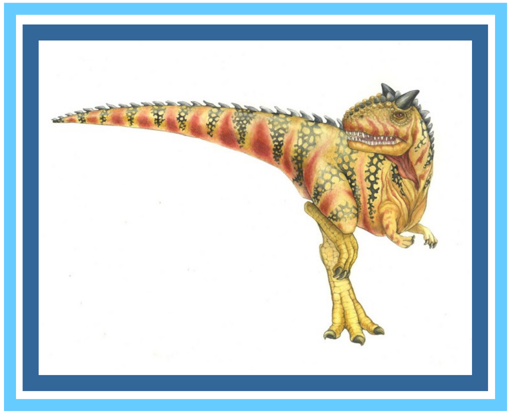
Protection



The Protection Problem

- A computer system consists of a collection of objects:
  - Hardware
  - Software
- Each object has a unique name and can be accessed through a well-defined set of operations
- Goal - ensure that each object is accessed correctly and only by those processes that are allowed to do so

The Security Problem

- System is **secure** if resources used and accessed as intended under all circumstances
  - Unachievable
- **Intruders** (**crackers**) attempt to breach security
- **Threat** is potential security violation
- **Attack** is attempt to breach security
- Attack can be accidental or malicious
- Easier to protect against accidental than malicious misuse

The Security/Protection Problem

- Both protection and security are vital to computer systems. We distinguish between these two concepts in the following way:
- Security is a measure of confidence that the integrity of a system and its data will be preserved.
- Protection is the set of mechanisms that control the access of processes and users to the resources defined by a computer system.

Goals of Protection

- A computer system consists of a collection of objects, hardware or software
- 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 processes that are allowed to do so

Principles of least privilege

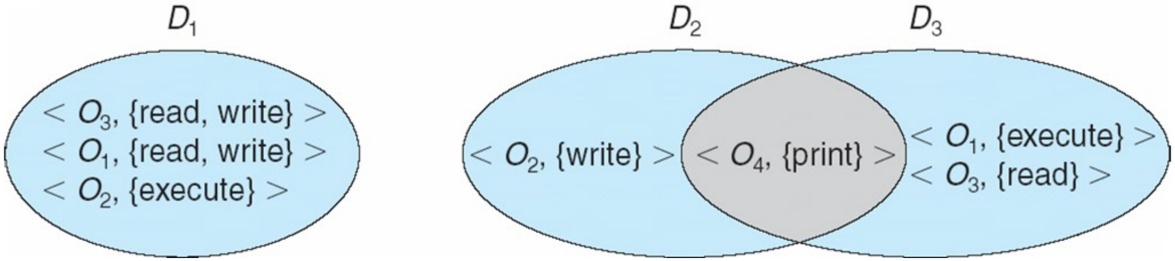
- Programs, users and systems should be given just enough **privileges** to perform their tasks
- Limits damage if entity has a bug, gets abused
- Can be static (during life of system, during life of process)
- Or dynamic (changed by process as needed) – **domain switching**, **privilege escalation**
- "**Need to know**" a similar concept regarding access to data

Principles of Protection

- Must consider “grain” aspect
  - Rough-grained privilege management easier, simpler, but least privilege now done in large chunks
    - For example, traditional Unix processes either have abilities of the associated user, or of root
  - Fine-grained management more complex, more overhead, but more protective
    - Access Control List (ACL) lists,
    - Role Based Access Control (RBAC)
- Domain can be user, process, procedure

Domain Structure

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

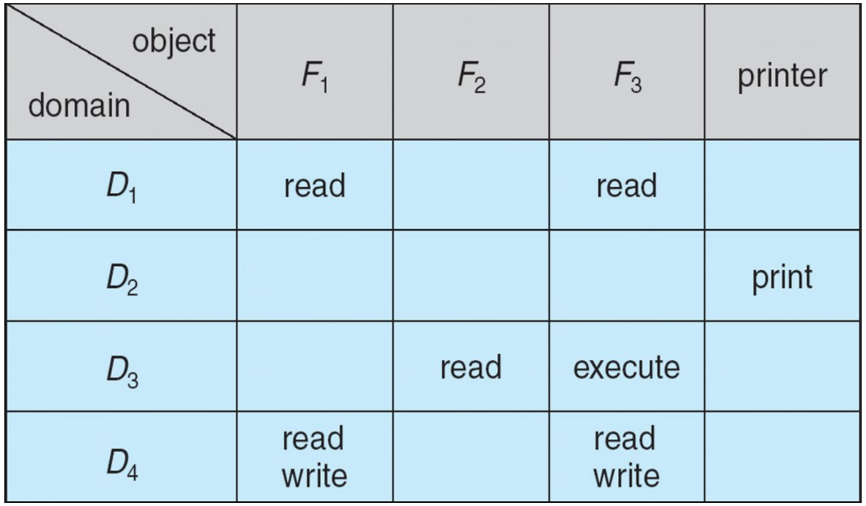


Domain Implementation (UNIX)

