Computer Security Capstone

Project 1:
TLS Connection Hijacking

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Goal

- Understand how to hijack a TLS connection

- You will learn about
  - □ Establish TLS connections with customized certificates
  - □ Handle multiple network connections
  - □ Importance of certificates and identity verification

What is HTTPS?

- Nowadays, HTTPS (HyperText Transfer Protocol Secure) is commonly used to secure HTTP connections between end devices and web servers
- In HTTPS, the communication is encrypted using the Secure Sockets Layer (SSL) or Transport Layer Security (TLS) convention

What is TLS?

- TLS is the successor to SSL
  - It is a security protocol that provides privacy and data integrity for Internet communications

- Key Features
  - Encryption: Protects data transmitted over the network from eavesdropping.
  - Authentication: Uses digital certificates to verify the identity of parties.
  - Data Integrity: Ensures that data has not been altered during transmission

TLS Primer: Certificate and CA

- TLS certificates are crucial for establishing secure connections
  - Containing public keys, identity information, and digital signature
  - Facilitating encryption, authentication, and data integrity

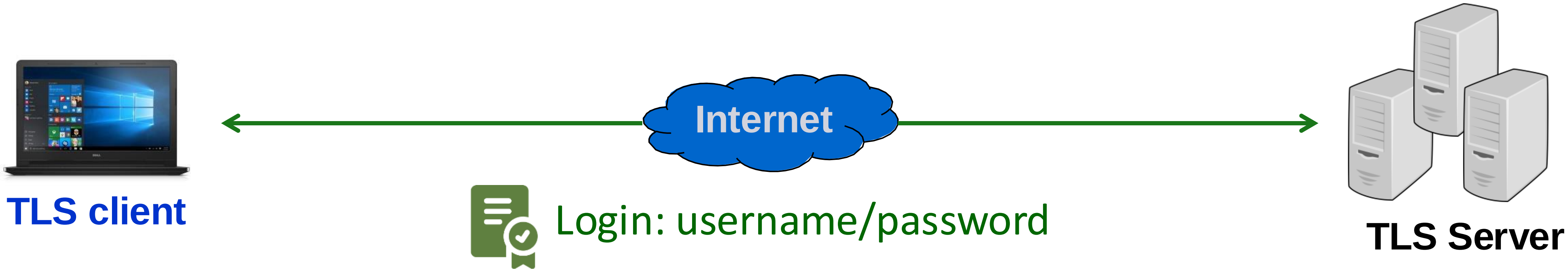
- A certificate authority (CA) is a trusted entity that issues certificates
  - Ensuring the authenticity of websites, domains and organizations
  - Help users verify they are connected to an official website, preventing fake or spoofed sites created by attackers

TLS Primer: Cipher Suite

- Cipher Suites are predefined sets of algorithms that dictate how TLS protects data
- Components of a Cipher Suite
  - Key Exchange Algorithm
    - Securely exchanging cryptographic keys between a client and a server
  - Encryption Algorithm
    - Encrypting the data being transmitted
  - Hashing Algorithm
    - Ensuring the integrity and authenticity of the message
  - E.g. TLS_RSA_WITH_AES_128_GCM_SHA256

