Security

Learning Outcomes

- Able to view computer security in terms of confidentiality, integrity, and availability.
- Have an overview of approaches to authentication, and an appreciation of their limitations.
- Understand a range of threats to computer security.
- Have a high-level understanding of approaches to mitigate some threats.

Security in the "Real" World

- We are all familiar with securing valuables
  - Guards
  - Locked doors, cabinets, safes
  - ID badges
- Goal: Only authorised people have access to the valuables
- How does this relate to computer systems?

Computer System "Valuables"

- Hardware
  - Threats include theft, accidental or deliberate damage.
  - Hardware security is similar to *physical security* of valuables
    - Use similar techniques to secure the physical hardware.

Computer System "Valuables"

- Data
  - Three general goals of data security
  - Confidentiality
    - Data is only readable by authorised people
      - Able to specify who can read what on system, and enforce it.
      - Preserve secrecy or privacy
  - Integrity
    - Data is only modifiable by authorised people
  - Availability
    - Data is available to authorized people

Threats

- Denial of Service
  - An asset of the system is destroyed, or becomes unavailable or unusable
  - Attack on *Availability*
  - Example:
    - Destruction of hardware
    - Cutting a communication line
    - Disabling a file server
    - Overloading a server or network

Threats

- Interception
  - An unauthorised party gains access to an asset
  - Attack on *Confidentiality*
  - Examples:
    - Wiretapping to capture data on a network
    - Illicit copying of files and programs

Threats

- Modification
  - An unauthorized party not only gained access, but tampers with data
  - Attack on *Integrity*
  - Examples:
    - Changing values in a file
    - Altering a program so that it performs differently
    - Modifying the content of messages being transmitted on a network

Data Security

- Providing confidentiality, integrity, availability
- Can be partially solved using physical security
- Usually too expensive or inconvenient to do so
  - Example:
    - Each user has private computer, in a locked guarded room.
    - No sharing of information is permitted
    - No outside connectivity permitted
      - No email, shared file server, shared printer, shared tape drive
      - No printouts or storage media can enter or exit the room.
    - Users can still memorise information a bit at a time and leak secrets
- However, physical security is still an important part of any computer security system.

Intruders

- Strategies to provide security typically consider the expected *intruders* (also called *adversaries*) to be protected against.
- Common categories
  1. Casual prying by nontechnical users
     - Stumble across others users files on file server
  2. Snooping by insiders
     - Local system admin/programmer explicitly attempting to break security
  3. Determined attempts to make money
     - Bank programmers installing software to steal money
  4. Commercial or military espionage
     - Well funded attempts to obtain corporate or government secrets
- Depending on the value of the data, and the perceived adversary,
  - more resources may be provided to secure the system
  - less convenient methods of access may be tolerated by users

Data Loss

- Protecting against data loss is an important part of any security policy
- Examples:
  1. Acts of God
     - fires, floods, wars
  2. Hardware or software errors
     - CPU malfunction, bad disk, program bugs
  3. Human errors
     - data entry, wrong tape mounted
- General approach is off-site backups

User Authentication

- Thus far, we have described various concepts with reference to authorised users
- Assume we can decide whether a given user is authorised to perform an operation, but how can we determine if the user is who he says he is?

⇒ How can we authenticate the users?

Approaches to User Authentication

- Three general approaches to identifying a user
  - Based on some unique property they possess
  1. Something the user knows
  2. Something the user has
  3. Something the user is
  - Each approach has its own complexities and security properties

Authentication Using Passwords

- Most common form of authentication is entering a login name and password
  - The password entered is not displayed for obvious reasons
  - Windows 2K/XP/Vista/7 is broken in this regard
    - Prints '*' for each character typed
      - Reveals the length of password
    - Also remembers the last login name
  - UNIX approach is much better
    - In security, the less revealed the better

Example: Less is More

- Careless login program can give away important information
  a) Successful login
  b) Valid login ID revealed
  c) No useful information revealed

(a)	(b)	(c)
LOGIN: ken PASSWORD: FooBar SUCCESSFUL LOGIN	LOGIN: carol INVALID LOGIN NAME LOGIN:	LOGIN: carol PASSWORD: Idunno INVALID LOGIN LOGIN:

Problems with Password Security

- One study from 1979
  - Given a list of first name, last names, street names, moderate dictionary, license plate number, some random strings, the previous spelt backwards, etc..
  - A comparison with a password file obtained 86% of all passwords
- A more recent study (1990) produced similar results

RockYou Passwords Dec 2009

MOST POPULAR PASSWORDS

Nearly one million RockYou users chose these passwords to protect their accounts.

