# Computer Security: Principles and Practice

## Fourth Edition
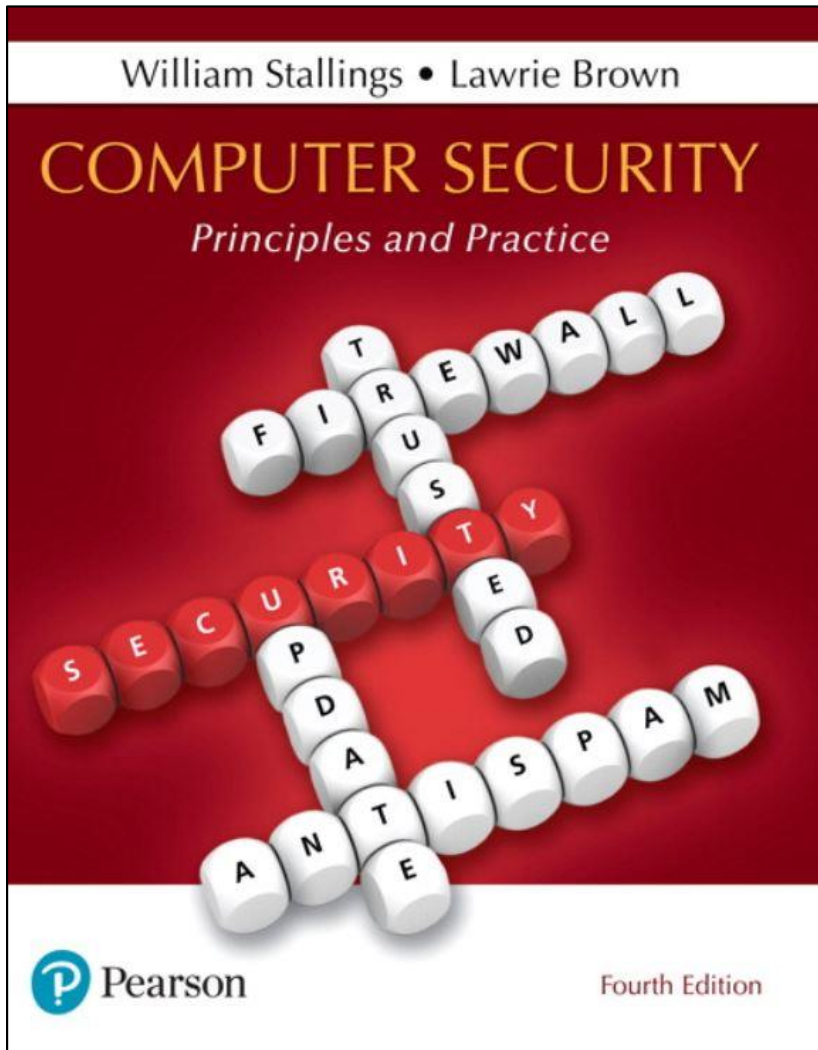
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COMPUTER SECURITY
Principles and Practice
Pearson
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# Chapter 6

## Malicious Software

# Malware

NIST 800-83 defines malware as:

"a program that is inserted into a system, usually covertly, with the intent of compromising the confidentiality, integrity, or availability of the victim's data, applications, or operating system or otherwise annoying or disrupting the victim."

# Table 6.1 Malware Terminology

| Name | Description |
|------|-------------|
| Advanced Persistent Threat (APT) | Cybercrime directed at business and political targets, using a wide variety of intrusion technologies and malware, applied persistently and effectively to specific targets over an extended period, often attributed to state-sponsored organizations. |
| Adware | Advertising that is integrated into software. It can result in pop-up ads or redirection of a browser to a commercial site. |
| Attack kit | Set of tools for generating new malware automatically using a variety of supplied propagation and payload mechanisms. |
| Auto-rooter | Malicious hacker tools used to break into new machines remotely. |
| Backdoor (trapdoor) | Any mechanism that bypasses a normal security check; it may allow unauthorized access to functionality in a program, or onto a compromised system. |
| Downloaders | Code that installs other items on a machine that is under attack. It is normally included in the malware code first inserted on to a compromised system to then import a larger malware package. |
| Drive-by-download | An attack using code on a compromised website that exploits a browser Vulnerability to attack a client system when the site is viewed. |
| Exploits | Code specific to a single vulnerability or set of vulnerabilities. |

