Operating System Security

CS 239, Spring 1996

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Outline

- Introduction
- Threats
- Basic security principles
- Security on a single machine
- Distributed systems security and data communications security

Introduction

Security is an engineering problem

Always a tradeoff between safety, cost, and inconvenience

Not much solid theory in the field

Hard to provide any real guarantees

Because making mistakes is easy

And the nature of the problem implies that mistakes are always exploited

History of Security Problem

Originally, there was no security problem

Later, there was a problem, but nobody cared

Now, there are increasing problems, and people are beginning to care

Fundamental Constraints of Practical Computer Security

- Security costs
  - If too much, it won't be used
- If it isn't easy, it won't be used
- Misuse often makes security measures useless
- Fit the stringency of the measures to the threat being countered

Security is as Strong as the Weakest Link

Those breaking security will attack the weakest point

Putting an expensive lock on a cheap door doesn't help much

Must look on security problems as part of an integrated system, not just a single component

Security Threats

Extremely wide range of threats

From a wide variety of sources

Requiring a wide variety of countermeasures

Generally, countering any threat costs something

So people frequently try to counter as few as they can afford

Physical Security

Some threats involve access to the equipment itself

Such as theft,

destruction,

tampering

Physical threats usually require physical prevention methods

Social Engineering and Security

Computer security easily subverted by bad human practices

E.g., giving key out over the phone to anyone who asks

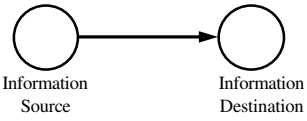
Social engineering attacks tend to be cheap, easy, effective

So all our work may be for naught

A Classification of Threats

Viewed as types of attacks on normal service

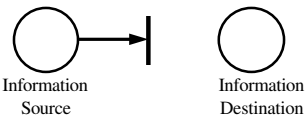
So what is normal service?



Classification of Threat Types

- Secrecy
- Integrity
- Availability
- Exclusivity

Interruption



Interruption Threats

Denial of service

Prevents source from sending information to receiver

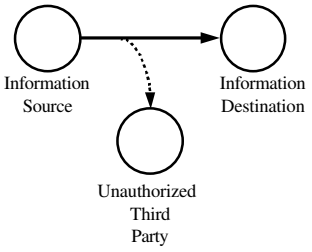
Or receiver from sending requests to source

A threat to availability

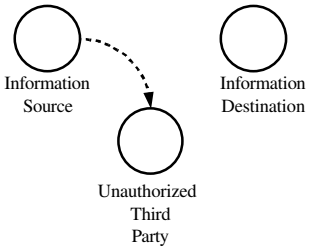
How Does an Interruption Threat Occur?

- Destruction of HW/SW
- Interference with communications channel
- Overloading a shared resource

Interception



Another Type of Interception



Interception Threats

Data or services provided to unauthorized party

Either in conjunction with or independent of authorized access

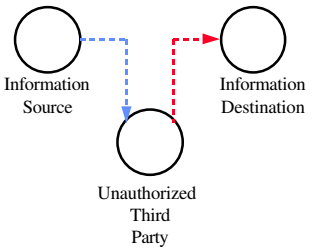
A threat to secrecy

Also a threat to exclusivity

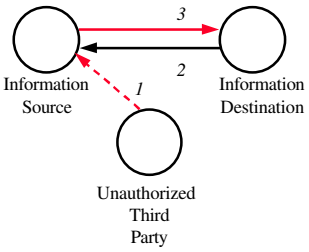
How Do Interception Threats Occur?

- Eavesdropping
- Masquerading
- Break-ins
- Illicit data copying

Modification



Another Type of Modification Threat



Modification Threats

Unauthorized parties modify data

Either on the way to the users

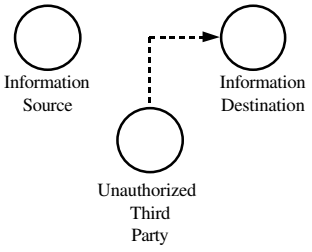
Or permanently at the servers

A threat to integrity

How Do Modification Threats Occur?

