Security

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The Security Problem

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  - How do we provide controlled access to programs and data stored in a computer system?

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  - How do we provide controlled access to programs and data stored in a computer system?
- Security requires both protection system and the consideration of the external environment within which the system operates.

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- Attack is attempt to breach security: accidental or malicious.

Security Violation Categories

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- Denial of Service (DoS): prevention of legitimate use

Security Violation Methods

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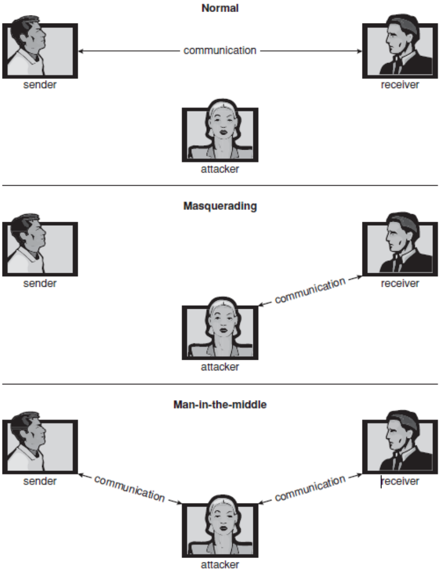
- Man-in-the-middle attack: intruder sits in data flow, masquerading as sender to receiver and vice versa
- Session hijacking: intercept an already-established session to bypass authentication

Standard Security Attacks



Security Measure Levels

- Security must occur at four levels to be effective:
  - Physical: data centers, servers, connected terminals
  - Human: only appropriate users have access to the system
  - OS: protection mechanisms, debugging
  - Network: intercepted communications, interruption, DOS

Program Threats

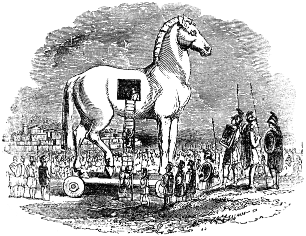
Program Threats

- Many variations, many names
  - Trojan horse
  - Trap door
  - Logic bomb
  - Stack and buffer flow
  - Viruses

Trojan Horse

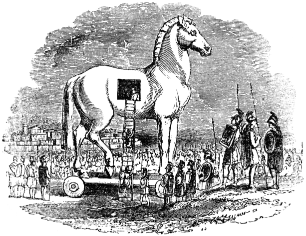
Trojan Horse (1/2)

- Code segment that misuses its environment.



Trojan Horse (1/2)

- Code segment that misuses its environment.
- Exploits mechanisms for allowing programs written by users to be executed by other users.
- Example:
  - A text-editor program has a code to search the file to be edited for certain keywords.
  - If any are found, the entire file may be copied to a special area accessible to the creator of the text editor.



Trojan Horse (2/2)

- Variation of Trojan horse:
- Emulating a login program
- Spyware: accompanies a program that the user has installed.
  - Download ads to display on the user's system
  - Create pop-up browser windows when certain sites are visited
  - Capture information from the user's system and return it to a central site: covert channel

Trap Door

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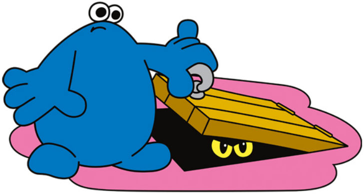
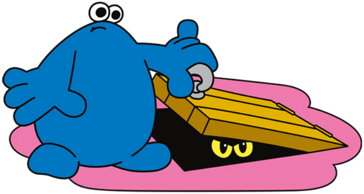


Trap Door

- A hole in the software that only designer of a program is capable of using.
- Could be included in a compiler.
- Difficult to detect: we have to analyze all the source code for all components of a system.



Logic Bomb

Logic Bomb

- Program that initiates a security incident under certain circumstances.

- Hard to detect: because under normal operations, there would be no security hole.

Stack and Buffer Flow

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- The most common way for an attacker to gain unauthorized access to the target system.
- The attack exploits a bug in a program.
  - E.g., The programmer neglected to code bounds checking on an input field.
  - The attacker sends more data than the program was expecting.
  - The attacker can write a program to do the next page steps.

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1. Overflow an input field, for example, a web-page form expects a user name, until it writes into the stack.
2. Overwrite the current return address on the stack with the address of the exploit code loaded in step 3.
3. Write a simple set of code for the next space in the stack that includes the commands that the attacker wishes to execute, for instance, spawn a shell.

Stack and Buffer Overflow (3/6)

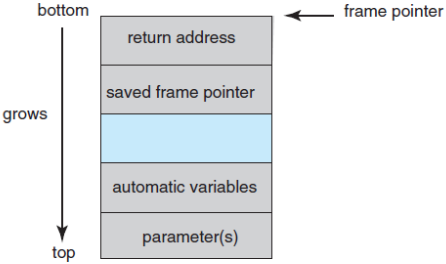
```
#include <stdio.h>
#define BUFFER_SIZE 256

int main(int argc, char *argv[])
{
   char buffer[BUFFER_SIZE];

   if (argc < 2)
      return -1;
   else {
      strcpy(buffer,argv[1]);
      return 0;
   }
}
```

- Lack of bounds checking
- If the command line input is longer than `BUFFER_SIZE`?

