

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”

- 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



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.



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

- **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

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.**

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 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**



Intruders

- Strategies to provide security typically consider the expected *intruders* (also called *adversaries*) to be protected against.
- Common categories
 1. Casual prying by non-technical 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



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



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?



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

LOG IN: ken
PASSWORD: FooBar
SUCCESSFUL LOGIN

(a)



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LOG IN: carol
INVALID LOGIN NAME
LOGIN:

(b)

LOG IN: carol
PASSWORD: Idunno
INVALID LOGIN
LOGIN:

(c)



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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 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



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PASSWORD: Idunno
INVALID LOGIN
LOGIN:

(c)



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The Importance Password Security

- Good password security is vital if computer is publicly accessible .
 - E.g., dialup server
 - Connected to a network or the Internet
- It's common for *war diallers* to probe phone numbers or crackers to probe internet connect machines



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Problems with Password Security

- One study from 1979
 - Given a list of first name, last names, street names, moderate dictionary, licence 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



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An Attack on Encrypted Passwords

- Take the dictionary of words, names, etc, and encrypt all of them using the same encryption algorithm
- Simply match pre-encrypted list with password file to get matches

Approaches to improving password security

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

Improving Password Security

- Storing passwords more securely does not help if user ‘homer’ has the password ‘homer’
- Users 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

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 = $e(\text{Dog1234}), 1234$
- Cracker must encrypt each dictionary word 2^n different ways
 - Make pre-computed list 2^n times larger
- UNIX takes this approach with $n = 12$
- Additional security via making encrypted passwords unreadable (*shadow passwords*)

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

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.

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.

One-time Passwords

- Password changing in the extreme
- Advantage:
 - Snooping login provides no useful information
 - Only a stale previous password
- Approach:
 - 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.

Challenge-Response

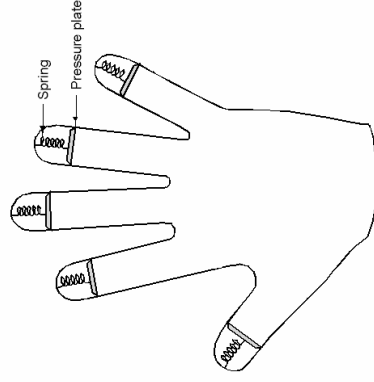
- Advantage:
 - Secret Key is never transmitted on potentially insecure networks
 - Eavesdropping is fruitless
 - Assuming function (f) is such that k cannot be easily deduced from a large number of observed challenge-responses
- Con:
 - Need a 'computer' present to login (compute response)
 - PDA, phone,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

Challenge-Response

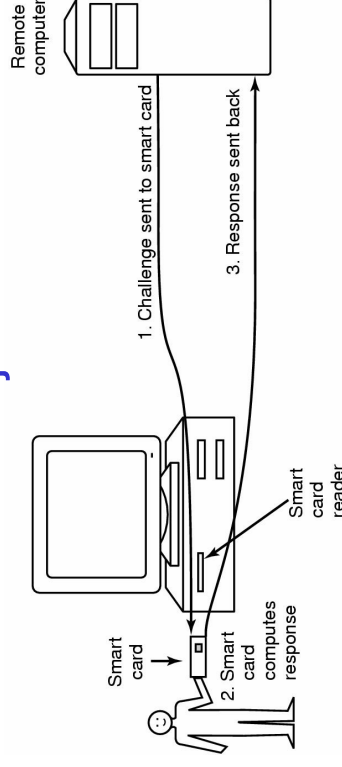
- Server and client both know secret key (k)
- Server sends a *challenge* -- random number (c) to client
- Client combines the secret key (k) with random number (c) and applies a publicly-known function $r = f(c,k)$
- Client sends the response to server
- On server, if supplied r equals $f(c,k)$ we have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

Authentication Using Biometrics

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



Authentication Using a Physical Object



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

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.



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



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).



Software Threats

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



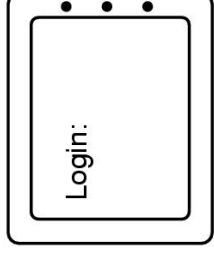
Logic Bombs

- 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

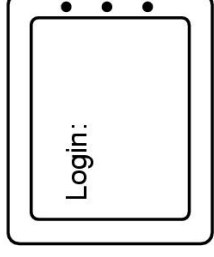


Login Spoofing

- 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 (**Secure Attention Key**)