# Table 6.1 Malware Terminology (2 of 3)

| Name | Description |
| --- | --- |
| Flooders (DoS client) | Used to generate a large volume of data to attack networked computer systems, by carrying out some form of denial-of-service (DoS) attack. |
| Keyloggers | Captures keystrokes on a compromised system. |
| Logic bomb | Code inserted into malware by an intruder. A logic bomb lies dormant until a Predefined condition is met; the code then triggers some payload. |
| Macro virus | A type of virus that uses macro or scripting code, typically embedded in a Document or document template, and triggered when the document is viewed or edited, to run and replicate itself into other such documents. |
| Mobile code | Software (e.g., script and macro) that can be shipped unchanged to a heterogeneous collection of platforms and execute with identical semantics. |
| Rootkit | Set of hacker tools used after attacker has broken into a computer system and gained root-level access. |
| Spammer programs | Used to send large volumes of unwanted e-mail. |
| Spyware | Software that collects information from a computer and transmits it to another system by monitoring keystrokes, screen data, and/or network traffic; or by scanning files on the system for sensitive information. |

# Table 6.1 Malware Terminology

| Name | Description |
| --- | --- |
| Trojan horse | A computer program that appears to have a useful function, but also has a hidden and potentially malicious function that evades security mechanisms, sometimes by exploiting legitimate authorizations of a system entity that invokes it. |
| Virus | Malware that, when executed, tries to replicate itself into other executable machine or script code; when it succeeds, the code is said to be infected. When the infected code is executed, the virus also executes. |
| Worm | A computer program that can run independently and can propagate a complete working version of itself onto other hosts on a network, by exploiting software vulnerabilities in the target system, or using captured authorization credentials. |
| Zombie, bot | Program installed on an infected machine that is activated to launch attacks on other machines. |

# Classification of Malware

- Classified into two broad categories:
  - Based first on how it spreads or propagates to reach the desired targets
  - Then on the actions or payloads it performs once a target is reached

- Also classified by:
  - Those that need a host program (parasitic code such as viruses)
  - Those that are independent, self-contained programs (worms, trojans, and bots)
  - Malware that does not replicate (trojans and spam e-mail)
  - Malware that does replicate (viruses and worms)

# Types of Malicious Software (Malware)

- Propagation mechanisms include:
  - Infection of existing content by viruses that is subsequently spread to other systems
  - Exploit of software vulnerabilities by worms or drive-by-downloads to allow the malware to replicate
  - Social engineering attacks that convince users to bypass security mechanisms to install Trojans or to respond to phishing attacks

- Payload actions performed by malware once it reaches a target system can include:
  - Corruption of system or data files
  - Theft of service/make the system a zombie agent of attack as part of a botnet
  - Theft of information from the system/keylogging
  - Stealthing/hiding its presence on the system

# Attack Kits

- Initially the development and deployment of malware required considerable technical skill by software authors
  - The development of virus-creation toolkits in the early 1990s and then more general attack kits in the 2000s greatly assisted in the development and deployment of malware

- Toolkits are often known as "crimeware"
  - Include a variety of propagation mechanisms and payload modules that even novices can deploy
  - Variants that can be generated by attackers using these toolkits creates a significant problem for those defending systems against them

- Examples are:
  - Zeus
  - Angler

# Attack Sources

- Another significant malware development is the change from attackers being individuals often motivated to demonstrate their technical competence to their peers to more organized and dangerous attack sources such as:
    - Politically motivated attackers
    - Criminals
    - Organized crime
    - Organizations that sell their services to companies and nations
    - National government agencies

- This has significantly changed the resources available and motivation behind the rise of malware and has led to development of a large underground economy involving the sale of attack kits, access to compromised hosts, and to stolen information

# Advanced Persistent Threats (APTs)

- Well-resourced, persistent application of a wide variety of intrusion technologies and malware to selected targets (usually business or political)

- Typically attributed to state-sponsored organizations and criminal enterprises

- Differ from other types of attack by their careful target selection and stealthy intrusion efforts over extended periods

- High profile attacks include Aurora, RSA, APT1, and Stuxnet

# APT Characteristics

- Advanced
  - Used by the attackers of a wide variety of intrusion technologies and malware including the development of custom malware if required
  - The individual components may not necessarily be technically advanced but are carefully selected to suit the chosen target

- Persistent
  - Determined application of the attacks over an extended period against the chosen target in order to maximize the chance of success
  - A variety of attacks may be progressively applied until the target is compromised

# APT Characteristics

- Threats
    - Threats to the selected targets as a result of the organized, capable, and well-funded attackers intent to compromise the specifically chosen targets
    - The active involvement of people in the process greatly raises the threat level from that due to automated attacks tools, and also the likelihood of successful attacks