Stack and Buffer Overflow (4/6)



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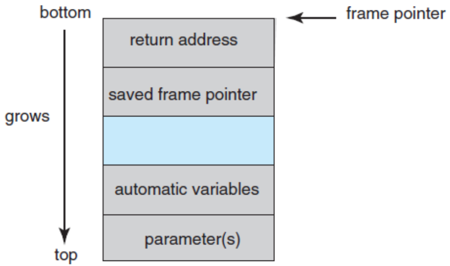

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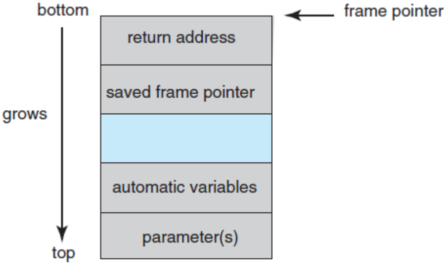

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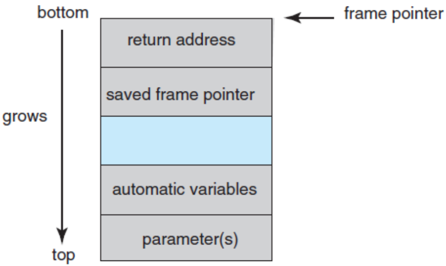

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- Frame pointer: the address of the beginning of the stack frame.
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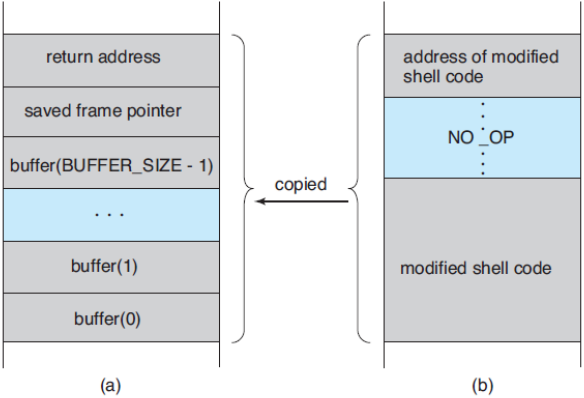
- Return address: where to return control once the function exits.

Stack and Buffer Overflow (5/6)



Stack and Buffer Overflow (6/6)

```
#include <stdio.h>

int main(int argc, char *argv[])
{
    execvp(''\bin\sh'',''\bin \sh'', NULL);
    return 0;
}
```

- The cracker could replace the return address with the address of the code segment containing the attacking program.

Viruses

Viruses

- Code fragment embedded in legitimate program.
- Self-replicating: designed to infect other computers.
- Very specific to CPU architecture, OS, applications.
- Usually borne via email or as a macro.

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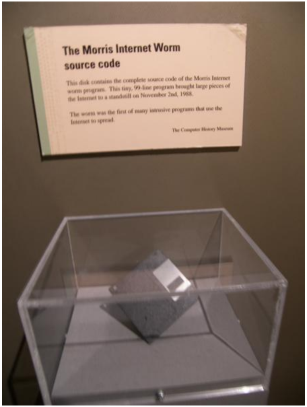
- They include:
  - Worms
  - Port scanning
  - Denial of Service (DoS)

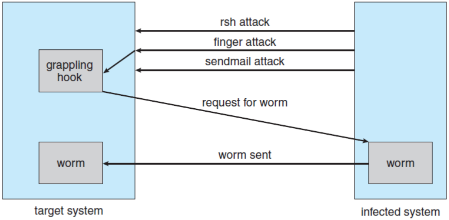
Worms (1/2)

- An standalone program that replicates itself in order to spread to other computers.
- Often, it uses a computer network to spread itself.
- Unlike a computer virus, it does not need to attach itself to an existing program.
- The Morris worm (the Internet worm) is the first computer worms distributed via the Internet: 1988



Worms (2/2)

- Morris worm: exploited UNIX networking features in `rsh` and bugs in `finger` and `sendmail` programs.
- It made up of two programs: a grappling hook program and the main program.
- The grappling hook program uploaded main worm program.



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- A means to detect a system's vulnerabilities to attack.
- Automated attempt to connect to a range of ports on IP addresses.
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- `nmap` scans all ports in a given IP range for a response
- `nessus` has a database of protocols and bugs (and exploits) to apply against a system.

Denial of Service (DoS)

- Overload the targeted computer preventing it from doing any useful work.
- Distributed denial-of-service (DDoS) come from multiple sites at once.
- Consider traffic to a web site.
- CS students writing bad `fork()` code.

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- Cryptography enables a recipient of a message to verify that the message was created by some computer possessing a certain key.