1. **123456**	17. **michael**
2. **12345**	18. **ashley**
3. **123456789**	19. **654321**
4. **password**	20. **qwerty**
5. **iloveyou**	21. **iloveu**
6. **princess**	22. **michelle**
7. **rockyou**	23. **111111**
8. **1234567**	24. **0**
9. **12345678**	25. **tigger**
10. **abc123**	26. **password1**
11. **nicole**	27. **sunshine**
12. **daniel**	28. **chocolate**
13. **babygirl**	29. **anthony**
14. **monkey**	30. **angel**
15. **jessica**	31. **FRIENDS**
16. **lovely**	32. **soccer**

Source: Imperva

The New York Times

LinkedIn 2012

1. link	16. master
2. 1234	17. b*tch
3. work	18. d*ck
4. god	19. michael
5. job	20. jordan
6. 12345	21. dragon
7. angel	22. soccer
8. the	23. killer
9. ilove	24. 654321
10. sex	25. pepper
11. jesus	26. devil
12. connect	27. princess
13. f**k	28. 1234567
14. monkey	29. Iloveyou
15. 12345	30. career

The Importance Password Security

- Good password security is vital if computer is publicly accessible .
  - Connected to a network or the Internet
- It's common for *intruders* probe internet connect machines for weakness, including poor (default) passwords.

Approaches to improving password security

- Passwords are are stored encrypted
  - Avoids sysadmins, and potentially unwanted computer "maintainers" from obtaining passwords
    - Example: from backup tapes
    - Example: RockYou attack yielded unencrypted passwords.
- Login procedure takes user-supplied string,
  - encrypts it
  - compares result to stored encrypted password

An Attack on Encrypted Passwords

- Take the dictionary of words, names, etc, and encrypt all of then using the same encryption algorithm
- Simply match pre-encrypted list with password file to get matches
  - Assumes you have access to encrypted passwords
    - One did by default in older versions of Linux/Unix
    - Web site break-ins are also common
- Also note: Users with like passwords all match the same encrypted password.

Improving Password Security with a *Salt*

- Idea: 42 text hash enc_v,42
  - Encrypt the password together with a n-bit random number (the *salt*) and store both the number and encrypted result
  - Example

    result = encrypt('Dog1234'), 1234
- Cracker must encrypt each dictionary word 2^n different ways
  - Make pre-computed list 2^n times larger
  - User's with like passwords no longer obviously match
- UNIX "crypt" takes this approach with n = 12
- Additional security via making encrypted passwords unreadable (*shadow passwords*)

Improving Password Security

- Storing passwords more securely does not help if user 'homer' has the password 'homer'
- User must be educated (or forced) to choose good passwords
  - Approaches:
    - Warn users who choose poor passwords
    - Pick passwords for users
      - easy to remember nonsense words
    - Force them to change the password regularly

Issues with 'Good' Passwords

- By forcing frequent password changes, users tend to choose simpler passwords
- By choosing too 'good' a password for users, users put them on post-it notes on the monitor
- Still many attacks involving intercepting password between user and service, and re-using it.
  - phishing

Aside: One-Way Functions

- Function such that given formula for f(x)
  - easy to evaluate y = f(x)
- But given y
  - computationally infeasible to find x

One-time Passwords

- Password changing in the extreme
- Advantage:
  - Snooping login provides no useful information
    - Only a stale previous password
- One approach - S/KEY, author: Leslie Lamport
  - Choose a secret phrase and the number of one time passwords required.
  - Each password is generated via re-applying a one-way function
  - Passwords are then used in reverse order
    - Easy to compute the previous password, but not the next.

