Security

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 be enforced
      - Preserve secrecy or privacy
  - Integrity
    - Data is only modifiable by authorised people
  - Availability
    - Data is available to authorized parties

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

- 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 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

```
LOGIN: ken
PASSWORD: FooBar
SUCCESSFUL LOGIN
```
(a)

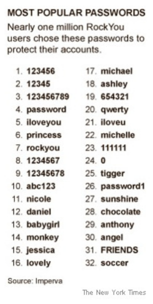
```
LOGIN: carol
INVALID LOGIN NAME
LOGIN:
```
(b)

```
LOGIN: carol
PASSWORD: Idunn
INVALID LOGIN
LOGIN:
```
(c)

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

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 old versions of Linux/Unix

Improving Password Security with a *Salt*

- Idea:
  - 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
- 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
- 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)

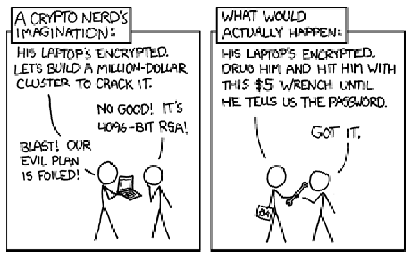
- On home PC
  - Compute one-time password to supply via 3 iterations of 1 way function
  - Subsequent via 2, 1, 0
- Note
  - Server never stores secret (s)
  - Home PC store number of passwords used, but does not need to store secret either.

Challenge-Response

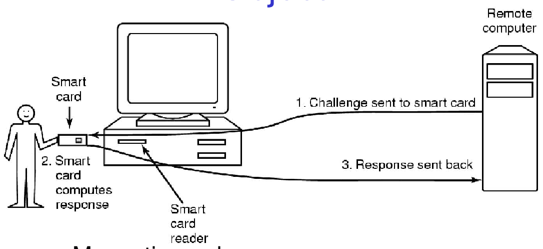
- Server and client both know secret key (k)
- Server sends a *challenge* random number (c) to client
- Client combines the secret key (k) with random number (c) and applies a publicly-known function r = f(c,k)
- Client sends the response to server
- On server, if supplied r equals f(c,k) we have successful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


A CRYPTO NERD'S IMAGINATION:
HIS LAPTOP'S ENCRYPTED. LET'S BUILD A MILLION-DOLLAR CLUSTER TO CRACK IT.
NO GOOD! IT'S 4096-BIT RSA!
BLAST! OUR EVIL PLAN IS FOILED!
WHAT WOULD ACTUALLY HAPPEN:
HIS LAPTOP'S ENCRYPTED. DRUG HIM AND HIT HIM WITH THIS $5 WRENCH UNTIL HE TELLS US THE PASSWORD.
GOT IT.

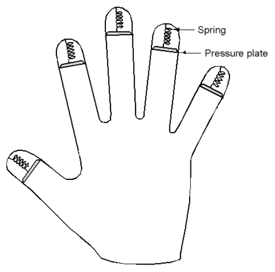
Authentication Using a Physical Object



- 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



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

Login:
Login:
(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

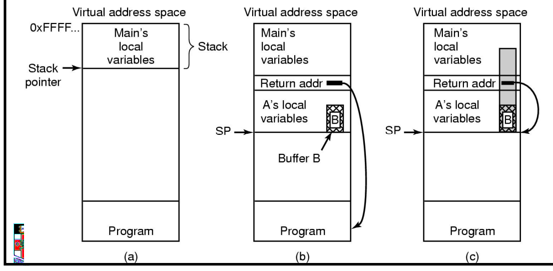
- Code inserted by the programmer to bypass some check.
  - Example: The login program

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

       (a)                                        (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



Viruses

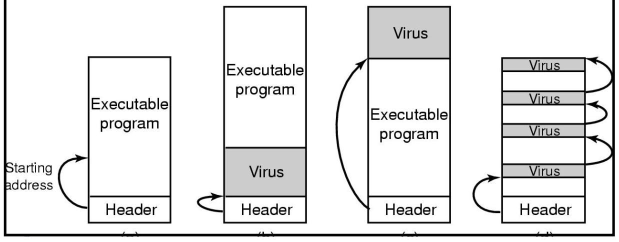
- A program that reproduces itself by attaching its code to another program.
- Can do anything the normal program could do
  - Print harmless message
  - Destroy all files on hard disk
  - Send all your data to the net
  - Trash the EEPROM BIOS to make your computer inoperable
  - Denial of service attack

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).

