CS 480/557
Introduction to Information Security

Presentation #10

Computer Security Threats

Tjaden – Ch. 8

Overview

- Computer Security
  1. Physical Security   2.Human Security   3.Program Security
- Computer security threats
  - Unintentional:
    - Coding faults   - Operational faults   - Environmental faults
  - Intentional (malicious code):
    - Trojan horses
    - Trap doors
    - Viruses
    - Worms

Physical Security

- **Physical security** entails restricting access to some object by physical means
  - Examples: locked doors and human guards
- Neglecting physical security can undermine other security mechanisms that protect a system
  - Example: a system with an superb file-protection mechanism
    - The disk drive that stores the file-system is publicly accessible
    - An attacker could attach his own computer to the drive and read its contents

Human Factors

- **Human factors** - the users of computer systems impact security
- Users can undermine system security through their naïveté, laziness, or dishonesty
  - Users of a system should also be educated about its security mechanisms so that they are unlikely to accidentally undermine them
    - Explain to users why certain passwords are weak or help them choose strong ones
  - Users of a system should be screened so that they are unlikely to purposely abuse the system privileges they are given
    - People who have exhibited a pattern of dishonest behavior in the past are risky users

Program Security

- **Program security** requires that the software that runs on a computer system must be:
  - Written correctly (NO *coding faults*)
  - Installed and configured properly (NO *operational faults*)
  - Used in the manner in which they were intended (NO *environmental faults*)
  - Properly behaved (NO *malicious code*)
- Flaws in any of these areas may be discovered and exploited by attackers

Program Security (cont)

- **Coding faults** – development bugs that can be exploited to compromise system security
- Examples:
  - **Condition validation errors** – a requirement is either incorrectly specified or incompletely checked
  - **Synchronization errors** – operations are performed in an improper order

Condition Validation Error – An "Incorrect Specification" Example

- The *uux* (Unix-to-Unix command execution) utility
- Used to execute a sequence of commands on a specified (remote) system
- For security reasons, the commands executed by *uux* should be limited to a set of "safe" commands
  - The *date* command (displays the current date and time) is a safe command and should be allowed
  - The *rm* command (removes files) is not a safe command and should not be allowed

Condition Validation Error – Example (cont)

- Processing *uux* requests:
  - For each command:
    - Check the command to make sure it is in the set of "safe" commands
    - Skip the command's arguments until a delimiter is reached
  - Example:
    - *cmd1 arg1 arg2 ; cmd2 ; cmd3 arg1*
  - The problem: some implementations did not include the ampersand (&) in the list of delimiters though it is a valid delimiter
  - The result: unsafe commands (e.g. cmd4) could be executed if they followed an ampersand:
    - *cmd2 & cmd4 arg1*

Synchronization Error – Improper Order of Execution : An Example

- The *mkdir* utility – creates a new subdirectory
  - Creates a new, empty subdirectory (owned by *root*)
  - Changes ownership of the subdirectory from *root* to the user executing *mkdir*
- The problem:
  - If the system is busy, it may be possible to execute a few other commands between the two steps of *mkdir*
  - Example:
    - Delete the new directory after step one and replace it with a link to another file on the system
    - When step two executes it will give the user ownership of the file

Program Security (cont)

- **Malicious code** - programs specifically designed to undermine the security of a system
  - Trojan horses
    - Login spoof
    - Root kits
  - Trap doors
  - Viruses
    - Virus scanning
    - Macro viruses
  - Worms
    - The Morris worm

Trojan Horses

- History – a hollow wooden horse used by the Greeks during the Trojan War
- Today - a **Trojan horse** is a program that has two purposes: one obvious and benign, the other hidden and malicious
- Examples:
  - Login spoof
  - Mailers, editors, file transfer utilities, etc.
  - Compilers

Trojan Horses (cont)

- Examples (cont):
  - Salami
    - Programmer writes bank software that credits interest to customer accounts each month
    - The result of the interest computation on many accounts may not be a whole number of cents
    - Example:
      - 0.25 percent of $817.40 is $2.0435
      - Should be rounded down to $2.04 in interest
    - Programmer instructs program to deposit fractional cents into the programmer's account