- Domain = user-id
- Domain switch accomplished via file system
  - Each file has associated with it a domain bit (setuid bit)
  - When file is executed and setuid = on, then user-id is set to owner of the file being executed
  - When execution completes user-id is reset
- Domain switch accomplished via passwords
  - `su` command temporarily switches to another user’s domain when other domain’s password provided
- Domain switching via commands
  - `sudo` command prefix executes specified command in another domain (if original domain has privilege or password given)

Access Matrix

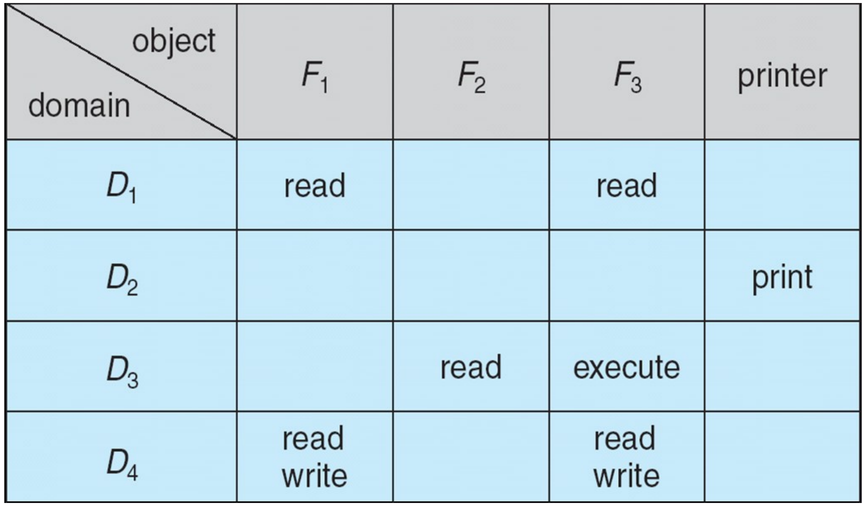
- View protection as a matrix (**access matrix**)
- Rows represent domains
- Columns represent objects
- **`Access(i, j)`** is the set of operations that a process executing in Domain_i can invoke on Object_j



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

Use of Access Matrix

- If a process in Domain D_i tries to do “op” on object O_j, then “op” must be in the access matrix
- User who creates object can define the access column for that object
- Example



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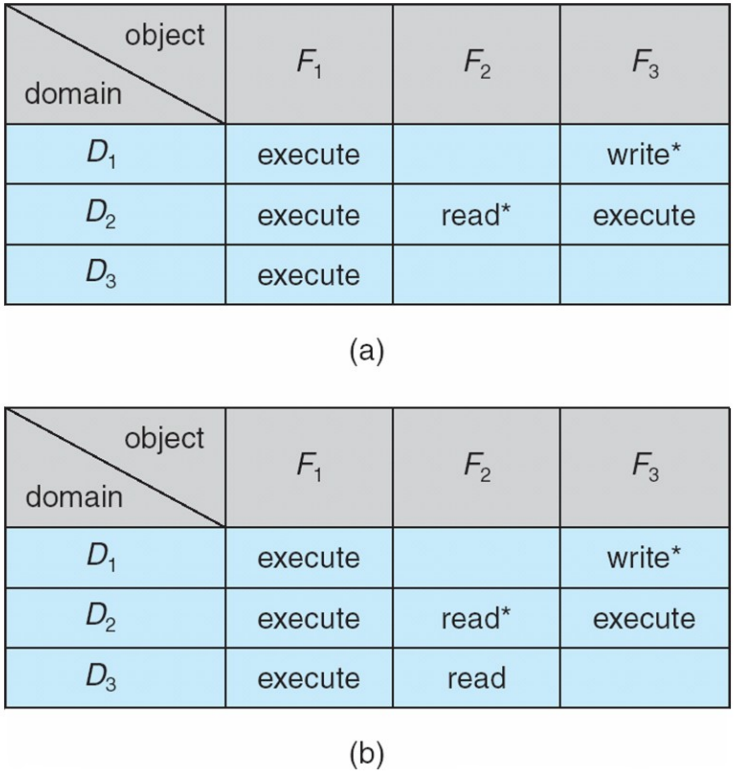
D_3		read	execute	
D_4	read write		read write	

