Goals of Protection

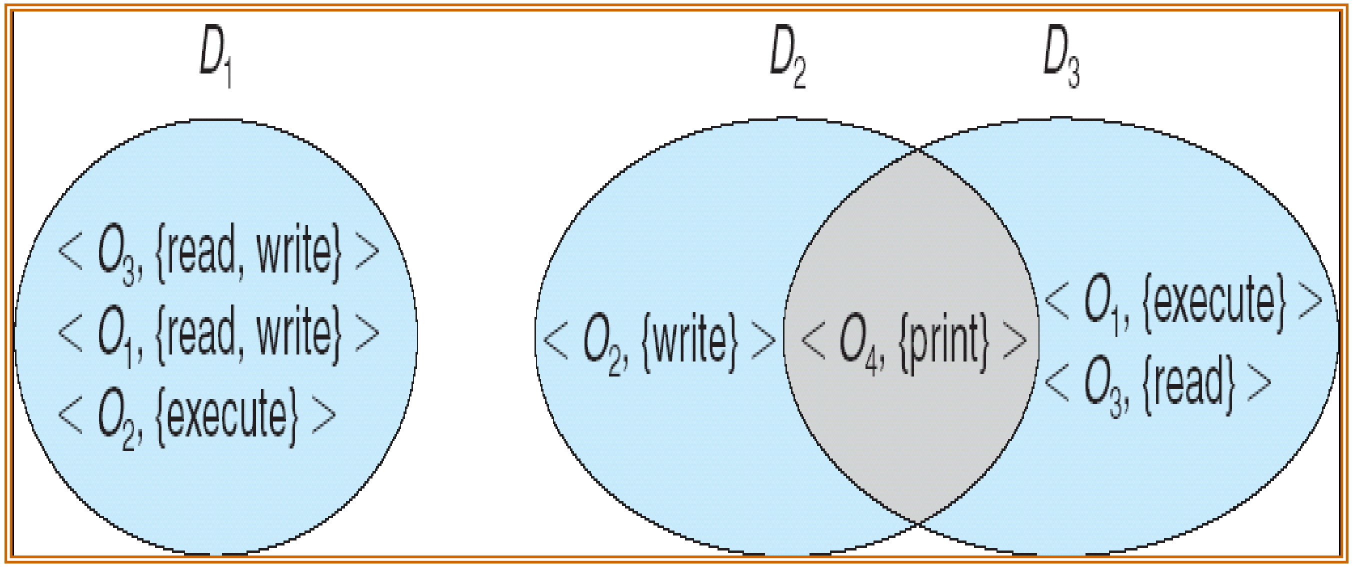
- Operating system consists of a collection of objects, hardware or software
- Each object has a unique name and can be accessed through a well-defined set of operations.
- Protection problem - ensure that each object is accessed correctly and only by those processes that are allowed to do so.

Principles of Protection

- Guiding principle – principle of least privilege
  - Programs, users and systems should be given just enough privileges to perform their tasks