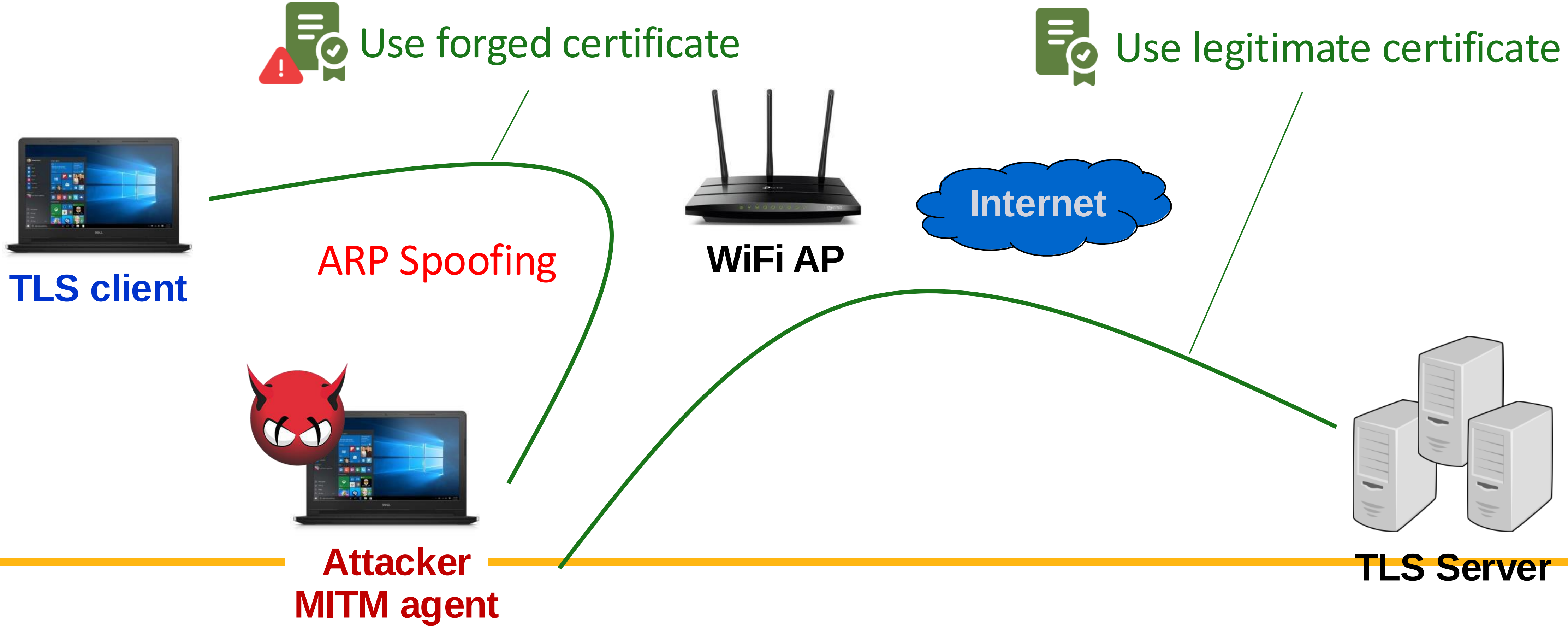
Normal TLS connection

- Establish a secure connection with a legitimate certificate



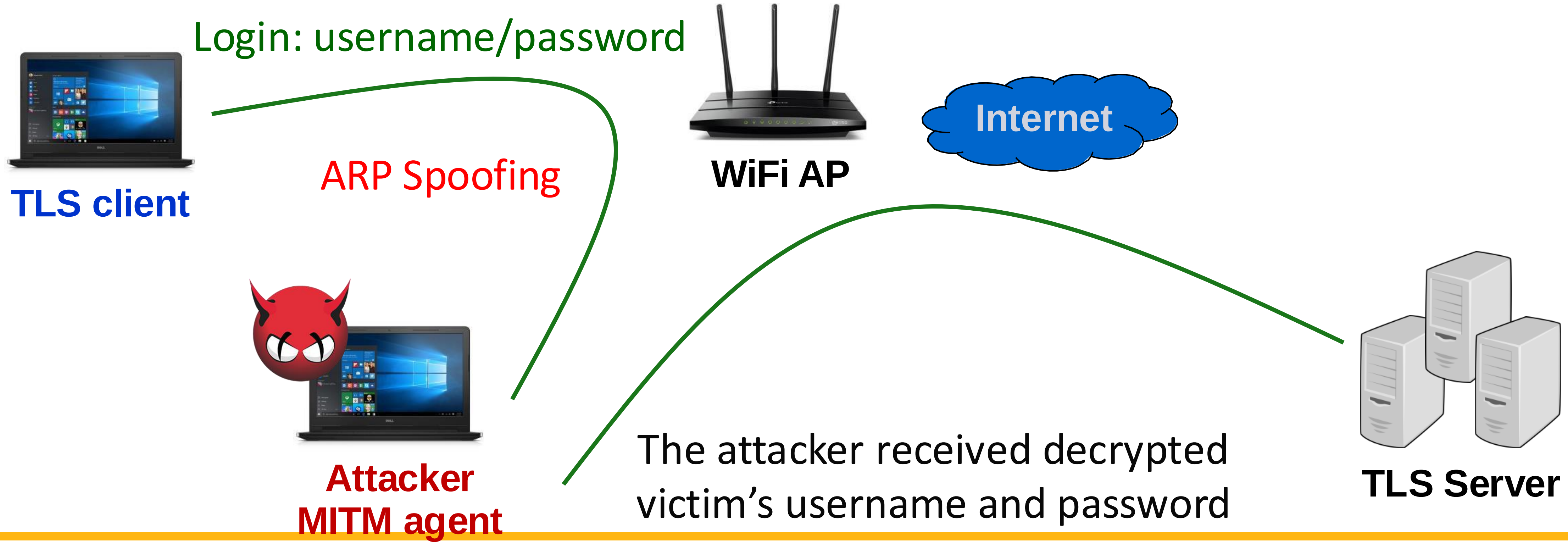
Attack Scenario

- How can Attacker steal Victim's user credential?