Use of Access Matrix

- Can be expanded to dynamic protection
  - Operations to add, delete access rights
  - Special access rights:
    - *copy* – ability to copy access-rights from D_i *to* D_j (denoted by "*")
    - *owner* – ability to add/remove access-rights
    - *control* – D_i *can modify* D_j *access rights*
    - *switch – switch from domain* D_i *to* D_j
  - *Copy* and *Owner* applicable to an object
  - *Control* applicable to domain object

Access Matrix with *Copy* Rights

- A process executing in Domain D_2 can copy the read access to file object F_2 to domain D_3



object domain	F_1	F_2	F_3
D_1	execute		write*
D_2	execute	read*	execute
D_3	execute		

(a)

object domain	F_1	F_2	F_3
D_1	execute		write*
D_2	execute	read*	execute
D_3	execute	read	

(b)

Access Matrix with *owner* Rights

- A process executing in Domain D_2 can create the write access-right to file F_2 to domain D_2 and D_3

object domain	F_1	F_2	F_3
D_1	owner execute		write
D_2		read* owner	read* owner write
D_3	execute		

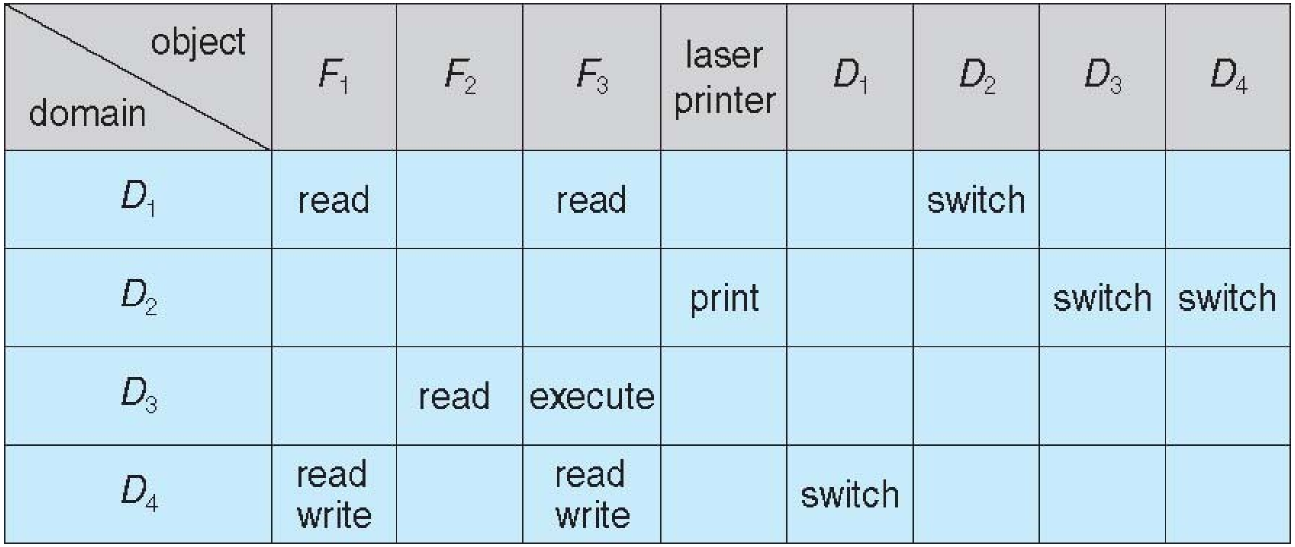
(a)

object domain	F_1	F_2	F_3
D_1	owner execute		write
D_2		owner read* write*	read* owner write
D_3		write	write

(b)

Access Matrix with Domains as Objects

- A process executing in Domain D_2 can switch to domain D_3



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			

Mechanism and Policy

- Access matrix provides a scheme to 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

Implementation of Access Matrix

- Generally, a sparse matrix
- Option 1 – 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 $M \in R_k$
  - But table could be large -> will not fit in main memory
  - Difficult to group objects (consider an object that all domains can read)

Implementation of Access Matrix (Cont.)