One-time Password: Example

- P_0=f(f(f(f(s))))
- P_1=f(f(f(s)))
- P_2=f(f(s))
- P_3=f(s)

- Server initially stores P_0
- Server receives O-T password (P) and computes f(P)
- If f(P) matches P_0, login successful, server stores P (= P_1)

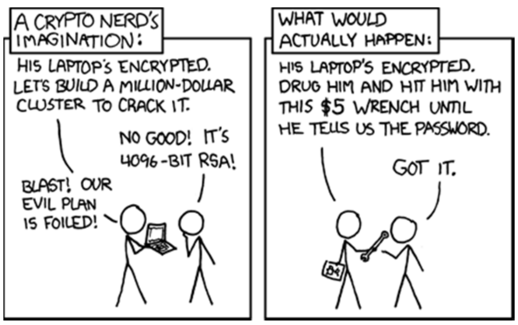
- On home PC
  - Compute one-time password to supply via 3 iterations of 1 way function
  - Subsequent via 2, 1, 0
- Note
  - Server never stores secret (s)
  - Home PC store number of passwords used, but does not need to store secret either.

Challenge-Response

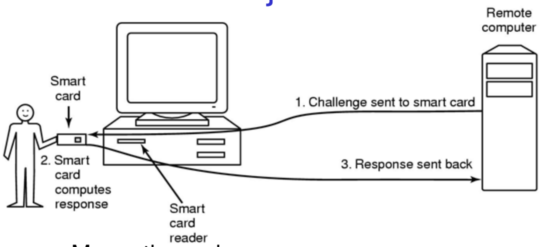
- Server and client both know secret key (k)
- Server sends a *challenge* random number (c) to client
- Client combines the secret key (k) with random number (c) and applies a publicly-known function r = f(c,k)
- Client sends the response to server
- On server, if supplied r equals f(c,k) we have successful login

Challenge-Response

- Advantage:
  - Secret Key is never transmitted on potentially insecure networks
  - Eavesdropping is fruitless
    - Assuming function (f) is such that k cannot be easily deduced from a large number of observed challenge-responses
- Con:
  - Need a 'computer' present to login (compute response)
    - PDA, phone, etc.



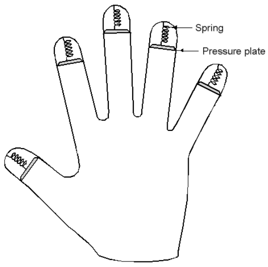
Authentication Using a Physical Object



- Magnetic cards
  - magnetic stripe cards
  - chip cards: stored value cards, smart cards

Authentication Using Biometrics

- A device for measuring finger length.
- Alternatives:
  - Retina scans
  - Voice analysis
  - Analysing signature dynamics



Multi-factor authentication

- Combination of
  1. Something the user knows
  2. Something the user has
  3. Something the user is
- Examples
  - Password plus one-time via phone (or dongle)
  - Smartcard plus PIN
  - Swipe card, one-time PIN, retina scan

Issue: User Acceptance

- Low user acceptance results in:
  - Users themselves compromising the system
    - Example: using post-it notes
  - Refusal to login
    - E.g. login using a blood sample
- Challenge:
  - To find a secure, unobtrusive, simple scheme

Authentication Summary

- Authentication is an important component of security
- Password-based schemes only modestly robust to attack. Many attacks possible
  - Insecure user behaviour
  - Password storage
  - Attacks on cryptographic algorithms (for storage or transfer)
  - Snooping Networks
- Physical and Biometric authentication improves security
  - Attacks still possible, but more resources required.

Software Threats

- Given an reasonable authentication mechanism, many other software threats exist.
- Software Exploits
  - Trojan Horses
  - Login Spoofing
  - Logic Bombs
  - Backdoors (Trapdoors)
  - Buffer Overflows
- Self replicating
  - Viruses

Trojan Horses

- Seemingly innocent program executed by an unsuspecting user
  - Either directly or indirectly
- Program can then do anything the user can
  - Modify or delete files, send them elsewhere on the net.
- Sample exploit
  - If a user has ".", ":/bin" or similar in their PATH, place a file called 'ls' in your directory (or /tmp).

