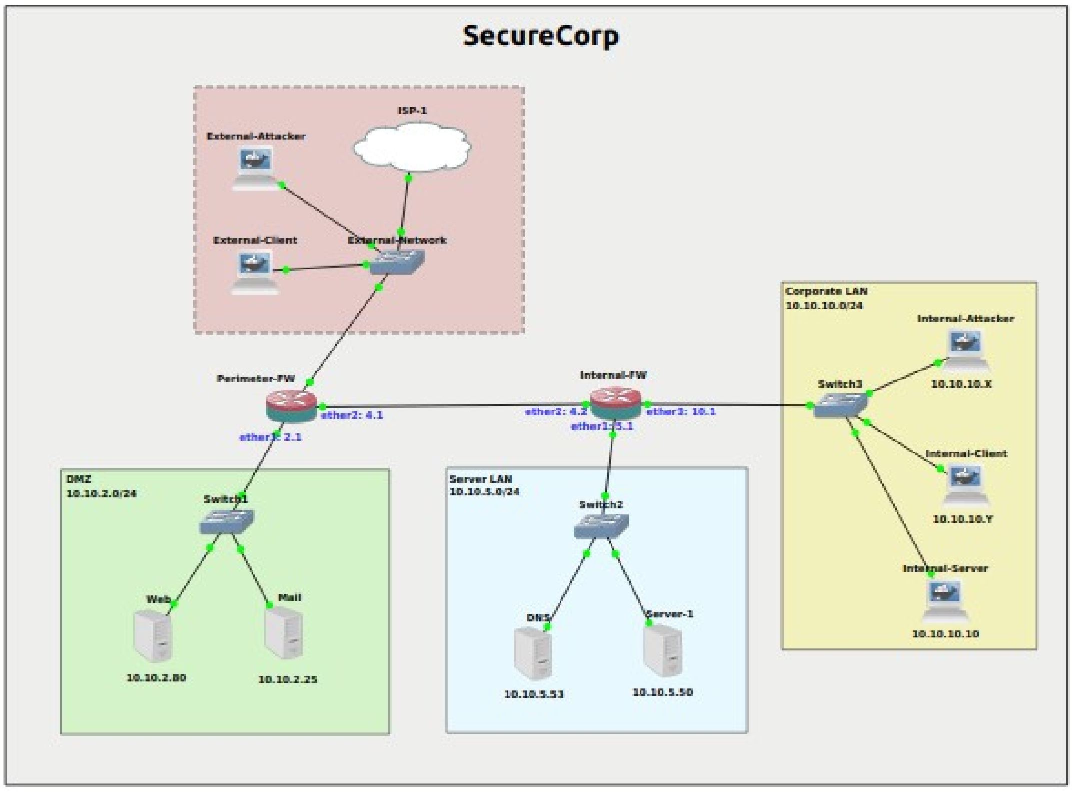
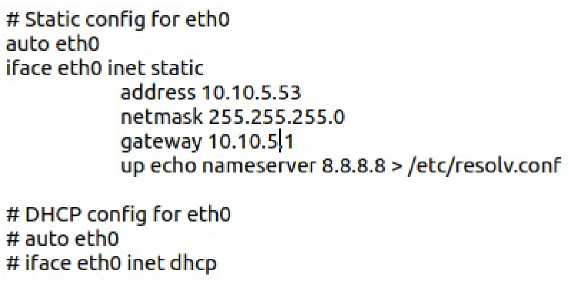


Figure 7: GNS3 for Remote DNS Attacks

Configure static IP for DNS:



```
# Static config for eth0
auto eth0
iface eth0 inet static
        address 10.10.5.53
        netmask 255.255.255.0
        gateway 10.10.5.1
        up echo nameserver 8.8.8.8 > /etc/resolv.conf

# DHCP config for eth0
# auto eth0
# iface eth0 inet dhcp
```

Figure 8: Static IP config for `DNS`

Now login to `Internal-FW` (username is 'admin', no password), and execute the following to disable NAT:

```
ip firewall nat remove 0
```