Attack Scenario

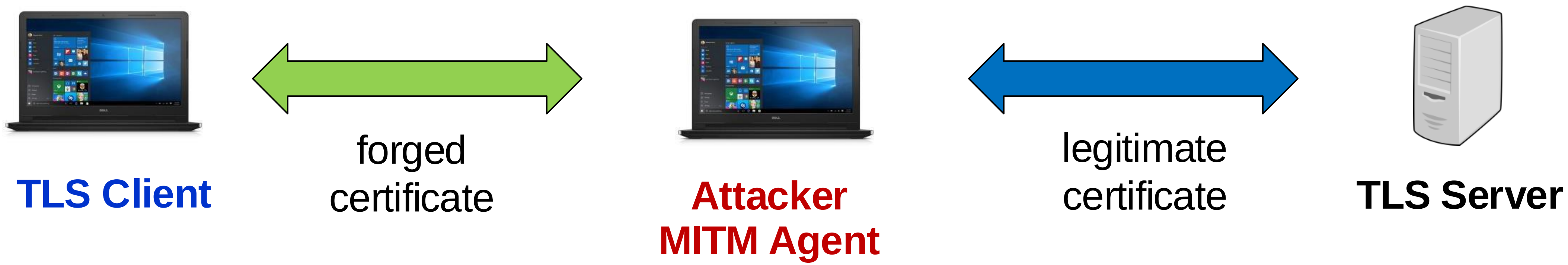
- How can Attacker steal Victim's user credential?



The attacker received decrypted victim's username and password

Major Ideas

- Redirect Victim’s traffic to Attacker
  - □ Man-in-the-middle based on ARP spoofing
- Dual Connection Establishment
  - □ What you need to implement in this project

