# Operating System Practice

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# Advanced Operating System Concepts

- Chapter 10: File System
- Chapter 11: Implementing File-Systems
- Chapter 12: Mass-Storage Structure
- Chapter 13: I/O Systems
- Chapter 14: System Protection
- Chapter 15: System Security

## Study Items

- Goals of Protection
- Principles of Protection
- Domain of Protection
- Access Matrix
- Implementation of Access Matrix
- Access Control
- Revocation of Access Rights
- Capability-Based Systems
- Language-Based Protection

## Goals of Protection

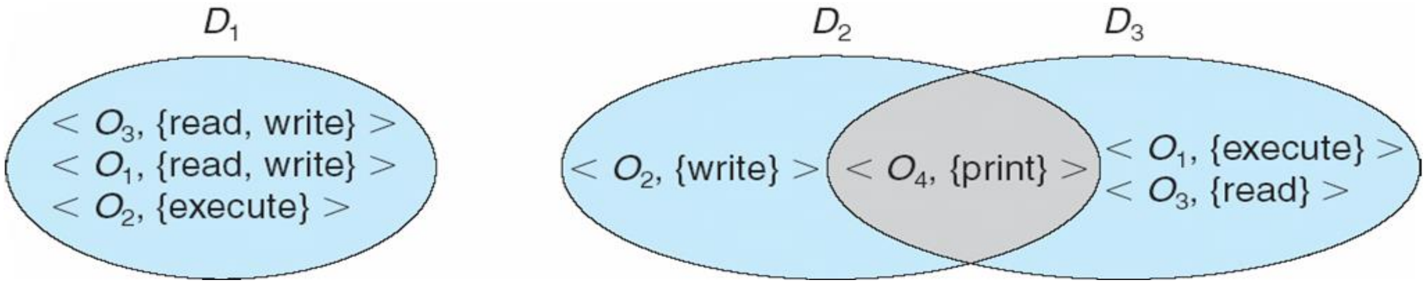
- In one protection model,  computer consists of a collection of hardware and software objects
- Each object has a unique name and can be accessed through a well-defined set of operations
- Protection problem is to ensure that each object is accessed correctly and only by those processes that are allowed to do so

## Principles of Protection

- 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 or gets abused
- Principle of Need-to-Know
  - At any time, a process should be able to access only those resources that it currently requires to complete its task

# Domain Structure

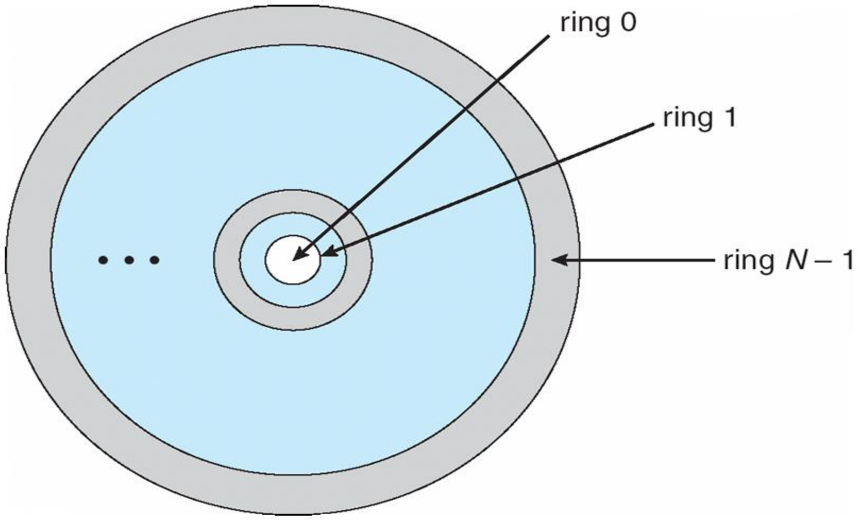
- A domain = a set of access-rights
- Access-right = <*object-name*, *rights-set*>
  where *rights-set* is a subset of all valid operations that can be performed on the object



- An example in Unix
  - Domain = user-id
  - When setuid = on, then user-id is set to owner of the file being executed
  - Domain switch accomplished via passwords
    - su command temporarily switches to another user's domain
    - sudo command prefix executes specified command in another