Then login to `Perimeter-FW` (username is 'admin', no password), and execute the following to enable NAT only to the public facing interface:

```
ip firewall nat remove 0
ip firewall nat add chain=srcnat action=masquerade out-interface=ether1
```

The previous local DNS attacks assume that the attacker and the DNS victim server are on the same LAN so that the attacker can observe the DNS query message and reply with a forged DNS packet. When the attacker and the DNS server are not on the same LAN, the attack becomes harder since the attacker cannot perform ARP poisoning attack and see the DNS query. When the DNS victim server cannot resolve a DNS query, it forwards the DNS query packet to the forwarder DNS server (Google DNS server in our current setup). The DNS query is sent via a UDP packet where the UDP's source port is a 16-bit random number. In addition, the 16-bit transaction ID in the DNS header is also self-created by the DNS victim server. Hence, if the remote attacker wants to forge the DNS response, the forged packet must contain the correct values of these two numbers; otherwise, the reply will not be accepted.

Without being able to sniff the query packet, the remote attacker can only guess these two numbers. The chance is one out of 2^{32} for each guess. If an attacker can send out 1000 spoofed responses, it may take several days to try up 2^{32} time. In contrast, it only takes few seconds to receive the correct packet response from the forwarder Google DNS. Consequently, that real reply will be cached by the local DNS victim server. To make another try, the attacker has to wait for the server to send out another DNS query when its cache times out. Hence, this attacking chance makes the remote DNS attack unrealistic.

The remote DNS attack had become an open problem until Dan Kaminsky came up with a simple trick in 2008. The attack is depicted in the following figure.

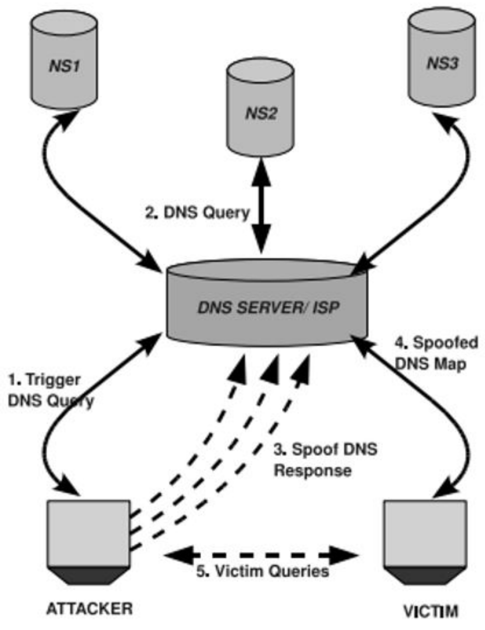


Figure 9: Kaminsky Attack

We choose a domain `test.com` as our targeted domain name in this task. When a client queries the `DNS` server for `www.test.com`, the attacker (`Internal-Attacker`) wants to cause the `DNS` server to use their DNS server (`ns.attacker.com`). The following steps with reference to above figure describe the outline of the attack.

1. The attacker queries the `DNS` server for a non-existing name in `test.com`, for example `xyz123.test.com`, where `xyz123` is a random name.
2. Since the mapping resolution cannot be resolved by the DNS server's cache, the server forwards the query to Google DNS (8.8.8.8) for that name resolution.
3. In the meantime, the attacker floods the `DNS` server with many spoofed DNS responses, each trying a different transaction ID and source port number (hoping one guess is correct). In that forged response, not only the attacker provides the IP resolution for the hostname `xyz123.test.com`, but also provides an authoritative name server for the domain `test.com`.