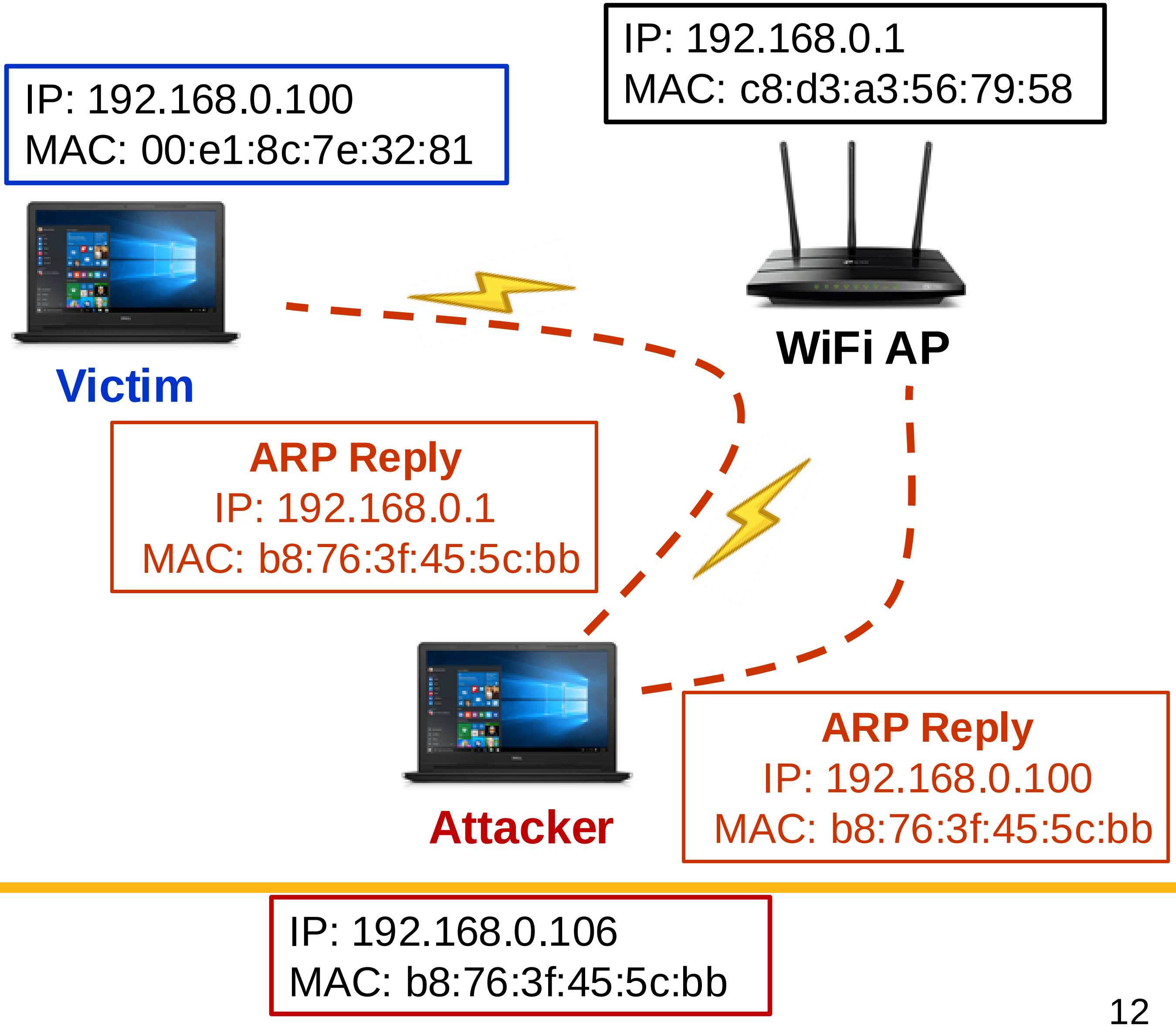


What is ARP (Address Resolution Protocol)?

- A communication protocol: discovering the link layer (or MAC) address associated with a given IP
- A request-response protocol: messages are encapsulated by a link-layer protocol
  - ARP request: broadcast
  - ARP response: unicast
- Never routed across internetworking nodes

What is ARP Spoofing?

- Generate spoofed ARP replies for all other client devices
  - □ Hint: ARP format and thread
- Both uplink and downlink should be considered
  - □ Other client devices' network services can work normally



IP: 192.168.0.100
MAC: 00:e1:8c:7e:32:81

Victim

IP: 192.168.0.1
MAC: c8:d3:a3:56:79:58

WiFi AP

ARP Reply
IP: 192.168.0.1
MAC: b8:76:3f:45:5c:bb

ARP Reply
IP: 192.168.0.100
MAC: b8:76:3f:45:5c:bb

Attacker

IP: 192.168.0.106
MAC: b8:76:3f:45:5c:bb

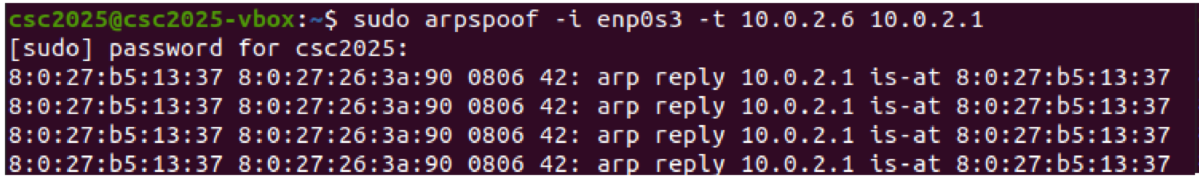
Experimental Setting

- The attacker VM executes the command below to redirect specific TLS packets to the MITM agent:
  - □ `sudo ./setup.sh`

- The victim VM should start the browser using the following command to establish a TLS connection with a forged certificate:
  - □ `google-chrome --ignore-certificate-errors --user-data-dir=/tmp/chrome_dev`
  - □ `chromium-browser --ignore-certificate-errors --user-data-dir=/tmp/chrome_dev`
    - In real-life situations, such as IoT environments, where certificates are often not verified or when a certificate is injected into the browser, this type of attack can be launched
    - chromium-browser is for arm64
  - □ Recommend to open the browser in Incognito mode.

