Lecture13 Security and Protection

1. Protection

Introduction

Goals of Protection

- Computer consists of a collection of objects (hardware objects or software objects)
- Each object has a unique name and can be accessed through a well-defined set of operations
- **Protection problem - ensure that each object is accessed correctly and only by those that are allowed to do so**

Principles of Protection

- Guiding principle - principle of least privilege
  - Programs, users and systems should be given **just enough privileges** to perform their tasks
  - Limits damage if entity has a bug, gets abused
  - Can be
    - **static**: during life of system, during life of process
    - **dynamic**: changed by process as needed, privilege escalation

Access Matrix

domain \ object	F_1	F_2	F_3	printer
D_1	read		read	
D_2				print
D_3		read	execute	
D_4	read write		read write	

- View protection as a matrix (**access matrix**)
- Rows: **domains** (e.g. users or processes)
- Columns: **objects**
- `Access(i, j)` is the set of operations that a process executing in Domain$_i$ can invoke on Object$_j$
- Access matrix design **separates mechanism from policy**

- **Mechanism**
    - Operating system provides access-matrix + rules
    - It ensures that the matrix is only manipulated by authorized agents and that rules are strictly enforced
- **Policy**
    - User dictates policy
    - Who can access what object and in what mode

Global Table

- Store ordered **triples** `<domain, object, rights-set>` in table
- A requested operation M on object O_j within domain D_i -> search table for $< D_i, O_j, R_k >$
    - with $M \in R_k$
- Table could be too **large** (won't fit in main memory)
- **Difficult to group objects** (consider an object that all domains can read)

Access-control lists for objects

- Each column implemented as an access-control list **for one object**
- Resulting per-object list consists of ordered pairs `<domain, rights-set>` defining all domains with non-empty set of access rights for the object
- Defines who can perform what operation
    - Domain 1 = Read, Write
    - Domain 2 = Read
    - Domain 3 = Read

Capability list for domains

- List is domain based
- Capability list for domain is list of objects together with operations allows on them
- Object represented by its name or address, called a **capability**
- Execute operation M on object O_j , process requests operation and specifies capability as parameter
    - Possession of capability means access is allowed
- For each domain, what operations allowed on what objects
    - Object F1 – Read
    - Object F4 – Read, Write, Execute
    - Object F5 – Read, Write, Delete, Copy

Combination of Access-control List and Capability

- **First access** to an **object** -> access-control list searched
    - If allowed, **capability** created and **attached to** process
        - Additional accesses need not be checked
    - After last access, capability destroyed

2. Security

System **secure** if resources used and accessed as intended under all circumstances

- **Intruders** (**crackers** or **hackers**): attempt to breach security
- **Threat**: **potential** security violation
    - not yet happen
- **Attack**: **attempt** to breach security
    - might not success, but have happened

Security Violation Categories

Category	Description
*Breach of **confidentiality**	Unauthorized **reading** of data
*Breach of **integrity**	Unauthorized **modification** of data
*Breach of **availability**	Unauthorized **destruction** of data
Theft of service	Unauthorized **use** of resources
Denial of service (DOS)	Prevention of legitimate use

Security Measure Levels

Impossible to have absolute security, but make cost to perpetrator sufficiently high to deter most intruders

Security is as weak as the weakest link in the chain

- **Physical**: Data centers, servers, connected terminals
- **Human**: Avoid social engineering, phishing, dumpster diving (the weakest part)
- **Operating System**: Protection mechanisms, debugging
- **Network**: Intercepted communications, interruption, DOS

Threat and Attack

Malware

- **Trojan Horse**: Code segment that misuses its environment
- **Trap Door**: Specific user identifier or password that circumvents normal security procedures
- **Virus**: Code fragment embedded in legitimate program, Self-replicating, designed to infect other computers
- **Logic Bomb**: Program that initiates a security incident under certain circumstances

Program Security

Stack and **Buffer Overflow**

- Exploits a **bug** in a program (overflow either the stack or memory buffers)
  - Failure to check bounds on inputs, arguments
- Write past arguments on the stack into the return address on stack
- When routine returns from call, returns to **hacked address**
  - Pointed to code loaded onto stack that executes malicious code
- Unauthorized user or privilege escalation

System and Network Threats

Port scanning

- Automated attempt to **connect to a range of ports on one or a range of IP addresses**
- Detection of answering service protocol
- Detection of OS and version running on system
- `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, how can you tell the difference between being a target and being really popular?
  - Accidental: CS students writing bad fork() code
  - Purposeful: extortion, punishment