Login Spoofing

- Write a program that emulates the login screen
  - Login, run the program to collect password of unsuspecting user, then exit to the real login prompt.
- Windows 2K/XP provides a key combination (CTRL-ALT-DEL) that can't be bypassed to produce the real login program

(a) (b)

Logic Bombs

- Code secretly embedded in an application or the OS that *goes off* when certain conditions are met.
  - Example: Payroll programmer embeds code that checks he is on the payroll, if not, the payroll software becomes malicious
- Variant: Time Bombs

Backdoors

- Code inserted by the programmer to bypass some check.
  - Example: The login program

```
while (TRUE) {
    printf("login: ");
    get_string(name);
    disable_echoing( );
    printf("password: ");
    get_string(password);
    enable_echoing( );
    v = check_validity(name, password);
    if (v) break;
}
execute_shell(name);
```

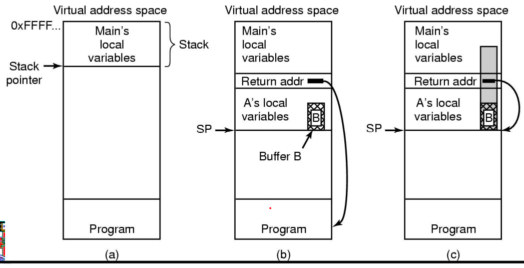
(a)

```
while (TRUE) {
    printf("login: ");
    get_string(name);
    disable_echoing( );
    printf("password: ");
    get_string(password);
    enable_echoing( );
    v = check_validity(name, password);
    if (v || strcmp(name, "zzzzz") == 0) break;
}
execute_shell(name);
```

(b)

Buffer Overflows

- *Main* calls *A* which has a local buffer
- Overflow the buffer with code + starting address of the code
- Good for both local and remote attacks
- Caused by programmers not checking buffer bounds



(a) (b) (c)

Viruses

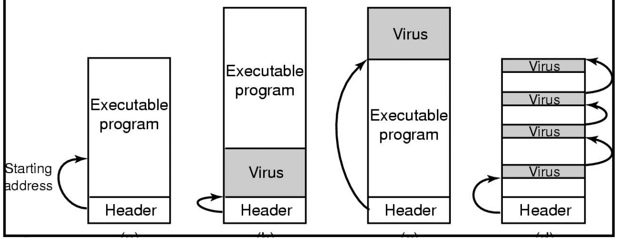
- A program that reproduces itself by attaching its code to another program.
- Can do anything the normal program could do
  - Print harmless message
  - Destroy all files on hard disk
  - Send all your data to the net
  - Trash the EEPROM BIOS to make your computer inoperable
  - Denial of service attack

How Viruses Work

- Virus written in assembly language
- Inserted into another program
  - use tool called a “dropper”
- Virus dormant until program executed
  - then infects other programs
  - eventually executes its “payload”

How Viruses Work

- Parasitic Viruses
  - Add their code to various locations in the executable
  - Redirect the start address in the header
  - On execution, it may replicate by modifying another executable file (and other malicious activities).

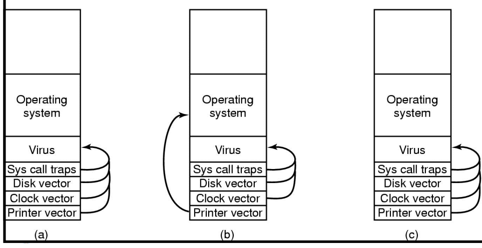


How Viruses Work

- Boot Sector Viruses
  - Copies original boot block to different location
  - Replaces boot block with itself
  - When machine boots, virus is loaded into RAM
  - It installs itself, and then boots OS via original boot block
- How does it regain control later?