Trojan Horses (cont)

- Examples (cont):
  - Root kits
    - A *root kit* is collections of Trojan Horse programs that replace widely-used system utility programs:
      - *ls* and *find* (hides files)
      - *ps* and *top* (hides processes)
      - *netstat* (hides network connections)
    - Goal: conceal the intruder's presence and activities from users and the system administrator

Trap Doors

- **Trap doors** are flaws that designers place in programs so that specific security checks are not performed under certain circumstances
- Example: a programmer developing a computer-controlled door to a bank's valut
  - After the programmer is done the bank will reset all of the access codes to the vault
  - However, the programmer may have left a special access code in his program that always opens the vault

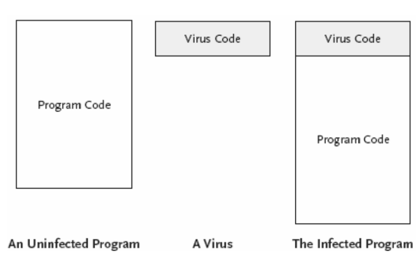
Viruses

- A **virus** is a fragment of code created to spread copies of itself to other programs
- Require a **host** (typically a program):
  - In which to live
  - From which to spread to other hosts
- A host that contains a virus is said to be **infected**
  - A virus typically infects a program by attaching a copy of itself to the program
- Goal: spread and infect as many hosts as possible

Viruses (cont)

- Virus may prepend its instructions to the program's instructions
  - Every time the program is run the virus' code is executed
    - **Infection propagation** – mechanism to spread infection to other hosts
    - **Manipulation routine** – (optional) mechanism to perform other actions:
      - Displaying a humorous message
      - Subtly altering stored data
      - Deleting files
      - Killing other running programs
      - Causing system crashes
      - Etc.

Viruses (cont)



Defending Against Computer Viruses

- **Virus scanning** programs check files for signatures of known viruses
  - **Signature** = some unique fragment of code from the virus that appears in every infected file
- Problems:
  - **Polymorphic viruses** that change their appearance each time they infect a new file
    - No easily recognizable pattern common to all instances of the vi rus
  - New viruses (and modified old viruses) appear regularly
    - Database of viral signatures must be updated frequently

Macro Viruses

- More than just programs can serve as hosts for viruses
- Examples: spreadsheet and word processor programs
  - Usually include a macro feature that allows a user to specify a series of commands to be executed
  - Macros provide enough functionality for a hacker to write a **macro virus**:
    - Executed every time an infected document is opened
    - Has an infection propagation mechanism
    - May have a manipulation routine
  - Example: Microsoft Word:
    - *AutoOpen* macro – run automatically whenever the document containing it is opened
    - *AutoClose* macro – run automatically whenever the document containing it is closed

The Melissa Macro Virus

- Appeared in March, 1999
- Exploited Microsoft Word macros
- Spread by e-mail:
  - Victim received an e-mail message with the subject line "Important Message From NAME"
  - Infected Word document as an attachment:
  - When an infected document was opened:
    - Virus attempted to infect other documents
    - E-mail a copy of an infected document to up to fifty other people
      - E-mail addresses of the new victims were taken from a user's Outlook address book
      - Value to use for NAME in the subject line was read from the Outlook settings

Melissa's Impact

- In three days, infected more than 100,000 computers
- Some sites received tens of thousands of e-mail messages in less than an hour
  - Mail server crashes
  - System performance degradation
- Besides spreading the virus:
  - Modified the settings in Microsoft Word to conceal its presence
  - Occasionally modified the contents of the documents that it infected
  - Occasionally sent sensitive documents without the owner's knowledge

Worms

- Virus = a program fragment
- **Worm** = a stand-alone program that can replicate itself and spread
- Worms can also contain manipulation routines to perform other actions:
  - Modifying or deleting files
  - Using system resources
  - Collecting information
  - Etc.