Domain of Protection

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

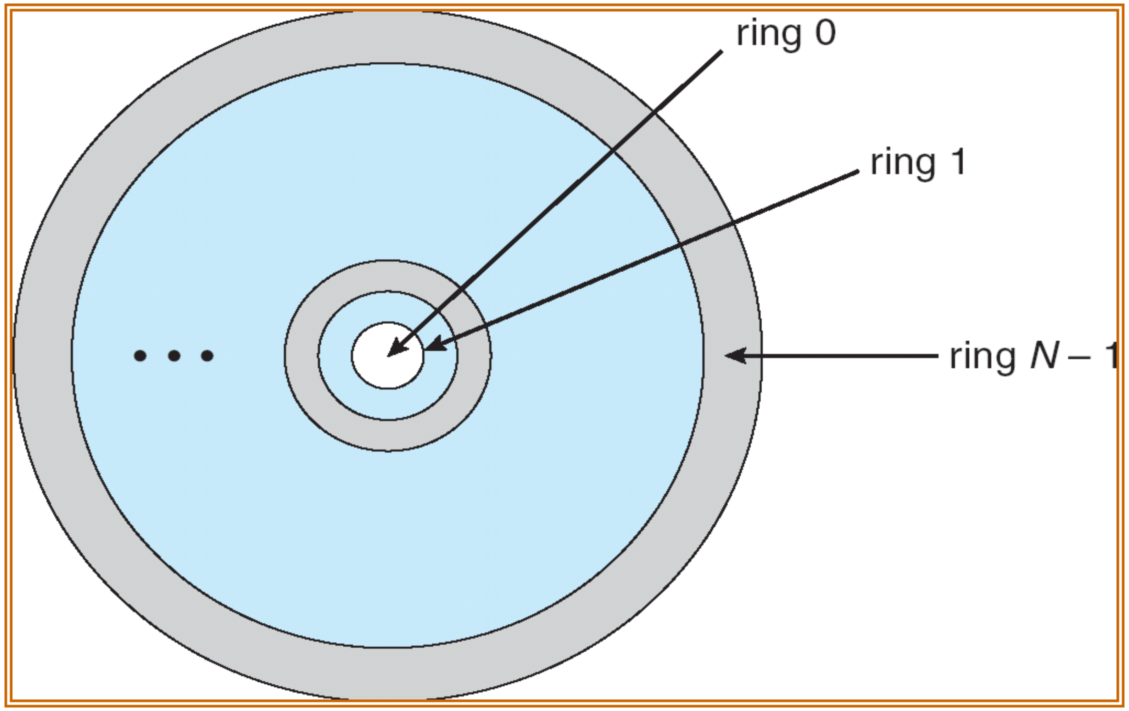


- Domain Implementation (UNIX):
- System consists of 2 domains:
  - User
  - Supervisor

- 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 Implementation (Multics):

- Let D_i and D_j be any two domain rings.
- If $j < I \Rightarrow D_i \subseteq D_j$



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.
- 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
    - control – D_i can modify D_j access rights
    - transfer – switch from domain D_i to D_j

- Access matrix design separates mechanism from policy.
  - Mechanism
    - Operating system provides access-matrix + rules.
    - If 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

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

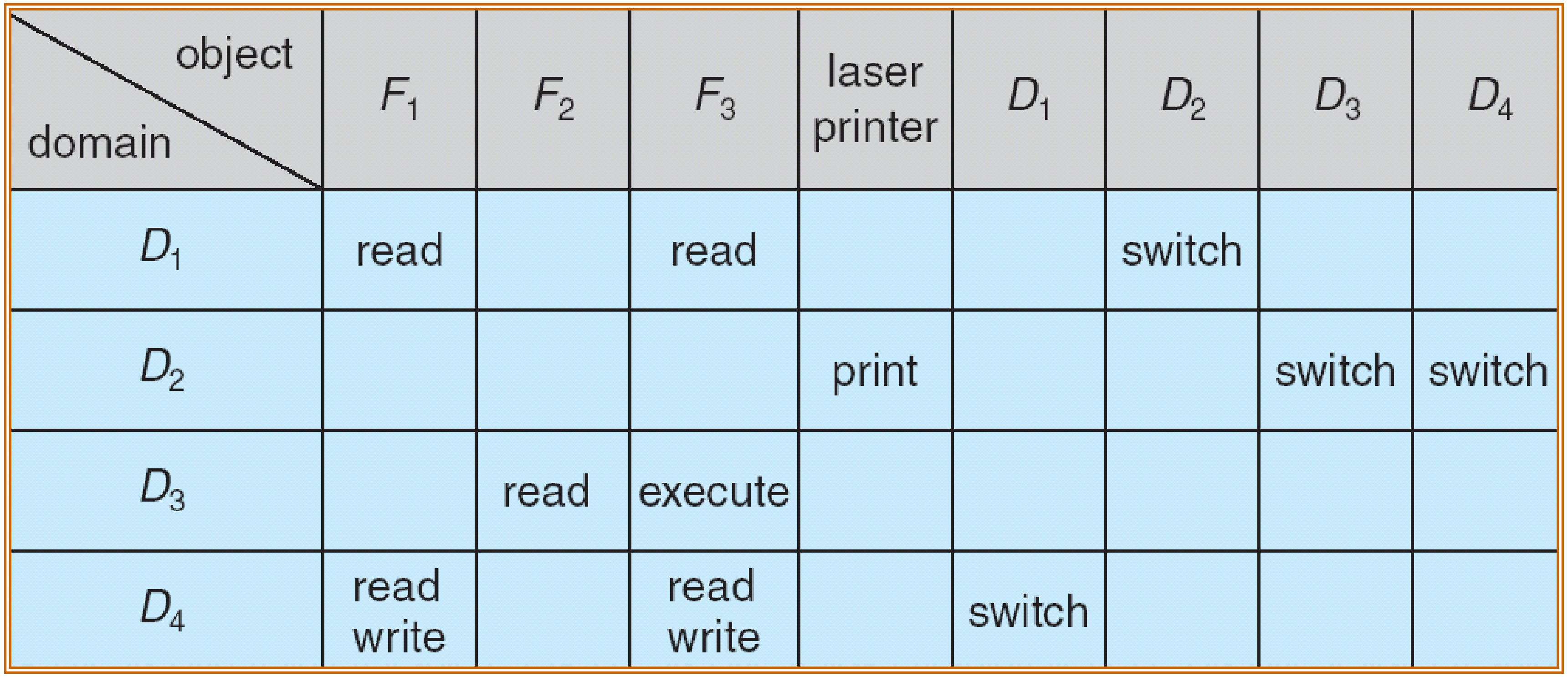
  Domain 1 = Read, Write
  Domain 2 = Read
  Domain 3 = Read