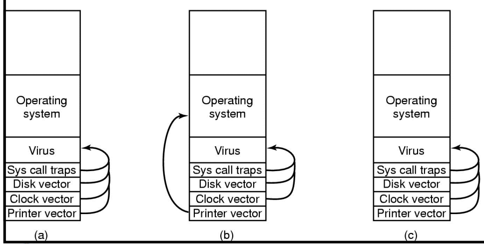
How Viruses Work

- Virus installs interrupt handlers which rely on OS not installing all its own handlers prior to next interrupt occurring
  - Older versions of Windows behaved that way
- Virus reinstalls trap handlers at next opportunity



How Viruses Work

- Memory Resident Viruses
  - Install themselves in main memory
  - Typically redirect the exception/interrupt handlers to itself
    - Still calls the real code to remain undetected
    - checks and reinstalls redirections changed
    - Replicate during, or manipulate and spy-on on syscalls



How Viruses Work

- Macro Viruses
  - Rely on overly powerful/feature overloaded macro languages
  - MS office uses visual basic – complete programming language that can read/write files
  - Opening a Word document is like running a program (it could do anything)
    - Most people ignore warnings about macros

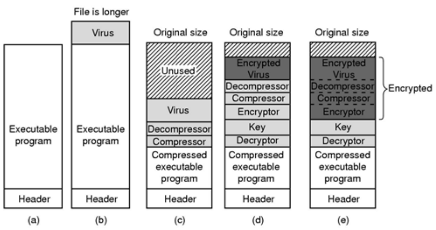
How Viruses Spread

- Virus placed where it's likely to be copied
- When copied
  - infects programs on hard drive, USB stick
  - may try to spread over LAN
- Attach to innocent looking email
  - when it runs, use mailing list (address book) to replicate

Antivirus Approach

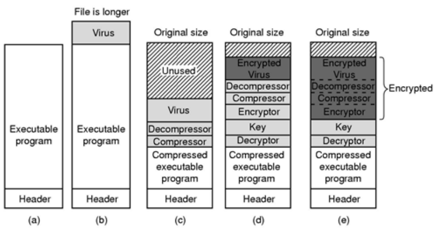
- Scanning
  - Search each file and check if virus present
    - 10,000 potential viruses and 10,000 files
    - Hard to make fast
  - Use fuzzy searches to catch small changes in known viruses
    - Slower, false positives
  - Trade-off between accuracy and acceptable performance

Antivirus and Anti-Antivirus Techniques



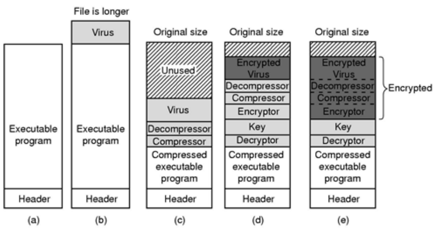
(a) A program
(b) Infected program
Change in file length a give away

Antivirus and Anti-Antivirus Techniques



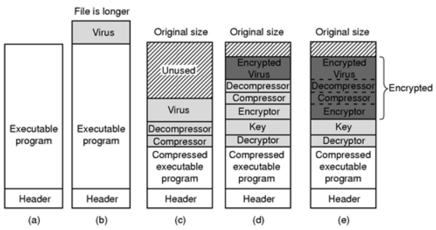
(c) Compressed infected program
Presence of virus code still a give away

Antivirus and Anti-Antivirus Techniques



(d) Encrypted virus
Presence of (de)compressor a give away

Antivirus and Anti-Antivirus Techniques



(e) Compressed virus with encrypted compression code
Can still search for remaining decryptor code

Antivirus and Anti-Antivirus Techniques

(a)	(b)	(c)	(d)	(e)
MOV A,R1	MOV A,R1	MOV A,R1	MOV A,R1	MOV A,R1
ADD B,R1	NOP	ADD #0,R1	OR R1,R1	TST R1
ADD C,R1	ADD B,R1	ADD B,R1	ADD B,R1	ADD C,R1
SUB #4,R1	NOP	OR R1,R1	MOV R1,R5	MOV R1,R5
MOV R1,X	ADD C,R1	ADD C,R1	ADD C,R1	ADD B,R1
	NOP	SHL #0,R1	SHL R1,0	CMP R2,R5
	SUB #4,R1	SUB #4,R1	SUB #4,R1	SUB #4,R1
	NOP	JMP .+1	ADD R5,R5	JMP .+1
	MOV R1,X	MOV R1,X	MOV R1,X	MOV R1,X
			MOV R5,Y	MOV R5,Y