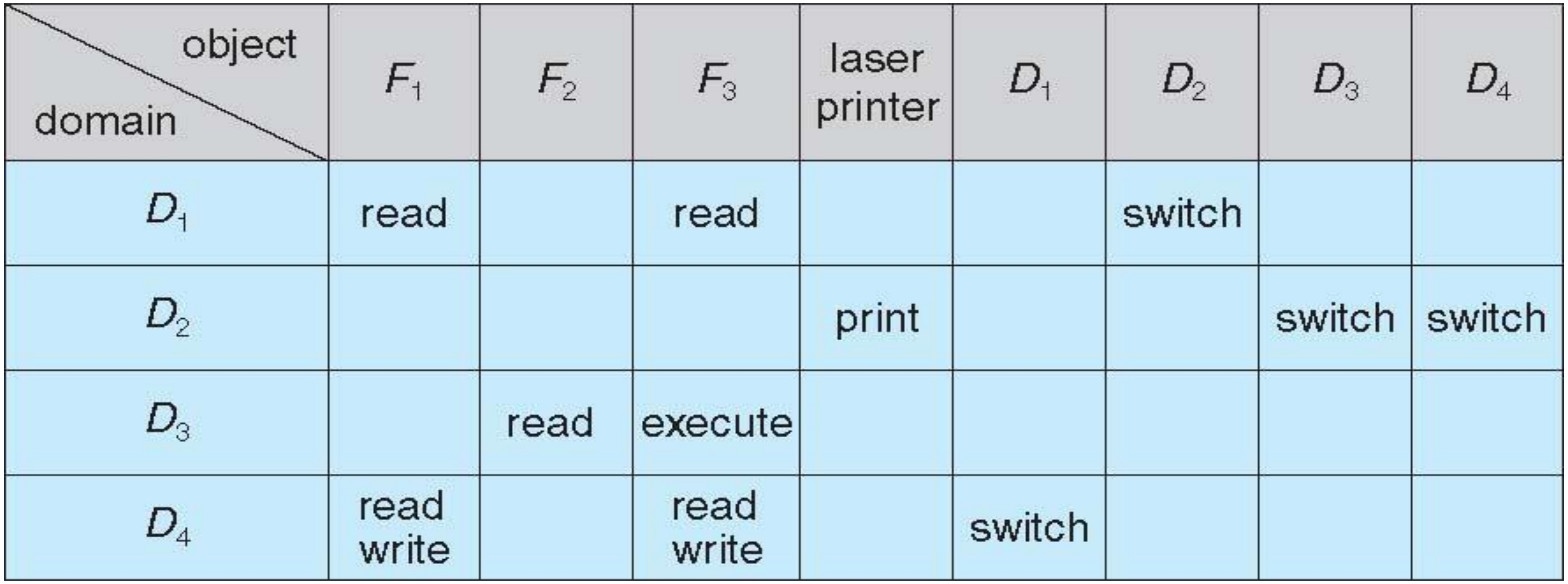
## MULTICS Ring Structure

- Let $D_i$ and $D_j$ be any two domain rings
  - If $j < i$ then $D_i \subseteq D_j$
- Problem:
  - Process A can access object X but should not access object Y
  - Process B can access object Y but should not access object X



# Access Matrix

- The entry access($i$,$j$) defines the set of operations that a process executing in domain $D_i$ can invoke on object $O_j$
- Switching from domain $D_i$ to domain $D_j$ is allowed if and only if the access right switch ∈ access($i$, $j$)



| object / domain | $F_1$ | $F_2$ | $F_3$ | laser printer | $D_1$ | $D_2$ | $D_3$ | $D_4$ |
|---|---|---|---|---|---|---|---|---|
| $D_1$ | read | | read | | | switch | | |
| $D_2$ | | | | print | | | switch | switch |
| $D_3$ | | read | execute | | | | | |
| $D_4$ | read write | | read write | | switch | | | |

## Access Matrix Operations

- Allowing controlled change in the contents of the access-matrix entries requires three additional operations: copy, owner, and control
- Copy: can copy the access methods to other domains
- Owner: can change the access methods of all domains
- Control: can remove the access methods of all domains