Experimental Setting: ARP Spoofing

- Attacker VM executes the command below in the MITM agent
  - □ `sudo arpspoof -i INTERFACE -t GATEWAY_IP CLIENT_IP`
  - □ `sudo arpspoof -i INTERFACE -t CLIENT_IP GATEWAY_IP`



```
csc2025@csc2025-vbox:~$ sudo arpspoof -i enp0s3 -t 10.0.2.6 10.0.2.1
[sudo] password for csc2025:
8:0:27:b5:13:37 8:0:27:26:3a:90 0806 42: arp reply 10.0.2.1 is-at 8:0:27:b5:13:37
8:0:27:b5:13:37 8:0:27:26:3a:90 0806 42: arp reply 10.0.2.1 is-at 8:0:27:b5:13:37
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```

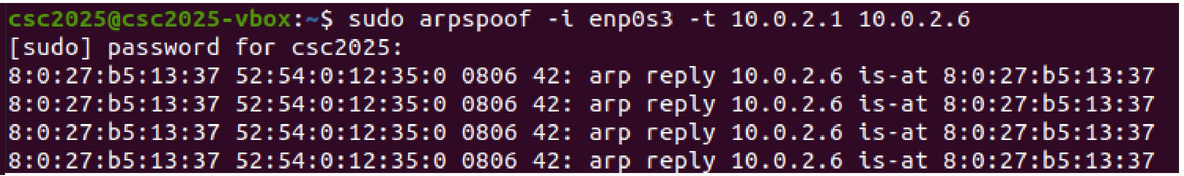

```
csc2025@csc2025-vbox:~$ sudo arpspoof -i enp0s3 -t 10.0.2.1 10.0.2.6
[sudo] password for csc2025:
8:0:27:b5:13:37 52:54:0:12:35:0 0806 42: arp reply 10.0.2.6 is-at 8:0:27:b5:13:37
8:0:27:b5:13:37 52:54:0:12:35:0 0806 42: arp reply 10.0.2.6 is-at 8:0:27:b5:13:37
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8:0:27:b5:13:37 52:54:0:12:35:0 0806 42: arp reply 10.0.2.6 is-at 8:0:27:b5:13:37
```
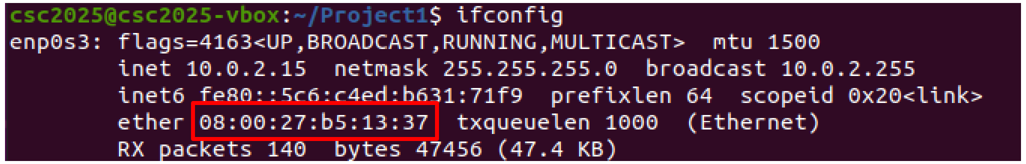
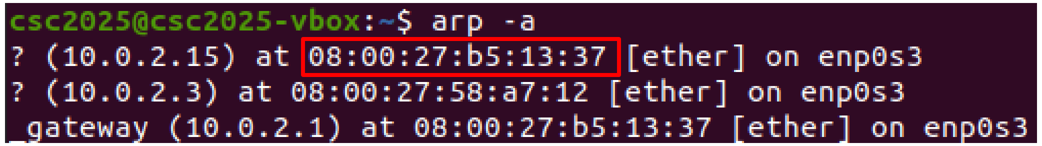

- Victim VM executes `arp -a` to check ARP table
  - □ If the gateway's mac address is the same with that of the attacker, ARP spoofing is successful



```
csc2025@csc2025-vbox:~/Project1$ ifconfig
enp0s3: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 10.0.2.15  netmask 255.255.255.0  broadcast 10.0.2.255
        inet6 fe80::5c6:c4ed:b631:71f9  prefixlen 64  scopeid 0x20<link>
        ether 08:00:27:b5:13:37  txqueuelen 1000  (Ethernet)
        RX packets 140  bytes 47456 (47.4 KB)
```

MITM Agent