- Interception of data requests
- Masquerading
- Illicit access to servers/services

Fabrication



Fabrication Threats

Unauthorized party inserts counterfeit objects into the system

Causing improper changes in data

Or improper use of system resources

A threat to integrity

How Do Fabrication Threats Occur?

- Masquerading
- Bypassing protection measures
- Duplication of legitimate requests

Active Threats vs. Passive Threats

Passive threats are forms of eavesdropping

No modifications, injections of requests, etc. occur

Active threats are more aggressive

Passive threats are mostly to secrecy

Active threats are to availability, integrity, exclusivity

What Are We Protecting?

- Hardware
- Software
- Data
- Communications lines and networks
- "Cycles" and economic values

Basic Security Principles

- Terms and concepts
- Mechanisms

Security and Protection

Security is a policy

E.g., "no unauthorized user may access this file"

Protection is a mechanism

E.g., "the system checks user identity against access permissions"

Protection mechanisms implement security policies

Design Principles for Secure Systems

- Economy
- Complete mediation
- Open design
- Least privilege
- Least common mechanism
- Acceptability
- Fail-safe defaults

Economy in Security Design

Economical to develop

And to use

Should add little or no overhead

Should do only what needs to be done

Generally, try to keep it simple and small

Complete Mediation

Apply security on every access to an object that a mechanism is meant to protect

E.g., each read of a file, not just the open

Does not necessarily require actual checking on each access

Open Design

Don't rely on "security through obscurity"

Assume all potential intruders know everything about the design

And completely understand it

Separation of Privileges

Provide mechanisms that separate the privileges used for one purpose from those used for another

To allow flexibility in the security system

E.g., separate access control on each file

Least Privilege

Give bare minimum access rights required to complete a task

Require another request to perform another type of access

E.g., don't give write permission if he only asked for read

Least Common Mechanism

Avoid sharing parts of the security mechanism among different users

Coupling users leads to possibilities for them to breach the system

Acceptability

Mechanism must be simple to use

Simple enough that people will use it automatically

Must rarely or never prevent permissible accesses

Fail-Safe Designs

Default to lack of access

So if something goes wrong/is forgotten/isn't done, no security is lost

If important mistakes are made, you'll find out about them

Without loss of security

Sharing Security Spectrum

- No protection
- Isolation
- Share all or nothing
- Share with access limitations
- Share with dynamic capabilities

Important Security Mechanisms

- Authentication
- Encryption
- Passwords
- Other authentication mechanisms
- Access control mechanisms

Authentication

If a system supports more than one user, it must be able to tell who's doing what

I.e., all requests to the system must be tagged with user identity

Authentication is required to assure system that the tags are valid

Encryption

Various algorithms can be used to make data unreadable to intruders

This process is called *encryption*

Typically, encryption uses a secret *key* known only to legitimate users of the data

Without the key, decrypting the data is computationally infeasible

Encryption Example

M is the *plaintext* (text to be encrypted)

E is the encryption algorithm

$\mathbf{K_e}$ is the key

C is the ciphertext (encrypted text)

$$\mathbf{C = E(M, K_e)}$$

Decrypting the Ciphertext

C is the ciphertext

D is the decryption algorithm

$\mathbf{K_d}$ is the decryption key

$$\mathbf{M = D(C, K_d)}$$

Symmetrical Encryption

Many common encryption algorithms are symmetrical

I.e., $\mathbf{E = D}$ and $\mathbf{K_e = K_d}$

Some important encryption algorithms are not symmetrical, however

Encryption Security Assumptions

Assume that someone trying to break the encryption knows-

- The algorithms **E** and **D**
- Arbitrary amounts of matching plaintext and ciphertext **M** and **C**

But does not know the keys $\mathbf{K_e}$ and $\mathbf{K_d}$

Evaluating Security of Encryption

Given these assumptions, and a new piece of ciphertext $\mathbf{C_n}$, how hard is it to discover $\mathbf{M_n}$?

Either by figuring out $\mathbf{K_d}$ or some other method

What if $\mathbf{M_n}$ matches one of the known pieces of plaintext?

Practical Security of Encryption

Most encryption algorithms can be broken

Goal is to make breaking them too expensive to bother

How do we protect our encryption?