## Implementation of Access Matrix (1/2)

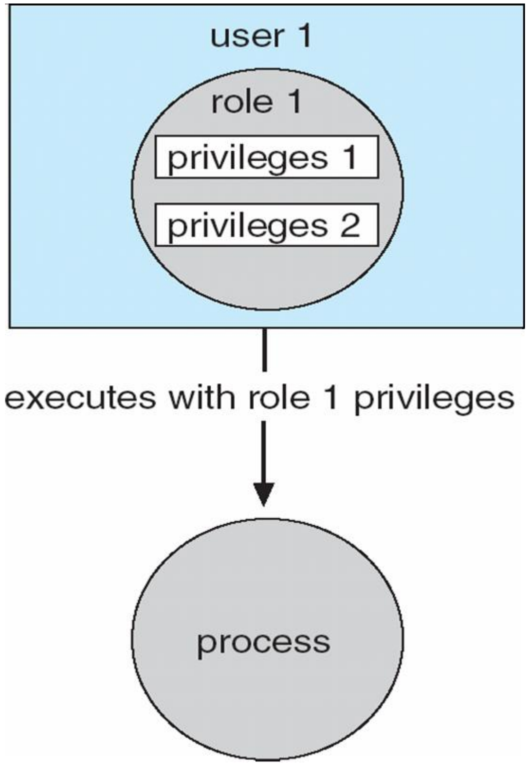
- Option 1 – Global table
  - Store ordered triples < *domain*, *object*, *rights-set* > in table
  - The table could be large → won’t fit in main memory
  - Difficult to group objects
    - Consider an object that all domains can read
- Option 2 – Access lists for objects
  - Resulting per-object list consists of ordered pairs < *domain*, *rights-set* > defining all domains with non-empty set of access rights for the object
  - Easily extended to contain default set
    - All domains can read an object → set the read operation in the default set

## Implementation of Access Matrix (2/2)

- Option 3 – Capability list for domains
  - Instead of object-based, the list is domain based
  - Capability list for domain is a list of objects together with operations allows on them
- Option 4 – Lock-key
  - Compromise between access lists and capability lists
  - Each object has a list of unique bit patterns, called **locks**
  - Each domain has a list of unique bit patterns called **keys**
  - A process in a domain can access an object if the domain has a key that matches one of the locks

# Access Control

- Solaris 10 provides role-based access control (RBAC) to implement least privilege
  - Privilege is the  right to execute a system call or use an option within a system call
  - Role is a collection of privilege
    - Enable role via password to gain its privileges
  - This implementation of privileges decreases the security risk associated with superusers and setuid programs



# Revocation of Access Rights

- Various options to remove the access right of a domain to an object
  - Immediate vs. delayed
  - Selective vs. general
  - Partial vs. total
  - Temporary vs. permanent
- Access List – Delete access rights from access list
  - Simply search access list and remove entry
- Capability List – Scheme required to locate capability in the system before capability can be revoked

## Language-Based Protection

- Specification of protection in a programming language allows the high-level description of policies for the allocation and use of resources
- Language implementation can provide software for protection enforcement when automatic hardware-supported checking is unavailable
- Interpret protection specifications to generate calls on whatever protection system is provided by the hardware and the operating system

# Protection in Java 2

- Protection is handled by the Java Virtual Machine (JVM)
- A class is assigned a protection domain when it is loaded by the JVM
- The protection domain indicates what operations the class can (and cannot) perform
- If a library method is invoked that performs a privileged operation, the stack is inspected to ensure the operation can be performed by the library

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## Study Items

- The Security Problem
- Program Threats
- System and Network Threats
- Cryptography as a Security Tool
- Firewalling to Protect Systems and Networks

## Security Violation Categories

- 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 Violation Methods

- Masquerading (breach authentication)
  - Pretending to be an authorized user to escalate privileges
- Replay attack
  - As is or with message modification
- 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

## Security Measure Levels

- Physical
  - Data centers, servers, connected terminals
- Human
  - Avoid social engineering, phishing, dumpster diving
- Operating System
  - Protection mechanisms, debugging
- Network
  - Intercepted communications, interruption, DOS