  ⋮

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

  Object 1 – Read
  Object 4 – Read, Write, Execute
  Object 5 – Read, Write, Delete, Copy

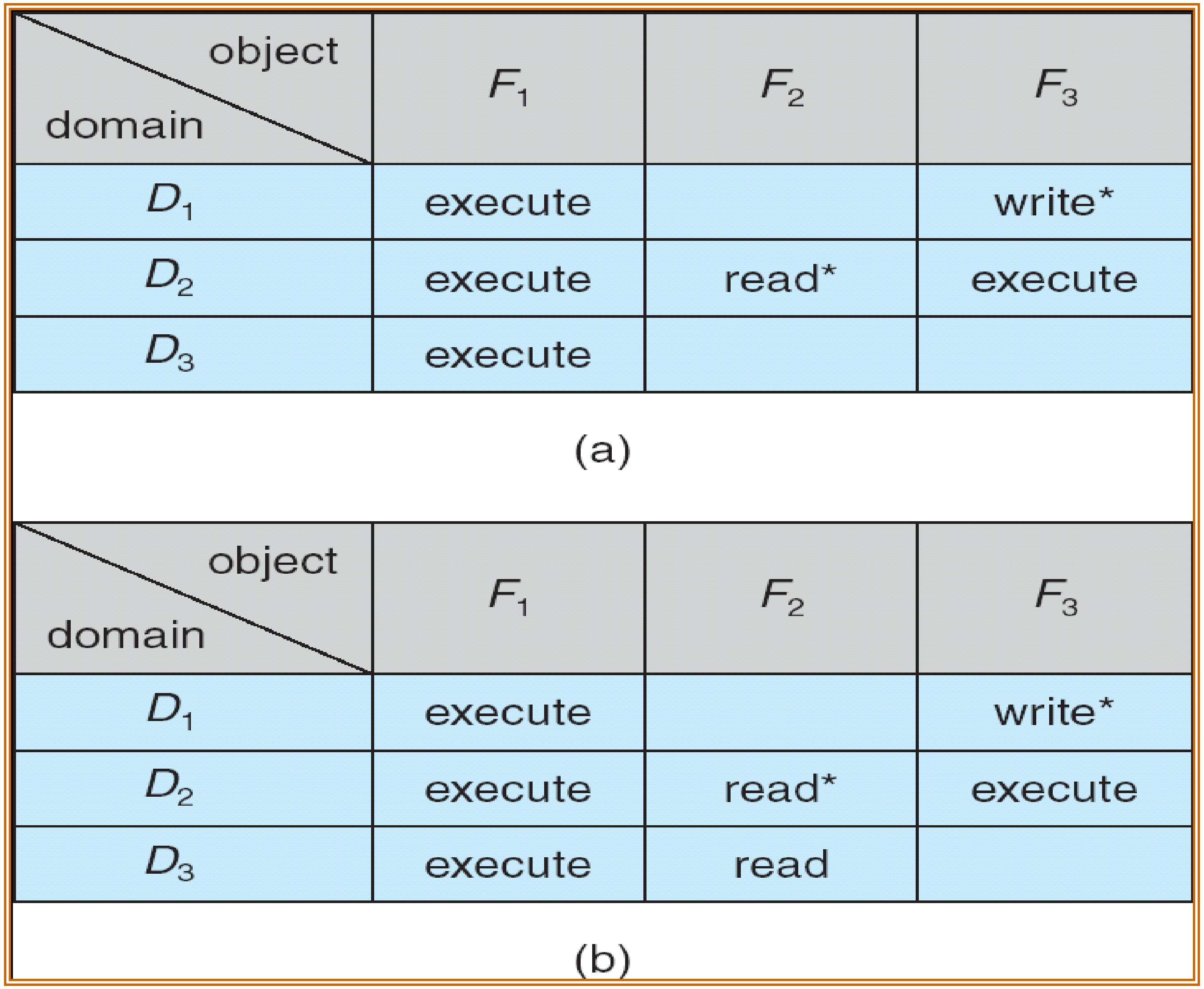
Access Matrix of Figure A With Domains as Objects