- Similarly, a sender can encode its message so that only a computer with a certain key can decode the message.

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- A function $D : K \rightarrow (C \rightarrow M)$
  - For each $k \in K$, D_k is a function for generating messages from ciphertexts.

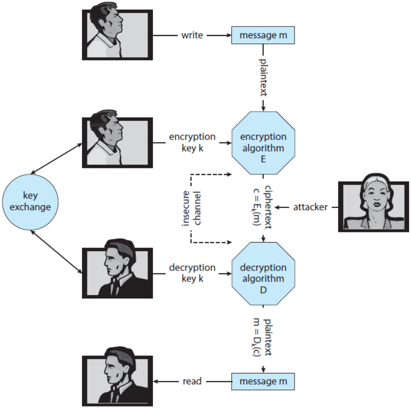
Encryption (2/2)

- An encryption algorithm must provide this essential property:
  - Given a ciphertext $c \in C$, a computer can compute m such that $E_k(m) = c$ only if it possesses k.

- Thus, a computer holding k can decrypt ciphertexts to the plaintexts.

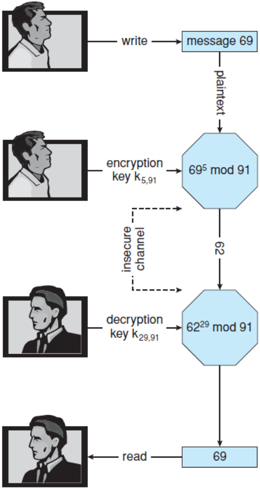
Symmetric Encryption

- Same key used to encrypt and decrypt.
  - k must be kept secret.
- E.g., DES, Triple-DES, AES, RC4



Asymmetric Encryption

- Each user having two keys:
  - Public key: published key used to encrypt data.
  - Private key: key known only to individual user used to decrypt data.
- Most common is RSA block cipher.



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  - A function $S : K \rightarrow (M \rightarrow A)$: for each $k \in K$, S_k is a function for generating authenticators from messages.
  - A function $V : K \rightarrow (M \times A \rightarrow \{\texttt{true}, \texttt{false}\})$: for each $k \in K$, V_k is a function for verifying authenticators on messages.

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- Thus, computer holding k can generate authenticators on messages so that any other computer possessing k can verify them.

- Practically, if $V_k(m, a) = \texttt{true}$ then we know m has not been modified and that send of message has k.

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- E.g., MD5 (128-bit hash), and SHA-1 (160-bit hash)

Authentication - Hash Function (2/2)

- Not useful as authenticators.
  - For example $H(m)$ can be sent with a message.
  - But if H is known someone could modify m to m' and recompute $H(m')$ and modification not detected
  - So must authenticate $H(m)$: MAC and digital signature

Authentication - MAC

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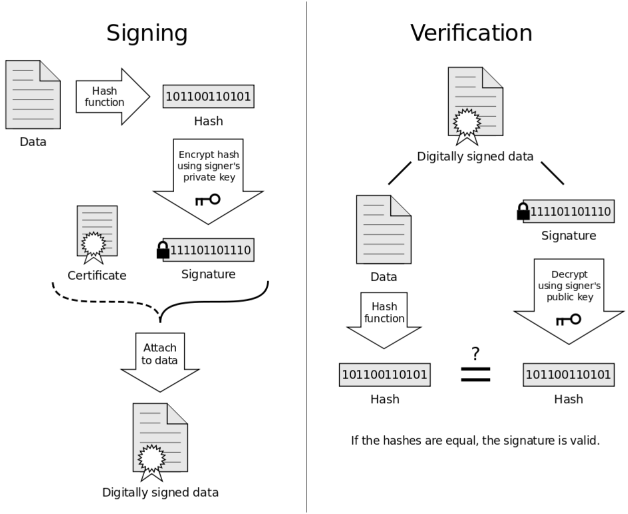
- Note that k is needed to compute both S_k and V_k, so anyone able to compute one can compute the other end digital signature.

Authentication - Digital Signature (1/2)

- Based on asymmetric keys and digital signature algorithm.
- Authenticators produced are digital signatures.
- Anyone can verify authenticity of a message.
- In a digital-signature algorithm, computationally infeasible to derive k_s from k_v.
- k_v is the public key and k_s is the private key.

Authentication - Digital Signature (2/2)



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  - Man-in-a-middle attack.
  - What we need is a proof of who owns a public key? digital certificate

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- Certificate authority are trusted party - their public keys included with web browser distributions.

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  - An attribute of the user (fingerprint, retina pattern, or signature)

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- One-time passwords
  - Use a function based on a seed to compute a password, both user and computer.

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- Vulnerability assessment compares real state of a system/network to the security policy.
- Intrusion detection systems to detect attempted or successful intrusions.
  - Signature-based detection spots known bad patterns.
  - Anomaly detection spots differences from normal behavior.

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- Auditing, accounting, and logging of all or specific system or network activities.

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- User authentication: password

Questions?