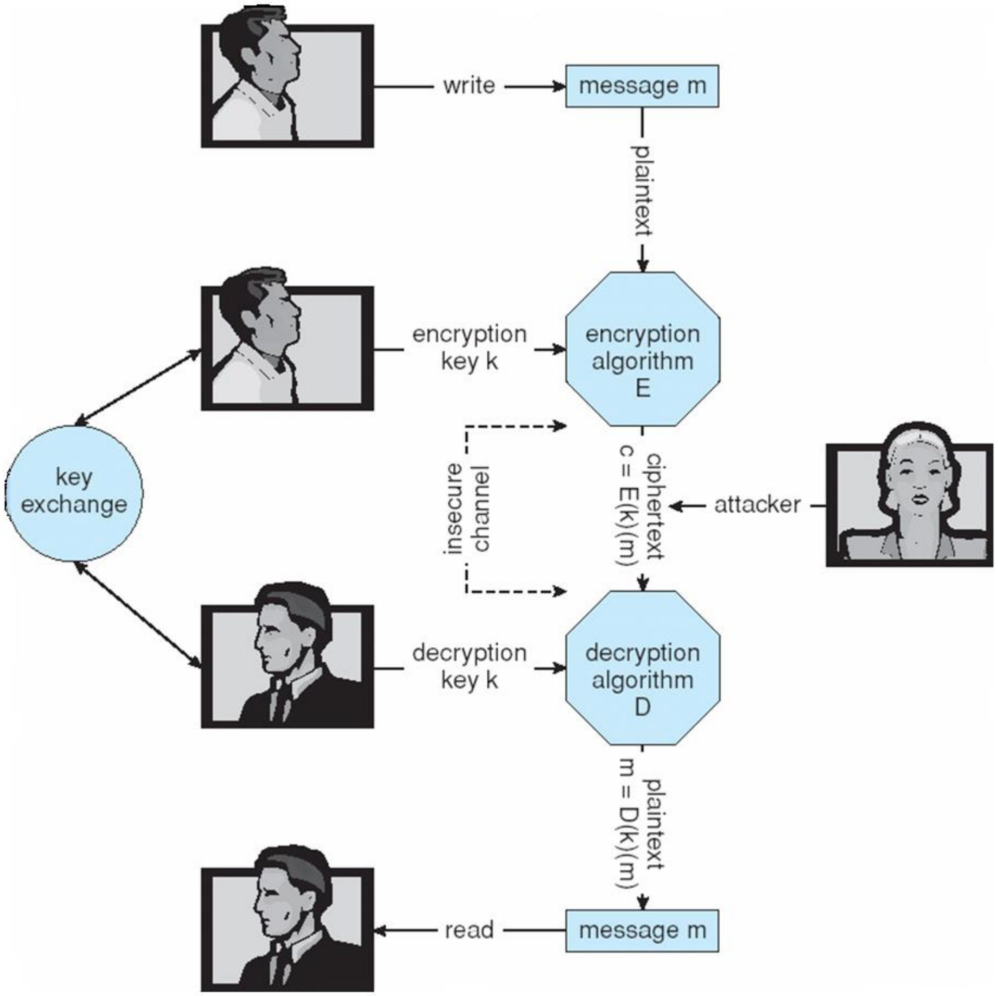
# Program Threats

- Trojan Horse
  - Code segment that misuses its environment
  - Up to 80% of spam delivered by spyware-infected systems
- Trap Door
  - Specific user identifier or password that circumvents normal security procedures
  - Could be included in a compiler
- Logic Bomb
  - Program that initiates a security incident under certain circumstances
- Stack and Buffer Overflow
  - Failure to check bounds on inputs, arguments
  - Pointed to code loaded onto stack that executes malicious code

## 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
  - Frequently launched from zombie systems
- Denial of Service
  - Overload the targeted computer preventing it from doing any useful work
  - Distributed denial-of-service (DDOS) come from multiple sites at once