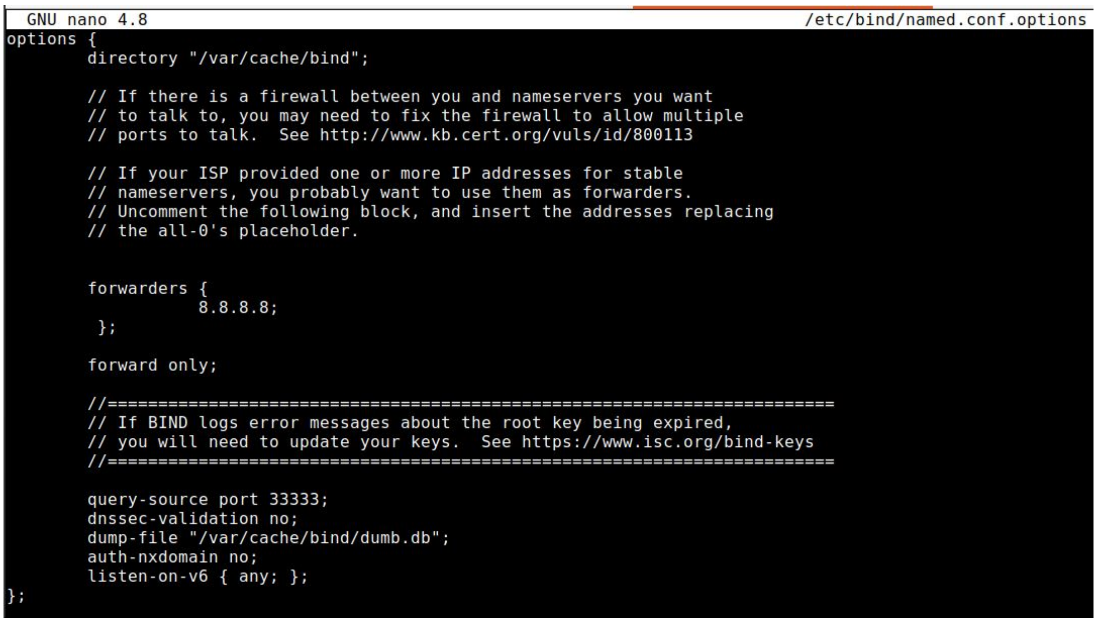
   Even if the response failed, the attacker would go back to Step 1, and try another non-existing random name until the attacker succeeds.
4. Once the attack succeeds, when the client sends a DNS query to the poisoned DNS server for `www.test.com`, the nameserver returned by the `DNS` server will actually be set by the attacker.

To simplify and shorten the attack's simulation time in this task, we suggest you follow the below steps before doing the task.

1. Double check the IP addresses of the server, attacker, and client to ensure the server and the attacker are not in the same LAN (using ifconfig command)
   - `DNS`: 10.10.5.53
   - `Internal-Attacker`: 10.10.10.X
   - `Internal-Client`: 10.10.10.X
2. In the DNS server's terminal, you can type the following command to configure DNS

   ```
   nano /etc/bind/named.conf.options
   ```

   Then, you should configure the forwarder 8.8.8.8, enable recursion and fix the query source port of the DNS server (i.e. 33333). With this constraint, the attacker now only needs to guess the transactionID of the DNS packet when performing remote DNS attacks. You can review the following figure for the correct configuration of DNS server.



```
  GNU nano 4.8                                                  /etc/bind/named.conf.options
options {
        directory "/var/cache/bind";

        // If there is a firewall between you and nameservers you want
        // to talk to, you may need to fix the firewall to allow multiple
        // ports to talk.  See http://www.kb.cert.org/vuls/id/800113

        // If your ISP provided one or more IP addresses for stable
        // nameservers, you probably want to use them as forwarders.
        // Uncomment the following block, and insert the addresses replacing
        // the all-0's placeholder.


        forwarders {
                   8.8.8.8;
         };

        forward only;

        //========================================================================
        // If BIND logs error messages about the root key being expired,
        // you will need to update your keys.  See https://www.isc.org/bind-keys
        //========================================================================

        query-source port 33333;
        dnssec-validation no;
        dump-file "/var/cache/bind/dumb.db";
        auth-nxdomain no;
        listen-on-v6 { any; };
};
```

Figure 10: DNS server config file

3. After making the changes in the above step, you should restart your DNS server by using the following command

```
/etc/init.d/named restart
```

We provide you the `remote_dns.py` script template on Moodle that helps to perform the Kaminsky attack.