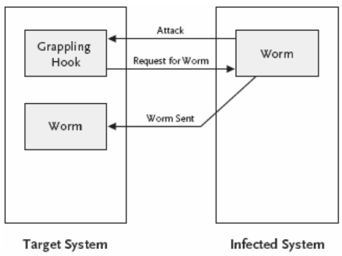
The Morris Worm

- Appeared in November, 1988
- Created by a Computer Science graduate student
- Brought down thousands of the ~60,000 computers then attached to the Internet
  - Academic, governmental, and corporate
  - Suns or VAXes running BSD UNIX

Operation of the Morris Worm

- Used four different attack strategies to try to run a piece of code called the **grappling hook** on a target system
- When run, the grappling hook:
  - Made a network connection back to the infected system from which it had originated
  - Transferred a copy of the worm code from the infected system to the target system
  - Started the worm running on the newly infected system

The Morris Worm's Grappling Hook



Attack Strategy #1: Exploiting *sendmail*

- Many versions of *sendmail* had a debug option
  - Allowed an e-mail message to specify a program as its recipient
- Named program ran with the body of the message as input
- The worm created an e-mail message:
  - Contained the grappling hook code
  - Invoked a command to strip off the mail headers
  - Passed the result to a command interpreter

Attack Strategy #2: Exploiting the *finger* daemon

- The finger daemon, *fingerd*, is a remote user information server
  - Which users currently logged onto the system
  - How long each has been logged on
  - The terminal from which they are logged on
  - Etc.
- A **buffer overflow** bug in *fingerd* on VAXes allowed the worm to execute the grappling hook code

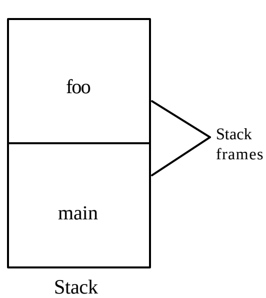
Buffer Overflows

- A program's *stack segment*:
  - Temporary working space for the program
  - Example: Subroutines

```
int foo(int P1, int P2) /* subroutine "foo" */
{
    int L1, L2; /* local variables L1 and L2 */
    L1 = P1 + P2;
    return(L1); /* return value */
}

int main() /* main program */
{
    …
    x = foo(1,2); /* call to subroutine "foo" */
    …
}
```


Stack Frames



Stack Frames (cont)

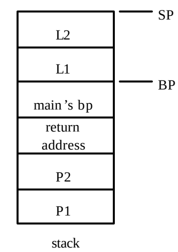
- A stack frame contains the corresponding routine's:
  - Parameters
  - Return address (i.e. next instruction to execute upon completion)
  - Saved registers
  - Local variables
- Many architectures have registers:
  - SP, the *stack pointer*, points to the top of the stack
  - BP, the *base pointer*, points to a fixed location within the frame
    - Used to reference the procedure's parameters and local variables

Stack Frames (cont)

- The *main* routine calls *foo*:
  - *foo*'s parameters are first pushed onto the stack
  - The next instruction in *main* to execute after *foo* finishes, the return address, is pushed
  - Control is transferred to *foo*
  - *foo*'s prologue:
    - Save caller's (*main*'s) base pointer
    - Set callee's (*foo*'s) *bp* equal to the current *sp*
    - Increment *sp* to reserve space on the stack for foo's local variables

Stack Frames (cont)

- *foo*'s stack frame after the completion of the prologue:

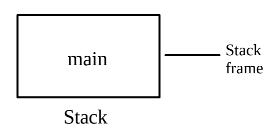


Stack Frames (cont)

- The execution of *foo*:
  - *P1 = BP*-4
  - *P2 = BP*-3
  - *L1 = BP*
  - *L2 = BP*+1
- The statement "L1 = P1 + P2" would performed by the following assembly language instruction:
  - add BP-4, BP-3, BP // adds first two arguments and stores the result in the third

Stack Frames (cont)