# APT Attacks

- Aim:
  - Varies from theft of intellectual property or security and infrastructure related data to the physical disruption of infrastructure

- Techniques used:
  - Social engineering
  - Spear-phishing email
  - Drive-by-downloads from selected compromised websites likely to be visited by personnel in the target organization

- Intent:
  - To infect the target with sophisticated malware with multiple propagation mechanisms and payloads
  - Once they have gained initial access to systems in the target organization a further range of attack tools are used to maintain and extend their access

# Viruses

- Piece of software that infects programs
    - Modifies them to include a copy of the virus
    - Replicates and goes on to infect other content
    - Easily spread through network environments

- When attached to an executable program a virus can do anything that the program is permitted to do
    - Executes secretly when the host program is run

- Specific to operating system and hardware
    - Takes advantage of their details and weaknesses

# Virus Components

- Infection mechanism
  - Means by which a virus spreads or propagates
  - Also referred to as the **infection vector**

- Trigger
  - Event or condition that determines when the payload is activated or delivered
  - Sometimes known as a **logic bomb**

- Payload
  - What the virus does (besides spreading)
  - May involve damage or benign but noticeable activity

# Virus Phases (1 of 2)

- Dormant phase
  - Virus is idle
  - Will eventually be activated by some event
  - Not all viruses have this stage

- Triggering phase
  - Virus is activated to perform the function for which it was intended
  - Can be caused by a variety of system events

# Virus Phases

- Propagation phase
    - Virus places a copy of itself into other programs or into certain system areas on the disk
    - May not be identical to the propagating version
    - Each infected program will now contain a clone of the virus which will itself enter a propagation phase

- Execution phase
    - Function is performed
    - May be harmless or damaging

# Macro and Scripting Viruses

- NISTIR 7298 defines a macro virus as:
  - "a virus that attaches itself to documents and uses the macro programming capabilities of the document's application to execute and propagate"
- Macro viruses infect scripting code used to support active content in a variety of user document types

- Are threatening for a number of reasons:
  - Is platform independent
  - Infect documents, not executable portions of code
  - Are easily spread
  - Because they infect user documents rather than system programs, traditional file system access controls are of limited use in preventing their spread, since users are expected to modify them
  - Are much easier to write or to modify than traditional executable viruses

# Virus Classifications

Classification by target

- Boot sector infector
    - Infects a master boot record or boot record and spreads when a system is booted from the disk containing the virus

- File infector
    - Infects files that the operating system or shell considers to be executable

- Macro virus
    - Infects files with macro or scripting code that is interpreted by an application

- Multipartite virus
    - Infects files in multiple ways

*hiding*

Classification by concealment strategy

- Encrypted virus
  - A portion of the virus creates a random encryption key and encrypts the remainder of the virus

- Stealth virus
  - A form of virus explicitly designed to hide itself from detection by anti-virus software

- Polymorphic virus
  - A virus that mutates with every infection

*change form not Act*

- Metamorphic virus
  - A virus that mutates and rewrites itself completely at each iteration and may change behavior as well as appearance

# Worms

- Program that actively seeks out more machines to infect and each infected machine serves as an automated launching pad for attacks on other machines

- Exploits software vulnerabilities in client or server programs

- Can use network connections to spread from system to system

- Spreads through shared media (USB drives, CD, DVD data disks)

- E-mail worms spread in macro or script code included in attachments and instant messenger file transfers

- Upon activation the worm may replicate and propagate again

- Usually carries some form of payload

- First known implementation was done in Xerox Palo Alto Labs in the early 1980s

# Worm Replication

- Electronic mail or instant messenger facility
  - Worm e-mails a copy of itself to other systems
  - Sends itself as an attachment via an instant message service

- File sharing
  - Creates a copy of itself or infects a file as a virus on removable media

- Remote execution capability
  - Worm executes a copy of itself on another system

# Worm Replication (2 of 2)

- Remote file access or transfer capability
  - Worm uses a remote file access or transfer service to copy itself from one system to the other

- Remote login capability
  - Worm logs onto a remote system as a user and then uses commands to copy itself from one system to the other