# Secure Communication over Insecure Medium



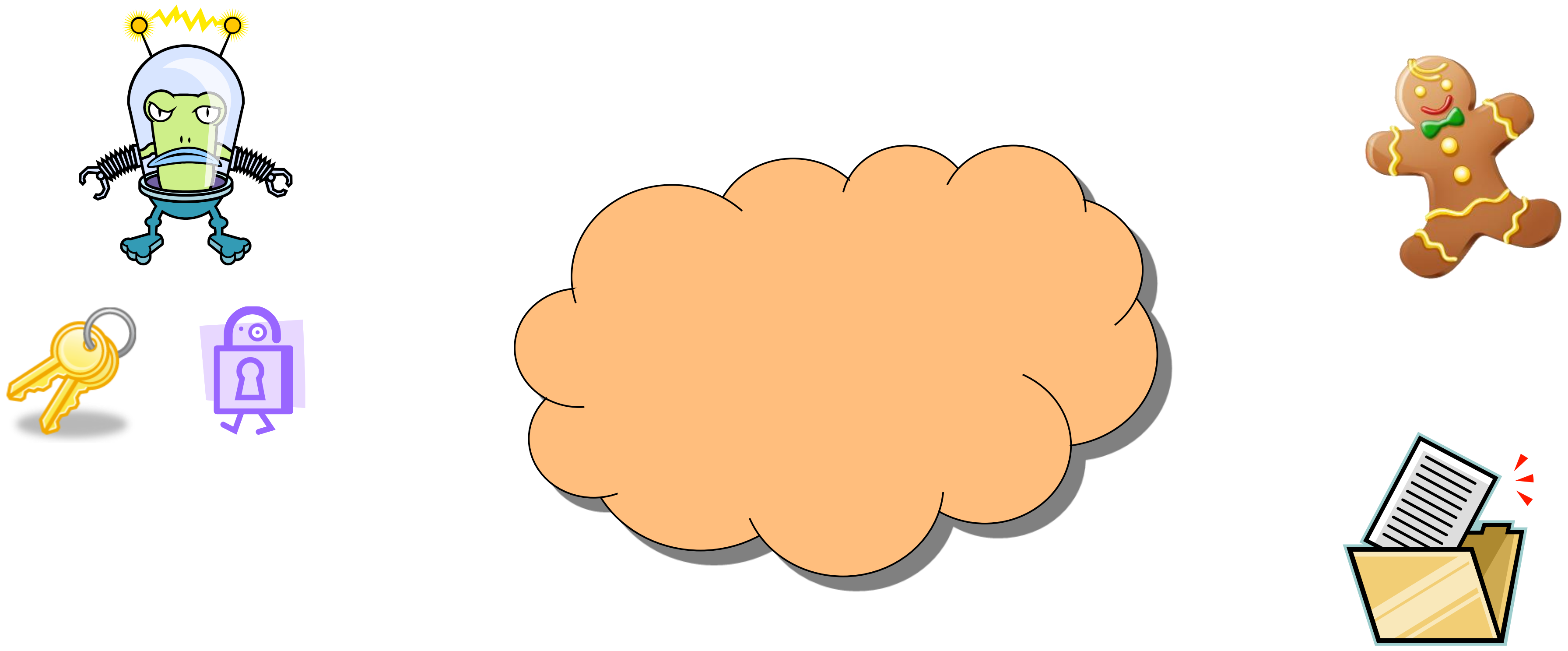
## Encryption

- Encryption algorithm consists of
  - Set K of keys
  - Set M of Messages
  - Set C of ciphertexts (encrypted messages)
- A encryption function $E : K \rightarrow (M \rightarrow C)$ which is a function for generating ciphertexts from messages
- A function $D : K \rightarrow (C \rightarrow M)$ which is a function for generating messages from ciphertexts