Examples of a polymorphic virus

All of these examples do the same thing

X=A+B-C-4

Antivirus and Anti-Antivirus Techniques

- Integrity checkers
  - Scan the disk and determine checksums for all executable files
  - Check checksums, if changed we have a virus
  - Counter, viruses can hack checksum database is
- Behavioral checkers
  - Look for virus like behaviour
    - Example: overwriting executable file
      - False alarms (e.g. a compiler)

Antivirus and Anti-Antivirus Techniques

- Virus avoidance
  - good OS
    - Separate user/system mode/protection to minimise damage
  - Run/install only reputable software
  - use antivirus software
  - Do not open attachments to email
  - *frequent backups*
- Recovery from virus attack
  - halt computer, reboot from safe disk, run antivirus
  - restore from backups

Running Foreign Code

- We can see that running foreign code can be dangerous (trojan horse, viruses, simply malicious, etc.)
- Problem is that all the code we run has all the privileges we do
- We need a method of running untrusted code safely

Principle of Least Privilege

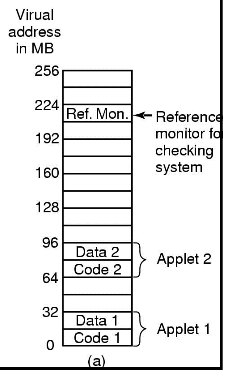
- A guiding principle we would like to apply
- Idea:
  - Give the suspicious program only the privileges required to complete the task you expect, nothing more
  - Example:
    - Can only perform file related system calls
    - Can only access files within a specified directory

Example: Active Web Content

- We'd like to browse "active" web content
  - Run content in the web browser
  - The browser has all the privileges we do
- Some approaches
  - Sandboxing
  - Interpretation
  - Code Signing

Sandboxing

- Idea:
  - Code runs within a sandbox within a browser (or some other larger application)
  - The applet can access only the data contained within its sandbox, and nothing else.
  - It can only jump to code within its sandbox (and cannot modify the code)
- How can we create a sandbox within a process?



Sandbox Implementation

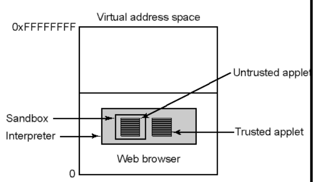
- Firstly, we can restrict access to code to avoid problem of self modifying code – read-only code pages
- To restrict code to the code segment
  - Scan the code
  - Check all jumps and branches jump to addresses within the sandbox
    - Handles both absolute and relative addresses
  - For computed (dynamic jumps) we insert extra instructions into the code to check the destination addresses are within the code
    - Involves fairly complex code rewriting. It is doable, but hard to make robust.
- To restrict data access to data section, we do the same thing we did for code
  - Rewrite or pointers with check, and check all address.

Sandbox Implementation

- What about system calls
  - We use a *reference monitor* that
    - Intercepts all system calls
    - Determine whether the call is allowed to succeed or not
      - Based on the type of call, or the arguments supplied.
  - Reference monitor restricts the system calls to a safe subset

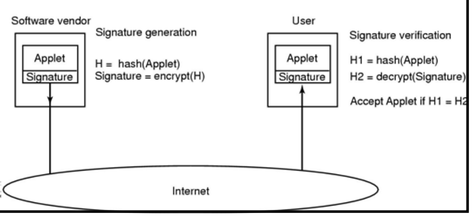
Interpretation

- Instead of running code directly (natively), we run it using an interpreter
  - Interpreter can apply addressing restrictions
  - Can consider the interpreter as implementing a sandbox
  - Example: JAVA



Code Signing

- Authenticity of the code is guaranteed
- Issues
  - Does not protect you against bad or buggy code
  - Example: Shockwave has had various "authentic" security problems



Summary

- Even given strong authentication, there are many software threats to data security policies.
- The affect of exploiting those threats can be minimised by adopting the *principle of least privilege*.