Q7: You need to complete Step 1 in the `remote_dns.py` to create 10000 dummy hostnames. Demonstrate and explain this task as before in your recorded video. **(5 marks)**

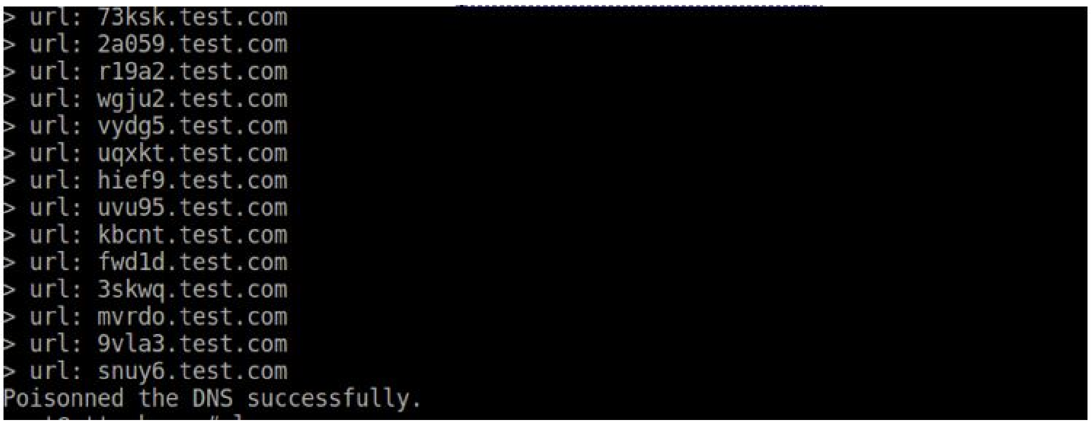
Q8: You need to complete Step 2 in the `remote_dns.py` to generate a random DNS query for each dummy hostnames. Demonstrate and explain this task as before in your recorded video.**(5 marks)**

Q9: You need to complete Step 3 in the `remote_dns.py` to flood about 100 random forged response packets. Demonstrate and explain this task as before in your recorded video. The demo should show that

- Each packet has a randomly generated transaction ID for DNSpkt. **(5 marks)**
- The malicious DNS server `ns.attacker.com` is included in the nameserver authority for the domain `test.com` when you construct DNSpkt. **(5 marks)**
- *Additional section* showing `ns.attacker.com` has the IP of the attacker 10.10.10.X. **(5 marks)**

Q10: Provide further video demonstration evidence to support and verify that you have performed the attack. In the video, you need to demonstrate the following key points:

- Wireshark traffic captured on `DNS` server on `eth1` shows the `transactionID` in DNS packet sent by `DNS` server to Google, and the correctly matched transaction ID in the forged packet sent by `Internal-Attacker` to the `DNS` server. **(5 marks for step by step explanation of the attack using Wireshark in the demonstration video)**
- Once the poisoning is completed, from `Internal-Client`'s terminal use `dig` command to send a DNS query for the specific subdomain for which the attack was successful (e.g. in below screenshot it's `issnuy6.test.com`). Do you get the attacker's IP? **(5 marks)**
- Now from the same terminal send a DNS query for `www.test.com`. If the attack was successful, the response should show `ns.attacker.com` in the *authority section* for the domain `test.com`. Was your attack successful? Explain in detail why or why not. (hint: you may refer to this paper for further information: `https://www.cs.cornell.edu/~shmat/shmat_securecomm10.pdf`) **(5 marks for your explanation during the demonstration video)**



```
> url: 73ksk.test.com
> url: 2a059.test.com
> url: r19a2.test.com
> url: wgju2.test.com
> url: vydg5.test.com
> url: uqxkt.test.com
> url: hief9.test.com
> url: uvu95.test.com
> url: kbcnt.test.com
> url: fwd1d.test.com
> url: 3skwq.test.com
> url: mvrdo.test.com
> url: 9vla3.test.com
> url: snuy6.test.com
Poisonned the DNS successfully.
```

Figure 11: Attacker's screen shows poisioning was successful

6 Acknowledgement

Parts of this assignment and instructions are based on the SEED project (Developing Instructional Laboratory for Computer Security Education) `https://seedsecuritylabs.org`.