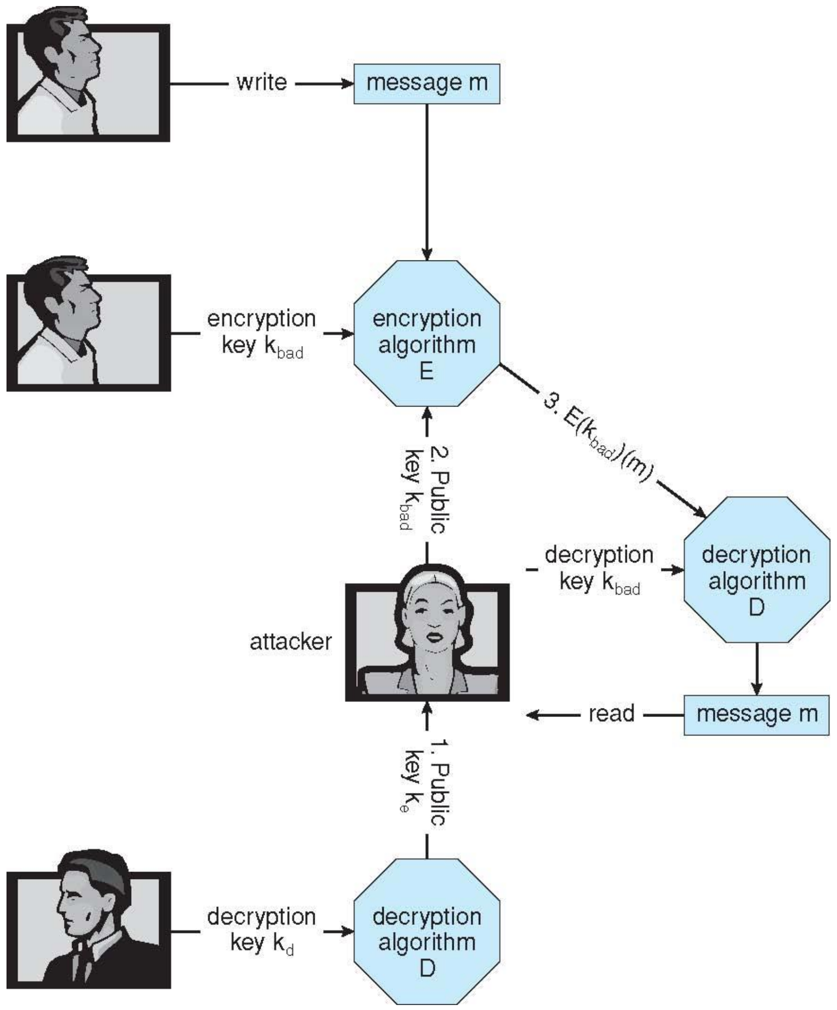
# Symmetric/Asymmetric Encryption

- Symmetric Encryption
  - Same key used to encrypt and decrypt
  - Data Encryption Standard (DES) is most commonly used symmetric block-encryption algorithm
  - Advanced Encryption Standard (AES)
- Asymmetric Encryption
  - 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