Attacks against Network Communication

- **Eavesdropping** (窃取): Stealing the content of network communication
- **Replay attack**: Resend a previously intercepted message
- **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

User Authentication

- Crucial to identify user correctly, as protection systems depend on user ID
- User identity most often established through **passwords**, can be considered a special case of either keys or capabilities

Implementing Security Defenses

Intrusion detection

Endeavors to detect attempted or successful intrusions, but False-positives and false-negatives a problem

- **Signature-based detection** spots known **bad patterns**
  - Can not detect zero-day attacks
- **Anomaly detection** spots abnormal behavior
  - Can detect zero-day attacks

Virus protection

- Searching all programs or programs at execution for known virus patterns
- Or run in **sandbox** so can't damage system

Firewall

A network firewall is placed between **trusted and untrusted hosts**. The firewall limits network access between these **two security domains**

- **Personal firewall** is software layer on given host
  - Can monitor / limit traffic to and from the host
- **Application proxy firewall** understands application protocol and can control them (i.e., SMTP)
- **System-call firewall** monitors all important system calls and apply rules to them (i.e., this program can execute that system call)

3. Cryptography

Encryption

Protect **confidentiality** of a message

Encryption Algorithm

Consist of

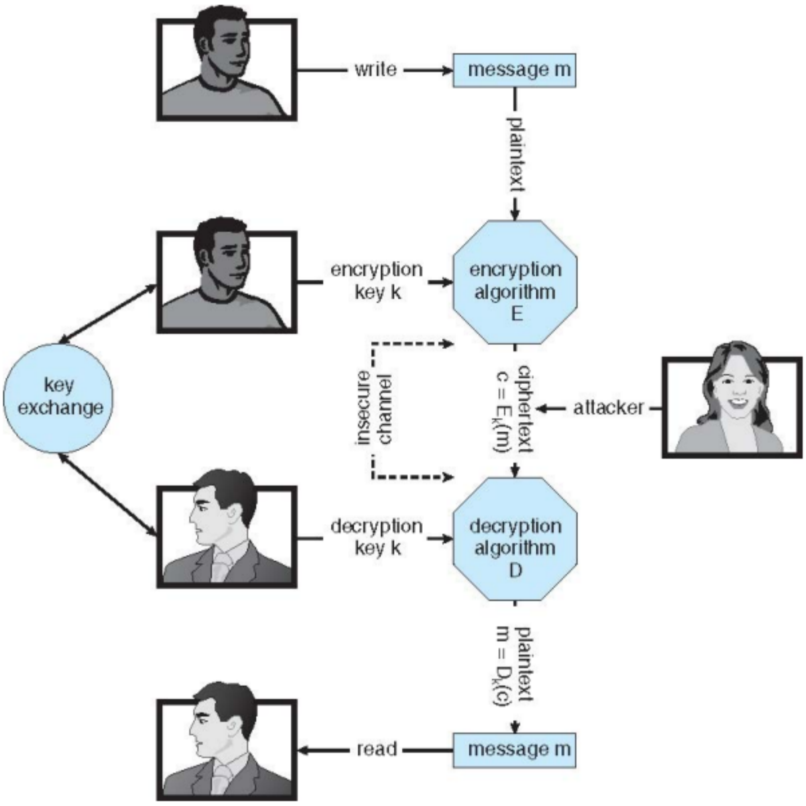
- Set K of keys
- Set M of Messages
- Set C of ciphertexts (encrypted messages)
- A function $E : K \to (M \to C)$. That is, for each $k \in K$, E_k is a function for generating ciphertexts from messages
  - Both E and E_k for any k should be efficiently computable functions
- A function $D : K \to (C \to M)$. That is, for each $k \in K,\ D_k$ is a function for generating messages from ciphertexts
  - Both D and D_k for any k should be efficiently computable functions