```
csc2025@csc2025-vbox:~$ arp -a
? (10.0.2.15) at 08:00:27:b5:13:37 [ether] on enp0s3
? (10.0.2.3) at 08:00:27:58:a7:12 [ether] on enp0s3
_gateway (10.0.2.1) at 08:00:27:b5:13:37 [ether] on enp0s3
```

TLS Client

Task I: Hijacking a TLS Connection

- TLS Client to MITM Agent:
  - The MITM agent can use a forged certificate to establish a TLS connection.
    - Configure the server settings (TLS version, check mode, etc.) so that the victim accepts the TLS connection.
- MITM Agent to TLS server:
  - The MITM agent can retrieve the destination address from the victim's packet
  - The MITM agent uses this address to connect to the TLS server.
    - A fixed address for the TLS server connection is not allowed.
      - Should be able to connect to different websites.

Task II: Hijacking multiple TLS conn. concurrently

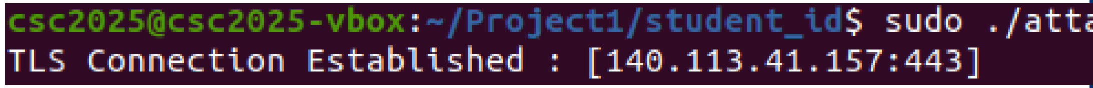
- The program should still work normally when connecting to another website
  - Handling concurrency
    - Ensure the program can manage multiple TLS connections concurrently
    - Consider using threading, fork(), or asynchronous I/O (select(), epoll()) to avoid blocking connections
  - Session management
    - Each connection should maintain its own independent TLS session context
    - Avoid session interference between multiple websites being accessed simultaneously

Verification Steps

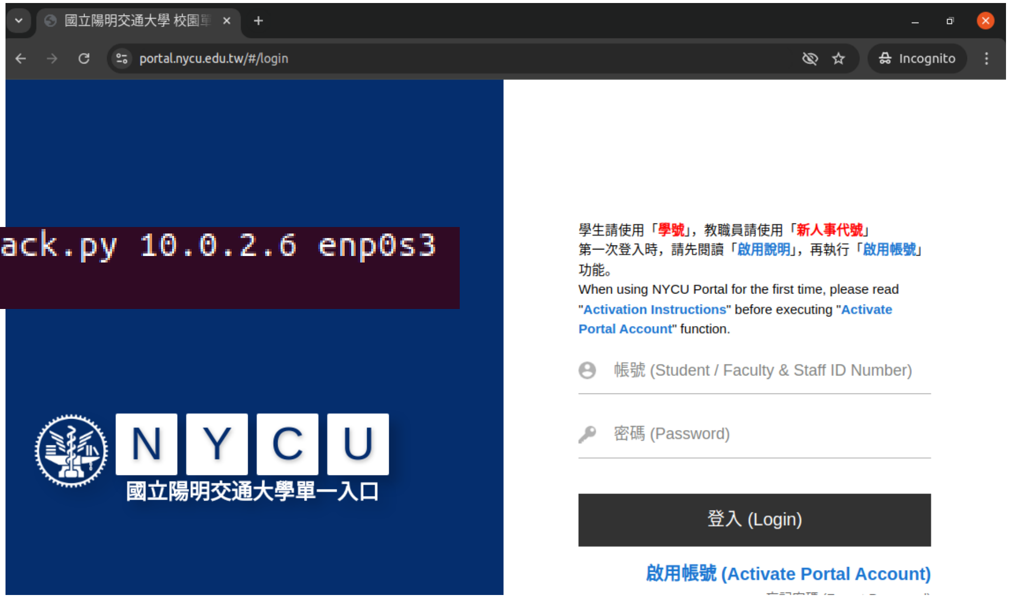
- 1. MITM agent can correctly hijack a TLS connection (60%)
  - □ A sub-connection between TLS client and MITM agent
  - □ A sub-connection between MITM agent and TLS server
- 2. Fetch the username/password and show on the terminal (20%)
  - □ MITM agent prints out the username/password inputted to nycu portal
- 3. MITM agent can concurrently hijack multiple TLS connections (20%)

Verification Steps

- 1. MITM agent can correctly hijack a TLS connection (60%)
  - □ When executing the attack program, the client can successfully connect to the school's portal webpage.
  - □ The program should also print out the destination IP and port.