# Recent Worm Attacks (1 of 2)

| Melissa | 1998 | E-mail worm<br>First to include virus, worm and Trojan in one package |
|---------|------|----------------------------------------------------------------------|
| Code Red | July 2001 | Exploited Microsoft IIS bug<br>Probes random IP addresses<br>Consumes significant Internet capacity when active |
| Code Red II | August 2001 | Also targeted Microsoft IIS Installs a backdoor for access |
| Nimda | September 2001 | Had worm, virus and mobile code characteristics<br>Spread using e-mail, Windows shares, Web servers, Web clients, backdoors |
| SQL Slammer | Early 2003 | Exploited a buffer overflow vulnerability in SQL server<br>compact and spread rapidly |
| Sobig.F | Late 2003 | Exploited open proxy servers to turn infected machines into spam engines |
| Mydoom | 2004 | Mass-mailing e-mail worm<br>Installed a backdoor in infected machines |
| Warezov | 2006 | Creates executables in system directories<br>Sends itself as an e-mail attachment<br>Can disable security related products |

# Recent Worm Attacks

| Conficker (Downadup) | November 2008 | Exploits a Windows buffer overflow vulnerability Most widespread infection since SQL Slammer |
|---|---|---|
| Stuxnet | 2010 | Restricted rate of spread to reduce chance of detection Targeted industrial control systems |

# WannaCry

- **Ransomware** attack in May 2017 that spread extremely fast over a period of hours to days, infecting hundreds of thousands of systems belonging to both public and private organizations in more than 150 countries

- It spread as a worm by aggressively scanning both local and random remote networks, attempting to exploit a vulnerability in the SMB file sharing service on unpatched Windows systems

- Once installed on infected systems, it also encrypted files, demanding a ransom payment to recover them

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# Drive-By-Downloads

- Exploits browser and plugin vulnerabilities so when the user views a webpage controlled by the attacker, it contains code that exploits the bug to download and install malware on the system without the user's knowledge or consent

- In most cases the malware does not actively propagate as a worm does

- Spreads when users visit the malicious Web page

# Watering-Hole Attacks

- A variant of drive-by-download used in highly targeted attacks

- The attacker researches their intended victims to identify websites they are likely to visit, then scans these sites to identify those with vulnerabilities that allow their compromise

- They then wait for one of their intended victims to visit one of the compromised sites

- Attack code may even be written so that it will only infect systems belonging to the target organization and take no action for other visitors to the site

- This greatly increases the likelihood of the site compromise remaining undetected

# Malvertising

*mal + ads*

- Places malware on websites without actually compromising them

- The attacker pays for advertisements that are highly likely to be placed on their intended target websites and incorporate malware in them

- Using these malicious ads, attackers can infect visitors to sites displaying them

- The malware code may be dynamically generated to either reduce the chance of detection or to only infect specific systems

- Has grown rapidly in recent years because they are easy to place on desired websites with few questions asked and are hard to track

- Attackers can place these ads for as little as a few hours, when they expect their intended victims could be browsing the targeted websites, greatly reducing their visibility

# Clickjacking

- Also known as a user-interface (UI) redress attack

- Using a similar technique, keystrokes can also be hijacked
  - A user can be led to believe they are typing in the password to their email or bank account, but are instead typing into an invisible frame controlled by the attacker

# Clickjacking

- Vulnerability used by an attacker to collect an infected user's clicks
  - The attacker can force the user to do a variety of things from adjusting the user's computer settings to unwittingly sending the user to Web sites that might have malicious code
  - By taking advantage of Adobe Flash or JavaScript an attacker could even place a button under or over a legitimate button making it difficult for users to detect
  - A typical attack uses multiple transparent or opaque layers to trick a user into clicking on a button or link on another page when they were intending to click on the top level page
  - The attacker is hijacking clicks meant for one page and routing them to another page

# Social Engineering

- "Tricking" users to assist in the compromise of their own systems

- Spam
  - Unsolicited bulk e-mail
  - Significant carrier of malware
  - Used for phishing attacks

- Trojan horse
  - Program or utility containing harmful hidden code
  - Used to accomplish functions that the attacker could not accomplish directly

- Mobile phone Trojans
  - First appeared in 2004 (Skuller)
  - Target is the smartphone

# Payload – Attack Agents Bots

- Takes over another Internet attached computer and uses that computer to launch or manage attacks

- **Botnet** - collection of bots capable of acting in a coordinated manner

- Uses:
    - Distributed denial-of-service (DDoS) attacks
    - Spamming
    - Sniffing traffic
    - Keylogging
    - Spreading new malware
    - Installing advertisement add-ons and browser helper objects (BHOs)
    - Attacking IRC chat networks
    - Manipulating online polls/games