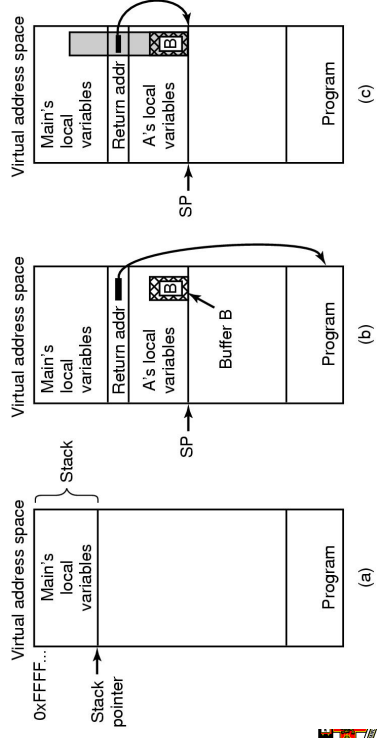
(a)



(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



Trap Doors

- 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)

How Viruses Work

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

Viruses

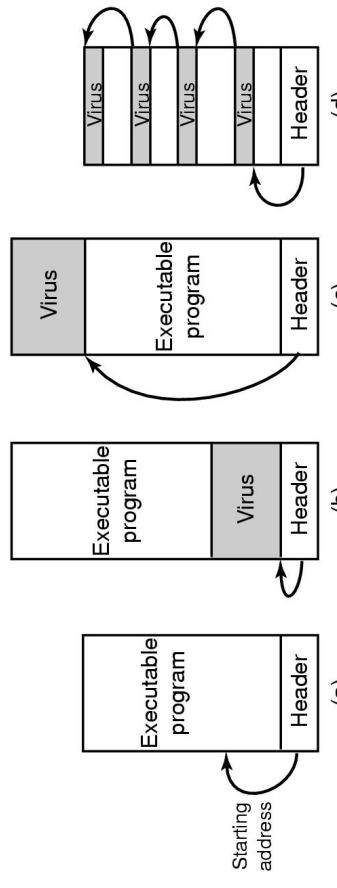
- A program that reproduces itself by attaching its code to another program.
- Can do anything the normal program could do
 - Print harmless message
 - Destroy all files on hard disk
 - Send all your data to the net
 - Trash the EEPROM BIOS to make your computer inoperable
 - Denial of service attack

How Viruses Work

- 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?

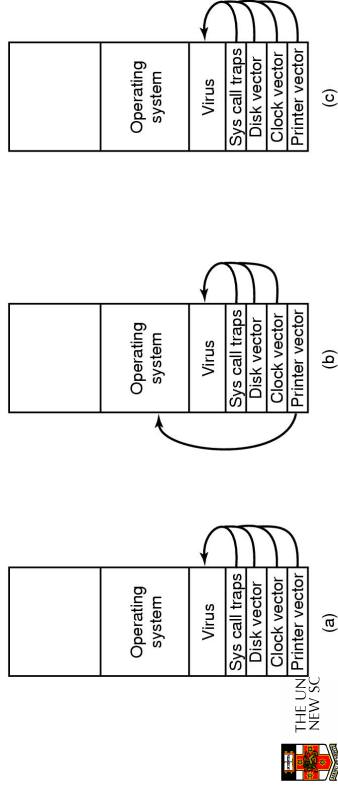
How Viruses Work

- 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).



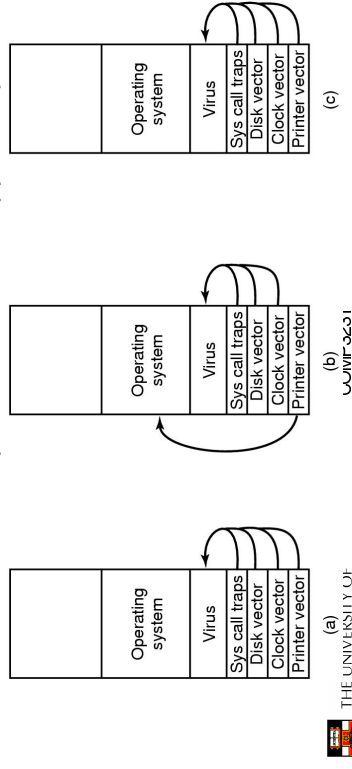
How Viruses Work

- 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

- 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



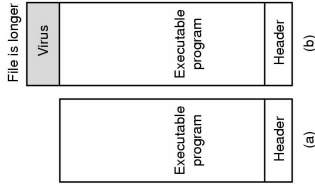
How Viruses Spread

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

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)