- Option 2 – Access lists for objects
  - Each column implemented as an access 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
  - Easily extended to contain default set -> If M ∈ default set, also allow access

Implementation: Option 2 (Cont.)

- Each column = Access-control list for one object
  - Defines who can perform what operation

Domain 1 = Read, Write
Domain 2 = Read
Domain 3 = Read

- Each Row = Capability List (like a key)
  - For each domain, what operations allowed on what objects

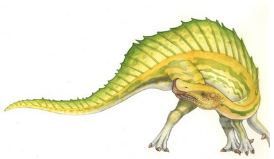
Object F1 – Read

Object F4 – Read, Write, Execute

Object F5 – Read, Write, Delete, Copy

Implementation of Access Matrix (Cont.)

- Option 3 – Capability list for domains
  - Instead of list being object based, 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
  - Capability list associated with domain but never directly accessible by domain
    - Rather, protected object, maintained by OS and accessed indirectly
    - Like a “secure pointer”
    - Idea can be extended up to applications



Implementation of Access Matrix (Cont.)

- Option 4 – Lock-key
  - Compromise between access lists and capability lists
  - Each object has list of unique bit patterns, called **locks**
  - Each domain as list of unique bit patterns called **keys**
  - Process in a domain can only access object if domain has key that matches one of the locks

Revocation of Access Rights

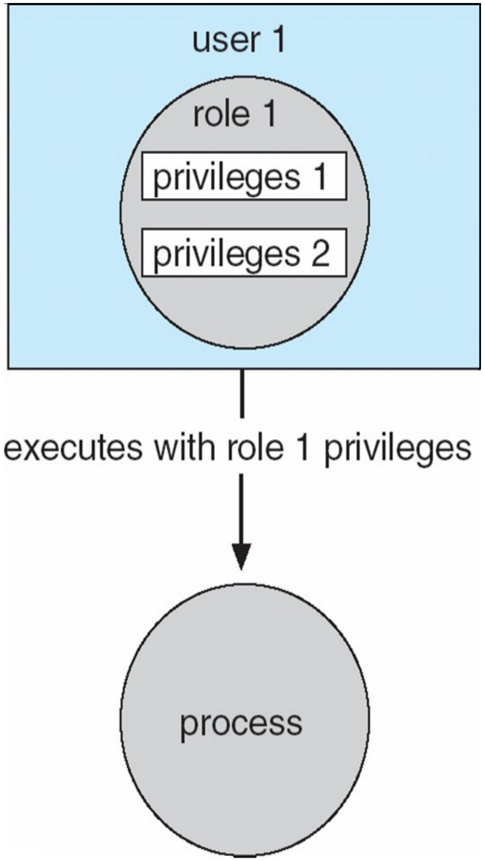
- Various options to remove the access right of a domain to an object
  - **Immediate vs. delayed**
  - **Selective vs. general**
  - **Partial vs. total**
  - **Temporary vs. permanent**

Revocation of Access Rights (Cont.)

- **Capability List** – Scheme required to locate capability in the system before capability can be revoked. Not simple since the capabilities are directly accessible to the users.
  - **Reacquisition** – periodic delete, with require and denial if revoked
  - **Back-pointers** – set of pointers from each object to all capabilities of that object (Multics)
  - **Indirection** – capability points to global table entry which points to object – delete entry from global table, not selective (CAL)
  - **Keys** – unique bits associated with capability, generated when capability created
    - Master key associated with object, key matches master key for access
    - Revocation – create new master key
    - Policy decision of who can create and modify keys – object owner or others?

Access Control

- Protection can be applied to non-file resources
- Oracle Solaris 10 provides **role-based access control** (**RBAC**) to implement least privilege
  - ***Privilege*** is right to execute system call or use an option within a system call
  - Can be assigned to processes
  - Users assigned ***roles*** granting access to privileges and programs
    - Enable role via password to gain its privileges
  - Similar to access matrix



Capability-Based Systems (Cont.)