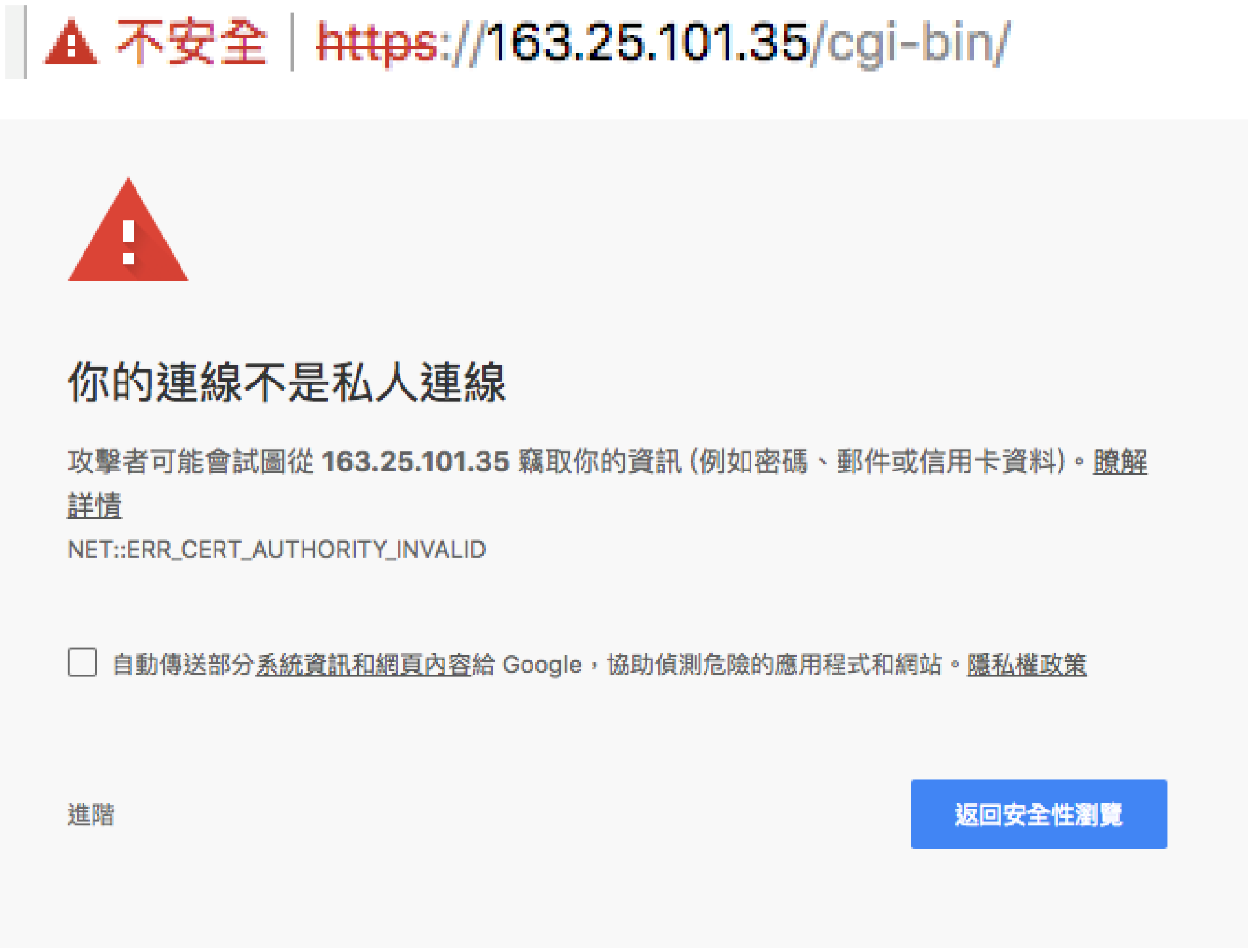
## Scenario of Asymmetric Encryption



# Man-in-the-middle Attack on Asymmetric Cryptography



## Example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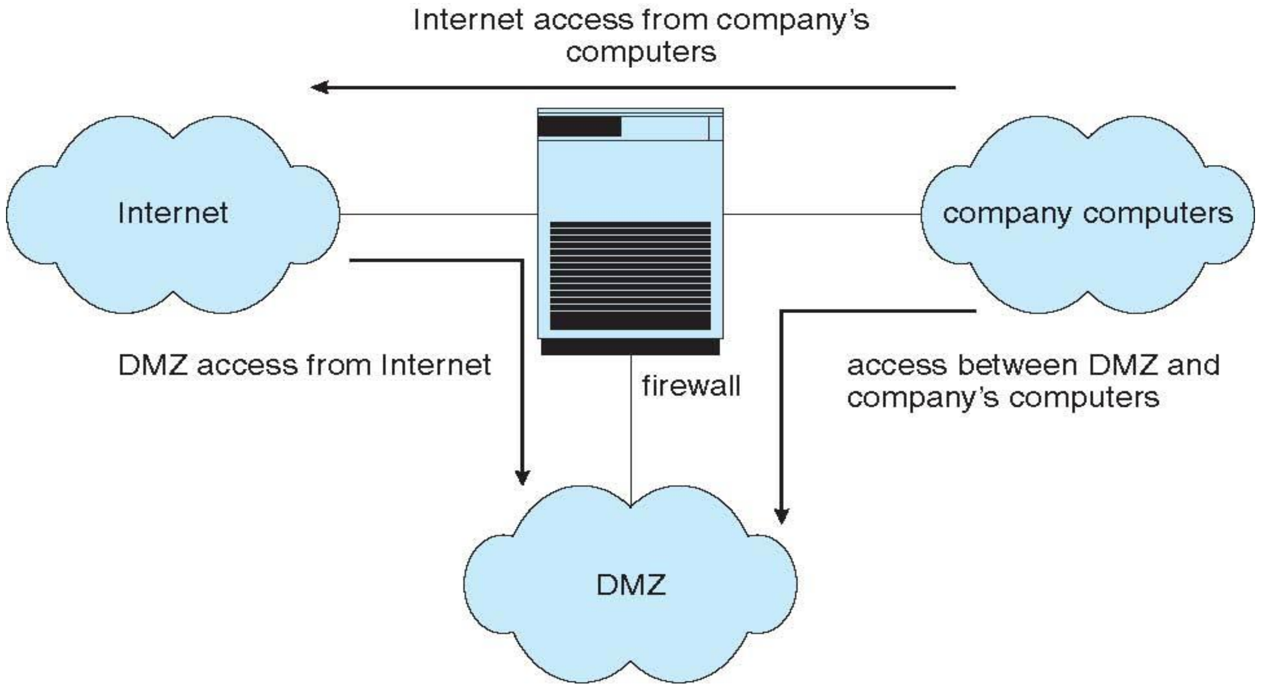
# Encryption Example – SSL

- SSL – Secure Socket Layer
  - A newer version is Transport Layer Security (TLS)
  - But we usually just call it SSL
- Insertion of cryptography at the transport layer of the ISO network model
- Cryptographic protocol that limits two computers to only exchange messages with each other
- Used between web servers and browsers for secure communication
  - e.g., 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

## Firewall

- Firewall is a software or hardware-based network security system that controls the incoming and outgoing network traffic
  - Untrusted domain
  - Internal computers
  - Demilitarized zone


Internet access from company's computers
Internet
company computers
DMZ access from Internet
firewall
access between DMZ and company's computers
DMZ