- *foo*'s epilogue cleans up the stack and returns control to the caller:
  - Caller's (*main*'s) *bp* is placed back into the *bp* register
  - The return address is placed into the *ip* (instruction pointer) register
  - The stack pointer is decremented to remove the callee's frame from the stack



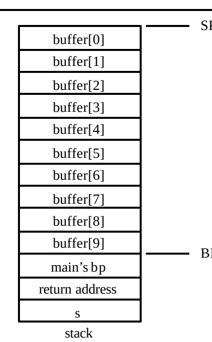
A Buffer Overflow

```
int foo(char *s) /* subroutine "foo" */
{
   char buffer[10]; /* local variable*/
   strcpy(buffer,s);
}

int main() /* main program */
{
   char name[]="ABCDEFGHIJKL";
   foo(name); /* call to subroutine "foo" */
}
```

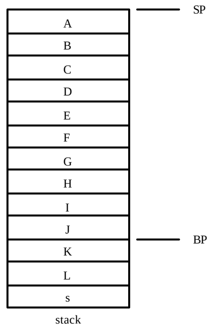

A Buffer Overflow (cont)

- *foo*'s stack frame after prologue:



A Buffer Overflow (cont)

- Stack after execution of *foo* (but before the epilogue):



A Buffer Overflow (cont)

- The string overflowed *foo*'s buffer:
  - Overwrote *main*'s bp
  - Overwrote the return address with 'L' = 89 (ASCII)
- When *foo* finishes control will be transferred to the instruction at address 89
  - Error
- The Morris worm sent a specially crafted 243-byte string to the finger daemon:
  - Overflowed a buffer and overwrote the return address
  - The *fingerd* executed the */bin/sh* program which executed the grappling hook code

Attack Strategy #3: Exploiting *rsh*

- *rsh* = "remote shell"
  - Allows users to execute commands on a remote host from a machine that the remote host trusts
    - */etc/hosts.equiv*
    - *.rhosts*
- The worm used *rsh* to run the grappling hook code on remote computers that trusted an infected machine

Attack Strategy #4: Exploiting *rexec*

- *rexec* = remote execution
  - Protocol that enables users to execute commands remotely
    - Must specify:
      - A host
      - A valid username and password for that host
- The worm attempted to crack passwords on each computer that it infected so that it could use *rexec* to infect other hosts
  - No password
  - The username
  - The username appended to itself
  - The user's last name or nickname
  - The user's last name reversed
  - Dictionary attack using 432-word dictionary carried with the worm
  - Dictionary attack using ~25,000 words in */etc/dict/words*

Operation of the Worm

- Performed many actions to try to camouflage its activity:
  - Changed its process name to *sh*
  - Erased its argument list after processing it
  - Deleted its executable from the filesystem once it was running
  - Various steps to make sure that a *core* file would not be generated
  - Spent most time sleeping
  - Forked every three minutes, parent process exited and the child continued
    - Changed the worm's process identification number (pid) often
    - Prevent the worm from accumulating too much CPU time
  - All constant strings inside the worm were XORed character-by-character with the value 81_{16}
  - Used a simple challenge and response mechanism to determine whether or not a machine it had just infected was already running a copy of the worm
    - Immortal – one in seven times this check was not performed

Aftermath

- The worm spread quickly and infected a large percentage of the computers connected to the Internet
- Noticed within hours
- Took days for researchers to discover how the worm worked and how to stop it
- In 1990, Morris was convicted by a federal court of violating the Computer Crime and Abuse Act of 1986:
  - Three years of probation
  - Four hundred hours of community service
  - $10,050 fine

Summary

- **Program security** requires that the programs that run on a computer system be:
  - Written correctly
  - Installed and configured properly
  - Used in the manner in which they were intended
  - Do not behave maliciously
    - Trojan horses - a program that has two purposes: one obvious and benign, the other hidden and malicious
    - Viruses - a fragment of code created to spread copies of itself to other programs
    - Worms - a stand-alone program that can replicate itself and spread