Antivirus and Anti-Antivirus Techniques

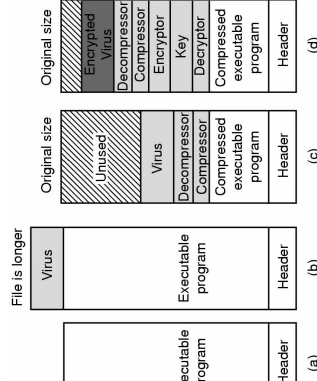


- (a) A program
 (b) Infected program
 Change in file length a give away

Antivirus Approach

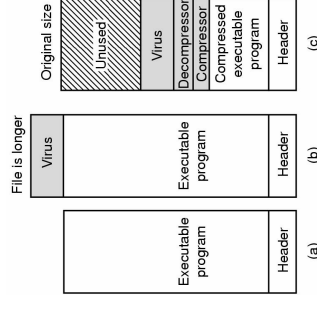
- Scanning
 - Search each file and check if virus present
 - 10,000 potential viruses and 10,000 files
 - Hard to make fast
 - Use fuzzy searches to catch small changes in known viruses
 - Slower, false positives
 - Trade-off between accuracy and acceptable performance

Antivirus and Anti-Antivirus Techniques



- (d) Encrypted virus
 Presence of (de)compressor 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

```

MOV A,R1
ADD B,R1
ADD C,R1
SUB #4,R1
MOV R1,X

MOV A,R1
NOP
ADD B,R1
NOP
ADD C,R1
NOP
SUB #4,R1
MOV R1,X

MOV A,R1
ADD #0,R1
ADD B,R1
OR R1,R1
ADD C,R1
SHL #0,R1
SUB #4,R1
JMP +1
MOV R1,X

MOV A,R1
OR R1,R1
ADD B,R1
MOV R1,R5
ADD B,R1
CMP R2,R5
SUB #4,R1
JMP +1
MOV R1,X
MOV R5,Y
    
```

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

Examples of a polymorphic virus

All of these examples do the same thing ⁵⁰

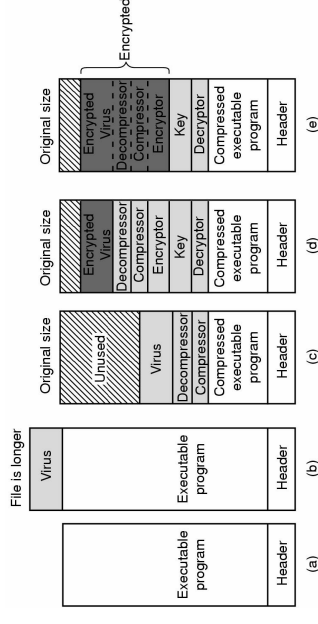


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Antivirus and Anti-Antivirus Techniques



(e) Compressed virus with encrypted compression code

Can still search for remaining decryptor code



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49

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



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52

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
- Behavioural checkers
 - Look for virus-like behaviour
 - Example: overwriting executable file
 - False alarms (e.g., a compiler)



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51

Principle of Least Privilege

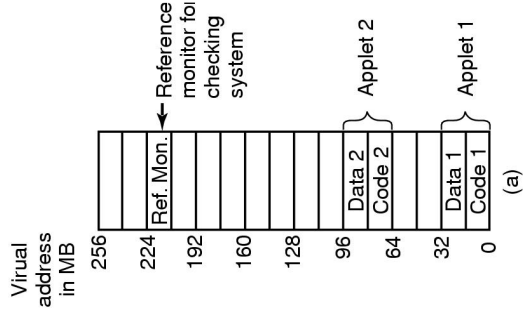
- A guiding principle we would like to apply
- Idea:
 - Give the suspicious program only the privileges required to complete the task you expect, nothing more
- Example:
 - Can only perform file related system calls
 - Can only access files within a specified directory

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

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?



Example: Active Web Content

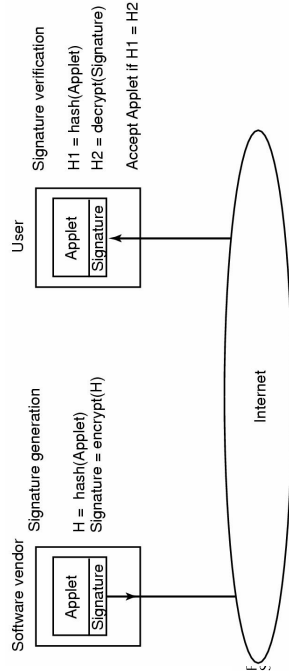
- We'd like to browse "active" web content
 - Run content in the web browser
 - The browser has all the privileges we do
- Some approaches
 - Sandboxing
 - Interpretation
 - Code Signing

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

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

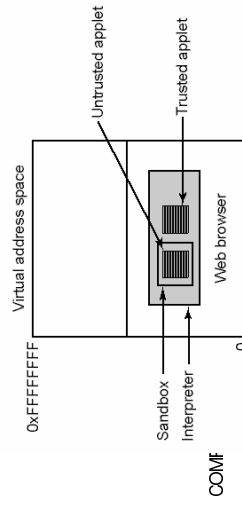


Sandbox Implementation

- 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

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



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*.