```
csc2025@csc2025-vbox:~/Project1/student_id$ sudo ./attack.py 10.0.2.6 enp0s3
TLS Connection Established : [140.113.41.157:443]
```



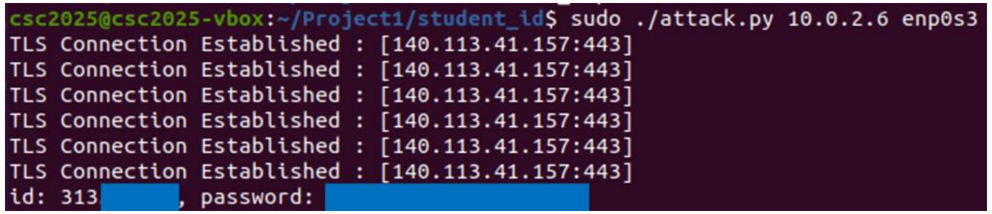
國立陽明交通大學 校園單
portal.nycu.edu.tw/#/login
Incognito
NYCU
國立陽明交通大學單一入口

學生請使用「學號」，教職員請使用「新人事代號」
第一次登入時，請先閱讀「啟用說明」，再執行「啟用帳號」功能。
When using NYCU Portal for the first time, please read "Activation Instructions" before executing "Activate Portal Account" function.

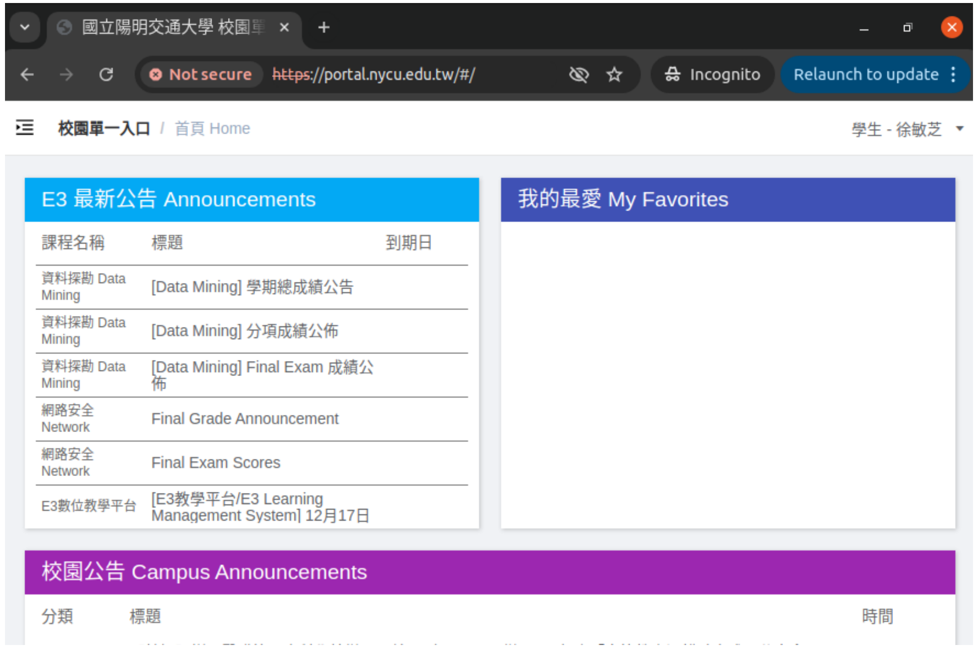
帳號 (Student / Faculty & Staff ID Number)
密碼 (Password)
登入 (Login)
啟用帳號 (Activate Portal Account)

Verification Steps

- 2. Fetch the username/password and show on the terminal (20%)
  - MITM agent prints out the username/password inputted to nycu portal



```
csc2025@csc2025-vbox:~/Project1/student_id$ sudo ./attack.py 10.0.2.6 enp0s3
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
id: 313[redacted], password: [redacted]
```



E3 最新公告 Announcements

課程名稱	標題	到期日
資料探勘 Data Mining	[Data Mining] 學期總成績公告	
資料探勘 Data Mining	[Data Mining] 分項成績公佈	
資料探勘 Data Mining	[Data Mining] Final Exam 成績公佈	
網路安全 Network	Final Grade Announcement	
網路安全 Network	Final Exam Scores	
E3數位教學平台	[E3教學平台/E3 Learning Management System] 12月17日	

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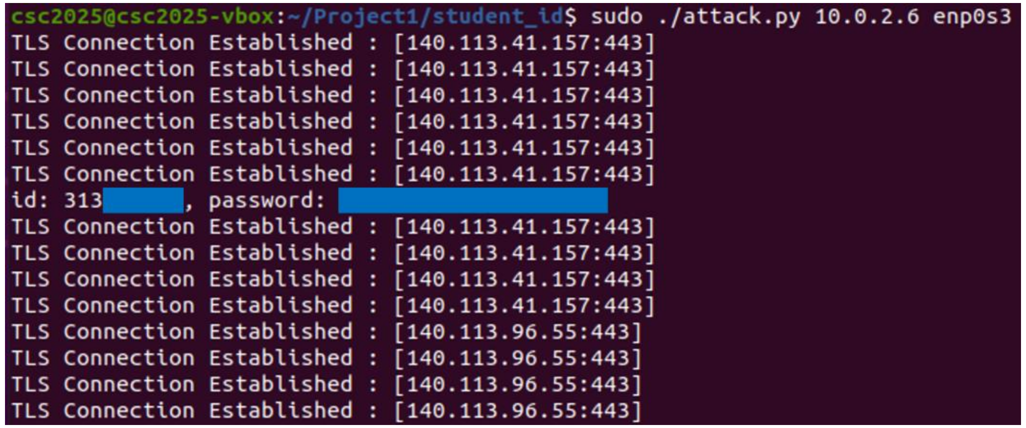
校園公告 Campus Announcements

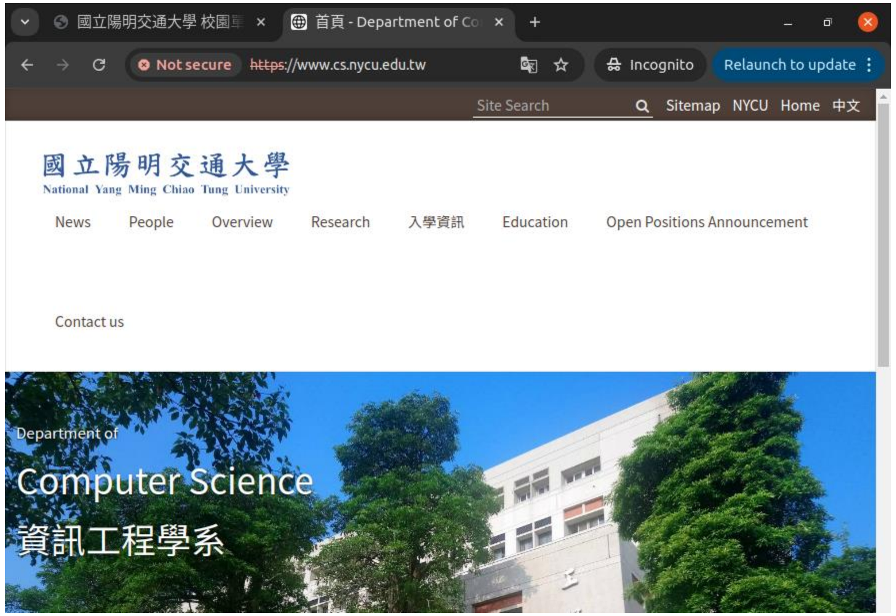
分類	標題	時間

Verification Steps

- 3. MITM agent can concurrently hijack multiple TLS connections (20%)
  - □ The program still works normally when connecting to other HTTPS websites