# Remote Control Facility

- Distinguishes a bot from a worm
  - Worm propagates itself and activates itself
  - Bot is initially controlled from some central facility
- Typical means of implementing the remote control facility is on an IRC server
  - Bots join a specific channel on this server and treat incoming messages as commands
  - More recent botnets use covert communication channels via protocols such as HTTP
  - Distributed control mechanisms use peer-to-peer protocols to avoid a single point of failure

# Payload – Information Theft Keyloggers and Spyware

- Keylogger
  - Captures keystrokes to allow attacker to monitor sensitive information
  - Typically uses some form of filtering mechanism that only returns information close to keywords ("login", "password")

- Spyware
  - Subverts the compromised machine to allow monitoring of a wide range of activity on the system
    - Monitoring history and content of browsing activity
    - Redirecting certain Web page requests to fake sites
    - Dynamically modifying data exchanged between the browser and certain Web sites of interest

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# Payload – Information Theft Phishing

- Exploits social engineering to leverage the user's trust by masquerading as communication from a trusted source
  - Include a URL in a spam e-mail that links to a fake Web site that mimics the login page of a banking, gaming, or similar site
  - Suggests that urgent action is required by the user to authenticate their account
  - Attacker exploits the account using the captured credentials

- Spear-phishing
  - Recipients are carefully researched by the attacker
  - E-mail is crafted to specifically suit its recipient, often quoting a range of information to convince them of its authenticity

# Payload – Stealthing Backdoor

- Also known as a **trapdoor**

- Secret entry point into a program allowing the attacker to gain access and bypass the security access procedures

- **Maintenance hook** is a backdoor used by Programmers to debug and test programs

- Difficult to implement operating system controls for backdoors in applications

# Payload - Stealthing Rootkit

- Set of hidden programs installed on a system to maintain covert access to that system

- Hides by subverting the mechanisms that monitor and report on the processes, files, and registries on a computer

- Gives administrator (or root) privileges to attacker
  - Can add or change programs and files, monitor processes, send and receive network traffic, and get backdoor access on demand

# Rootkit Classification Characteristics

- Persistent
- Memory based
- User mode
- Kernel mode
- Virtual machine based
- External mode

# Malware Countermeasure Approaches

- Ideal solution to the threat of malware is prevention

- Four main elements of prevention:
    - Policy
    - Awareness
    - Vulnerability mitigation
    - Threat mitigation

- If prevention fails, technical mechanisms can be used to support the following threat mitigation options:
    - Detection
    - Identification
    - Removal

# Generations of Anti-Virus Software

- First generation: simple scanners
  - Requires a malware signature to identify the malware
  - Limited to the detection of known malware
- Second generation: heuristic scanners
  - Uses heuristic rules to search for probable malware instances
  - Another approach is integrity checking
- Third generation: activity traps
  - Memory-resident programs that identify malware by its actions rather than its structure in an infected program
- Fourth generation: full-featured protection
  - Packages consisting of a variety of anti-virus techniques used in conjunction
  - Include scanning and activity trap components and access control capability

# Sandbox Analysis

- Running potentially malicious code in an emulated sandbox or on a virtual machine

- Allows the code to execute in a controlled environment where its behavior can be closely monitored without threatening the security of a real system

- Running potentially malicious software in such environments enables the detection of complex encrypted, polymorphic, or metamorphic malware

- The most difficult design issue with sandbox analysis is to determine how long to run each interpretation

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# Host-Based Behavior-Blocking Software

- Integrates with the operating system of a host computer and monitors program behavior in real time for malicious action
  - Blocks potentially malicious actions before they have a chance to affect the system
  - Blocks software in real time so it has an advantage over anti-virus detection techniques such as fingerprinting or heuristics

- Limitations
  - Because malicious code must run on the target machine before all its behaviors can be identified, it can cause harm before it has been detected and blocked

# Perimeter Scanning Approaches

- Anti-virus software typically included in e-mail and Web proxy services running on an organization's firewall and IDS

- May also be included in the traffic analysis component of an IDS

- May include intrusion prevention measures, blocking the flow of any suspicious traffic

- Approach is limited to scanning malware

# Perimeter Scanning Approaches (2 of 2)

Two types of monitoring software

- Ingress monitors
  - Located at the border between the enterprise network and the Internet
  - One technique is to look for incoming traffic to unused local IP addresses

- Egress monitors
  - Located at the egress point of individual LANs as well as at the border between the enterprise network and the Internet
  - Monitors outgoing traffic for signs of scanning or other suspicious behavior

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