Essential Property

An encryption algorithm must provide this essential **property**

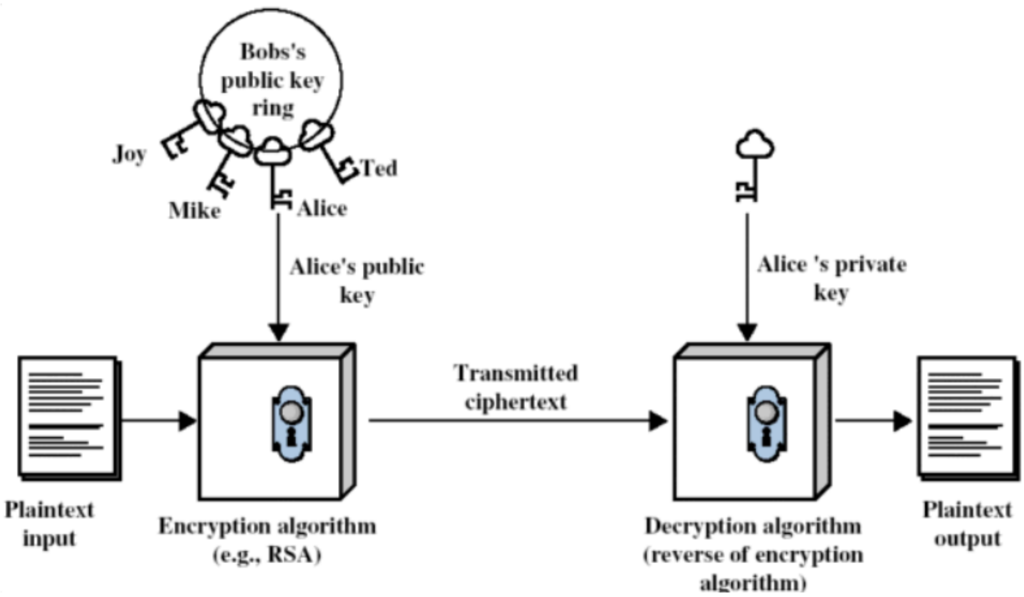
- Given a ciphertext $c \in C,$ a computer can compute m such that $E_k(m)$ = c only if it possesses k
  - Thus, a computer holding k can decrypt ciphertexts to the plaintexts used to produce them, but a computer not holding k cannot decrypt ciphertexts
  - Since **ciphertexts** are generally **exposed** (for example, sent on the network), it is important that it be infeasible to derive k from the ciphertexts

Symmetric Encryption



- Same key used to encrypt and decrypt: Therefore k must be kept secret
- **Block cipher** (messages encrypted block-by-block)
  - DES was most commonly used symmetric **block-encryption** algorithm
- **Stream cipher** (message encrypted bit-by-bit or byte-by-byte)
  - RC4 is most common symmetric stream cipher, but known to have **vulnerabilities**

Asymmetric Encryption



- **Public-key encryption** based on 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**

- Must be an encryption scheme that can be made public without making it easy to figure out the decryption scheme
    - Most common is **RSA** cipher

Authentication

Protect integrity of a message

Authentication Algorithm

- A set K of keys
- A set M of messages
- A set A of authenticators
- A function $S : K \to (M \to A)$
    - That is, for each $k \in K$, S_k is a function for generating authenticators from messages
    - Both S and S_k for any k should be efficiently computable functions
- A function $V : K \to (M \times A \to \{\text{true, false}\})$
    - That is, for each $k \in K$, V_k is a function for verifying authenticators on messages
    - Both V and V_k for any k should be efficiently computable functions

Description

- For a message m, a computer can generate an authenticator $a \in A$ such that $V_k(m, a) = \text{true}$ only if it possesses k
- Thus, computer holding k can generate authenticators on messages so that any other computer possessing k can **verify them**
- Computer not holding k cannot generate authenticators on messages that can be verified using V_k
- Since authenticators are generally **exposed** (for example, they are sent on the network with the messages themselves), it must not be feasible to derive k from the authenticators
- Practically, if $V_k(m, a)$ = true then we know m has not been modified and that send of message has k
    - If we share k with only one entity, know where the message originated

Implementation

- **Message-authentication code (MAC)**
  - Based on symmetric encryption
  - Both parties share secret keys
- **Digital signatures** authentication algorithm
  - Based on asymmetric encryption
  - **anyone** can verify authenticity of a message using the public key

Key distribution

- Symmetric: huge challenge, sometimes done out-of-band
- Asymmetric: distribute public key
  - Even asymmetric key distribution needs care: **man-in-the-middle attack**

Digital Certificates

- Proof of who or what owns a public key
- Public key digitally signed a trusted party
- Trusted party receives proof of identification from entity and certifies that public key belongs to entity
- **Certificate authority** are trusted party – their public keys included with web browser distributions
  - They vouch for other authorities via digitally signing their keys, and so on

SSL/TLS

- Used between **web servers** and **browsers** for **secure communication** (credit card numbers)
- The **server** is verified with a **certificate** assuring client is talking to correct server
- **Asymmetric cryptography** used to establish a **secure session key** (symmetric encryption) for bulk of communication during session
- **Communication** between each computer then uses symmetric key cryptography