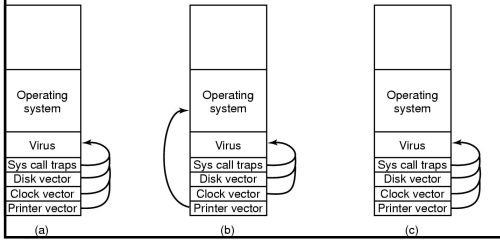


How Viruses Work

- 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?

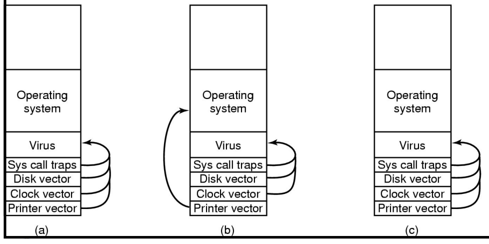
How Viruses Work

- 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

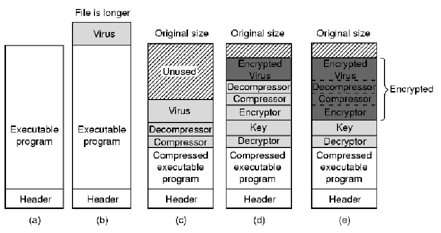
How Viruses Spread

- 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

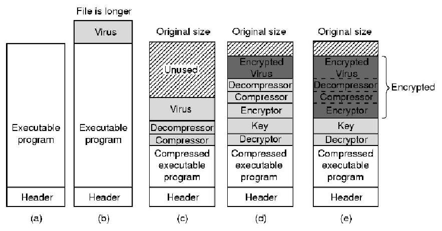
- Scanning
  - Search each file and check if virus present
    - 10,000 potential viruses and 10,000 files
    - Hard to make fast
  - Use fuzzy searches to catch small changes in known viruses
    - Slower, false positives
  - Trade-off between accuracy and acceptable performance

Antivirus and Anti-Antivirus Techniques



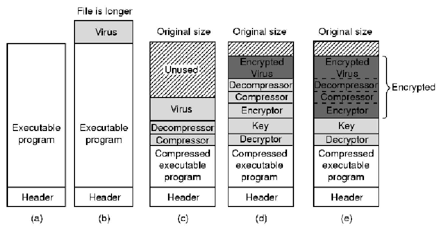
(a) A program
(b) Infected program
Change in file length a give away

Antivirus and Anti-Antivirus Techniques



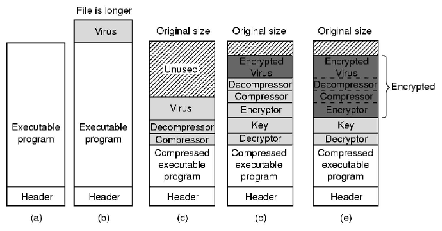
(c) Compressed infected program
Presence of virus code still a give away

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

```
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
  (a)           (b)           (c)           (d)           (e)
```

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

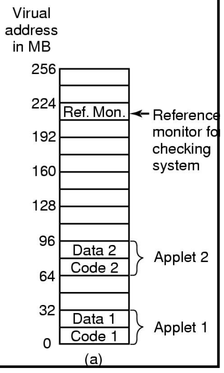
- A guiding principle we would like to apply
- Idea:
  - Give the suspicious program only the privileges required to complete the task you expect, nothing more
  - Example:
    - Can only perform file related system calls
    - Can only access files within a specified directory

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

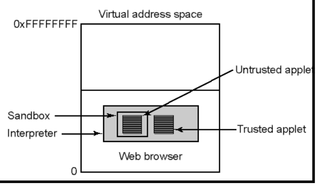
- Firstly, assume we can restrict access to code to avoid problem of self modifying code
- To restrict code to the code segment
  - Scan the code
  - Check all jumps and branches jump to addresses within the sandbox
    - Handle both absolute and relative addresses
  - For computed (dynamic jumps) we insert extra instruction into the code to check the destination addresses are within the code
    - Involves fairly complex code rewriting, but it is doable
- To restrict data access to data section, we do the some thing we did for code

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

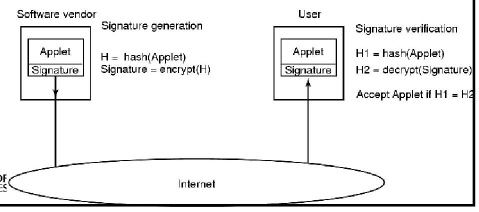
Interpretation

- 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*.