- Cambridge CAP System
  - Simpler but powerful
  - **Data capability** - provides standard read, write, execute of individual storage segments associated with object – implemented in microcode
  - **Software capability** -interpretation left to the subsystem, through its protected procedures
    - Only has access to its own subsystem
    - Programmers must learn principles and techniques of protection

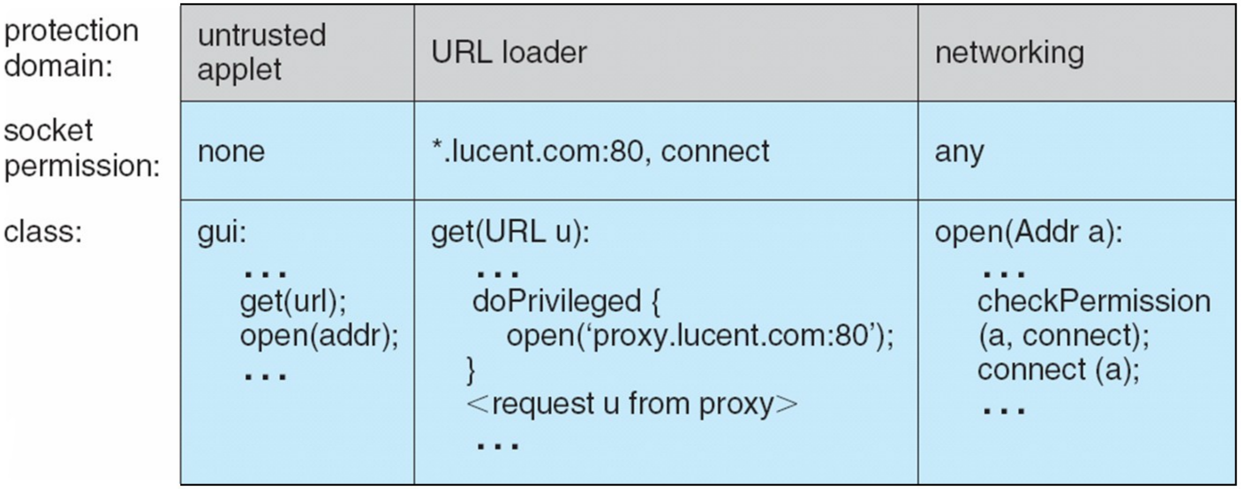
Language-Based Protection

- 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
- Generally, Java's load-time and run-time checks enforce **type safety**
- Classes effectively **encapsulate** and protect data and methods from other classes

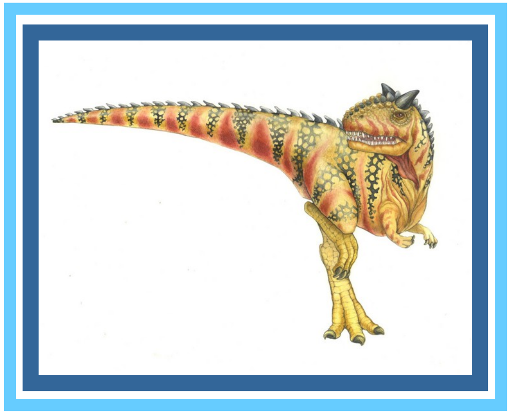
Stack Inspection



protection domain:	untrusted applet	URL loader	networking
socket permission:	none	*.lucent.com:80, connect	any

class:	gui:
	. . .
	get(url);
	open(addr);
	. . .
		get(URL u):
		. . .
		doPrivileged {
		open('proxy.lucent.com:80');
		}
		<request u from proxy>
		. . .
			open(Addr a):
			. . .
			checkPermission (a, connect);
			connect (a);
			. . .

End of Chapter



Comparison of Implementations

- Many trade-offs to consider
  - Global table is **simple**, but can be large
  - Access lists correspond to needs of users
    - Determining set of access rights for domain non-localized so difficult
    - Every access to an object must be checked
      - Many objects and access rights -> slow
  - Capability lists useful for localizing information for a given process
    - But revocation capabilities can be inefficient
  - Lock-key effective and flexible, keys can be passed freely from domain to domain, easy revocation

Access Matrix with Domains as Objects

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D_2				print			switch	switch
D_3		read	execute					
D_4	read write		read write		switch			

Use of Access Matrix

- Can be expanded to dynamic protection
  - Operations to add, delete access rights
  - Special access rights:
    - *owner of O_i*
    - *copy op from O_i to O_j (denoted by "*")*
    - *control – D_i can modify D_j access rights*
    - *transfer – switch from domain D_i to D_j*
  - *Copy* and *Owner* applicable to an object
  - *Control* applicable to domain object