```
csc2025@csc2025-vbox:~/Project1/student_id$ sudo ./attack.py 10.0.2.6 enp0s3
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
id: 313[redacted], password: [redacted]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.41.157:443]
TLS Connection Established : [140.113.96.55:443]
TLS Connection Established : [140.113.96.55:443]
TLS Connection Established : [140.113.96.55:443]
TLS Connection Established : [140.113.96.55:443]
```



Important: How to Prepare Your Attack Programs?

- You need to develop and run your program in the provided VM
  - **VM Image**: Please download it from the provided link(x86) / link(arm64)
    - Username/password: csc2025/csc2025
  - Network setting: **NAT Network**
- Do not hardcode the network interface. You are allowed to assign it during execution.
  - During the demo, the program may be run on either VMware or VirtualBox, so ensure that no fixed values are used.
- Only Python is allowed for the development.

Important: How to Prepare Your Attack Programs?

- Must provide an attack program named **attack.py** (Missing: -20%)
- Test requirements for the program
  - □ Due to the environment settings, this project focuses on hijacking websites within the school's IP domain (140.113.*.*)
    - You can use the nslookup command to verify if a specific host is within the school IP domain
  - □ During the demo, all certificates will be provided by the TA and will be located in the ../certificates/directory
- The program must work with the following test commands:
  - □ `sudo ./attack.py <victim ip>` or `sudo ./attack.py <victim ip> <interface>`
- You are allowed to team up. Each team has at most 2 students.
  - □ Teams: discussions are allowed, but no collaboration

Project Submission

- Due date: 3/19
- Makeup submission (75 points at most): TBA (After the final)
- Submission rules
  - Put your source code files into a directory and name it using your student ID(s)
    - If your team has two members, please concatenate your IDs separated by “-”
  - Zip the directory and upload the zip file to E3 (only upload python files)
  - A sample of the zip file: 01212112-02121221.zip

```
01212112-02121221.zip
└── 01212112-02121221(dir)
    ├── attack.py
    └── bbb.py
```

- If files are not in a directory after unzip, 10 points will be deducted.

Online Project Demo

- Demo date: 3/21
- TA will prepare your zip file and run your programs for the demo on behalf of you
  - TA will run your program in the same given virtual environment(x86)
- You will
  - be asked to launch a TLS hijacking attack
  - be not allowed to modify your codes or scripts in the demo
  - be asked some questions
  - be responsible to show and explain the outcome to TA

Questions?