Key Issues in Encryption

Security often depends on length of key
  Longer keys give better security
  But slows down encryption
The more data sent with a given key, the greater the chance of compromise
The more data sent with a given key, the greater the value of deducing it

One-Time Pads

Theoretically unbreakable security
A symmetrical encryption system
Use one bit of key for each bit of plaintext
Never reuse any key bits
Generate key bits truly randomly

Advantages of One-Time Pads

- Proved secure (in information theoretic sense)
- Encryption algorithm is computationally cheap
  XOR message with key
- Required procedures for proper use well understood

Problems With One-Time Pads

- They burn keys like crazy
- Need to keep key usage in sync
- If the keys aren't truly random, patterns can be deduced in the bits
- Distribution of pads

Passwords

A fundamental authentication mechanism
A user proves his identity by supplying a secret
  Either at login or other critical time
The secret is the password

Password Security

- Password selection
- Password storage and handling
- Password aging

Selecting a Password

Desirable characteristics include:

- Unguessable
- Easy to remember (and type)
- Not in a dictionary
- Too long to search exhaustively

Password Storage and Handling

Passwords are secrets, so their security depends on careful handling

But seemingly the system must store the password

To compare when users log in

If system storage is compromised, so is all authentication

Securely Storing Passwords

Store only in encrypted form

To check a password, encrypt it and compare to the encrypted version

Encrypted version can be stored in a file

But there are tricky issues

Tricky Issues in Storing Encrypted Passwords

- What do I encrypt them with?
  - If I use single key to encrypt them all, what if the key is compromised?
  - That key must be stored in the system
- What if two people choose the same password?

Example: The Unix Password File

Each password has an associated *salt*

Unix encrypts a block of zeros

Key built from password plus 12-bit salt

Encryption done with DES

Stored information = E(zeros, salt + password)

To check password, repeat operations

How Does This Help the Problems?

- No single key for encryption
  - So can't crack that key
  - And needn't ever store it
- Each encryption (probably) performed with a different key
  - So two people with the same password have different encrypted versions

Does This Solve the Problem?

Not entirely

Passwords exist in plaintext in process checking them

Passwords may travel over communications lines in plaintext

Especially for remote logins

Or logins over modems

Problems With Passwords

- People choose bad ones
- People forget them
- People reuse them
- People rarely change them

How To Deal With Bad Passwords

- Educate users so they choose good ones
- Automatic password generation
- Check when changed
- Periodically run automated cracker

Any solution must balance user needs, password security, and resources

Other Authentication Mechanisms

- Challenge/response
- Smartcards
- Other special hardware
- Detection of personal characteristics

All have some drawbacks

Some are combined with passwords

Data Access Control Mechanisms

Methods of specifying who can access what in which ways when

Based on assumption that the system has authenticated the user

Access Matrix

Describes permissible accesses for the system

Subjects access *objects* with particular *access rights*

A theoretical concept, never kept in practice

Access Matrix Example

	File 1	File 2	Server X	Segment 57
User A	Read Write	None	Query	Read
User B	Read	Write	Update	None
User C	None	Read	Start/Stop	None
User D	None	None	Query	None

Methods for Implementing Access Matrix

- Access control lists
  Decomposition by columns
- Capabilities
  Decomposition by rows

Access Control Lists

Each object controls who can access it
  Using an *access control list*
Add subjects by adding entries
Remove subjects by removing entries
+ Easy to determine who can access object
+ Easy to change who can access object
– Hard to tell what someone can access

Access Control List Example

File 1's ACL

User A: Read
        Write
User B: Read

Segment 57's ACL

User A: Read

Capabilities

Each subject keeps track of what it can access
Typically by keeping a *capability* for each object
Capabilities are like admission tickets
+ Easy to tell what a subject can access
– Hard to tell who can access an object
– Hard to revoke/control access

Capability Example

User A's Capabilities

File 1:	Read
	Write
Server A:	Query
Segment 57:	Read

User A's Capabilities

File 1:	Read
File 2:	Write
Server A:	Update

Other Models of Access Control

- Military model
- Information flow models
- Lattice model of information flow