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			

Figure B

Access Matrix with *Copy* Rights



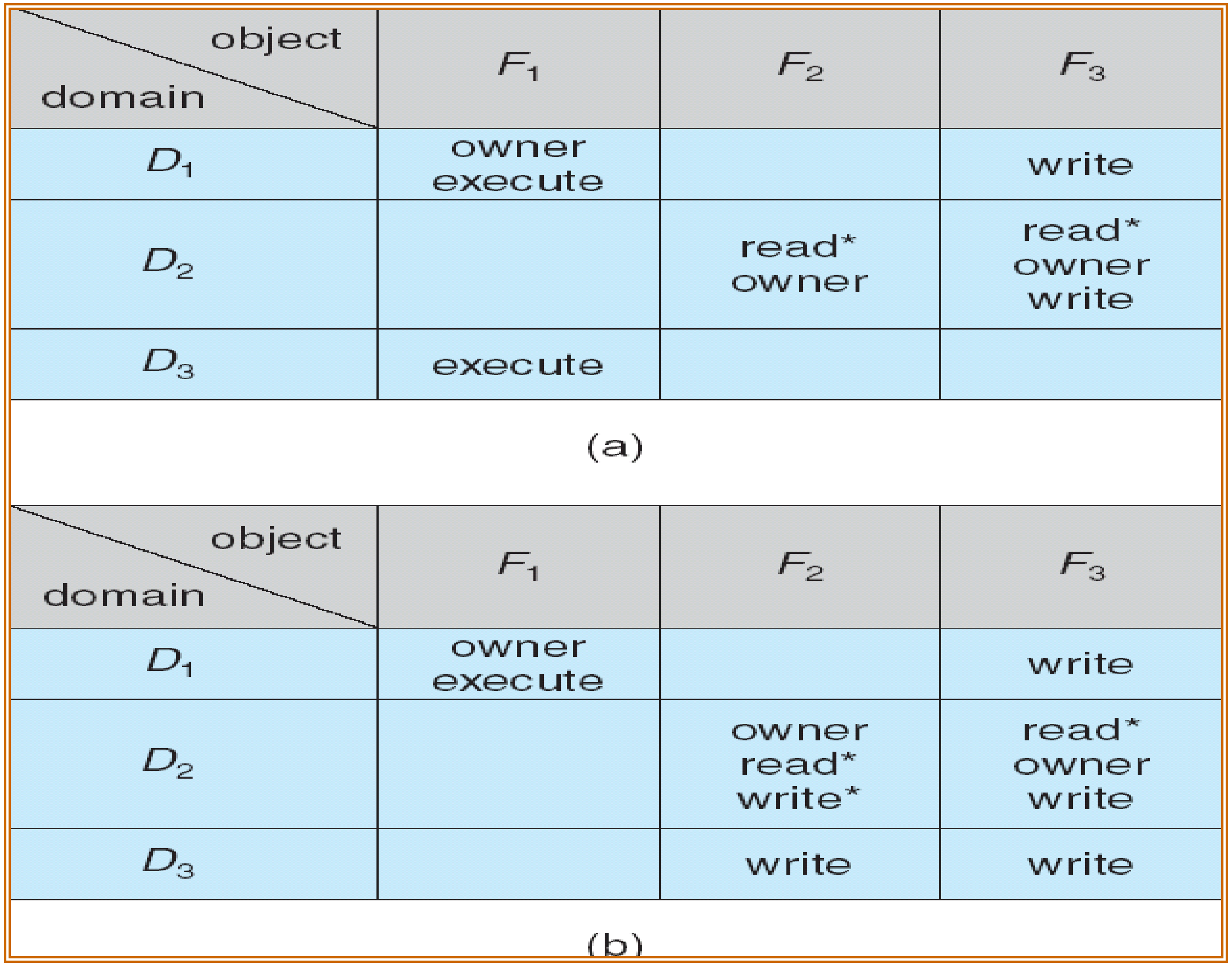
object domain	F_1	F_2	F_3
D_1	execute		write*
D_2	execute	read*	execute
D_3	execute		

(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



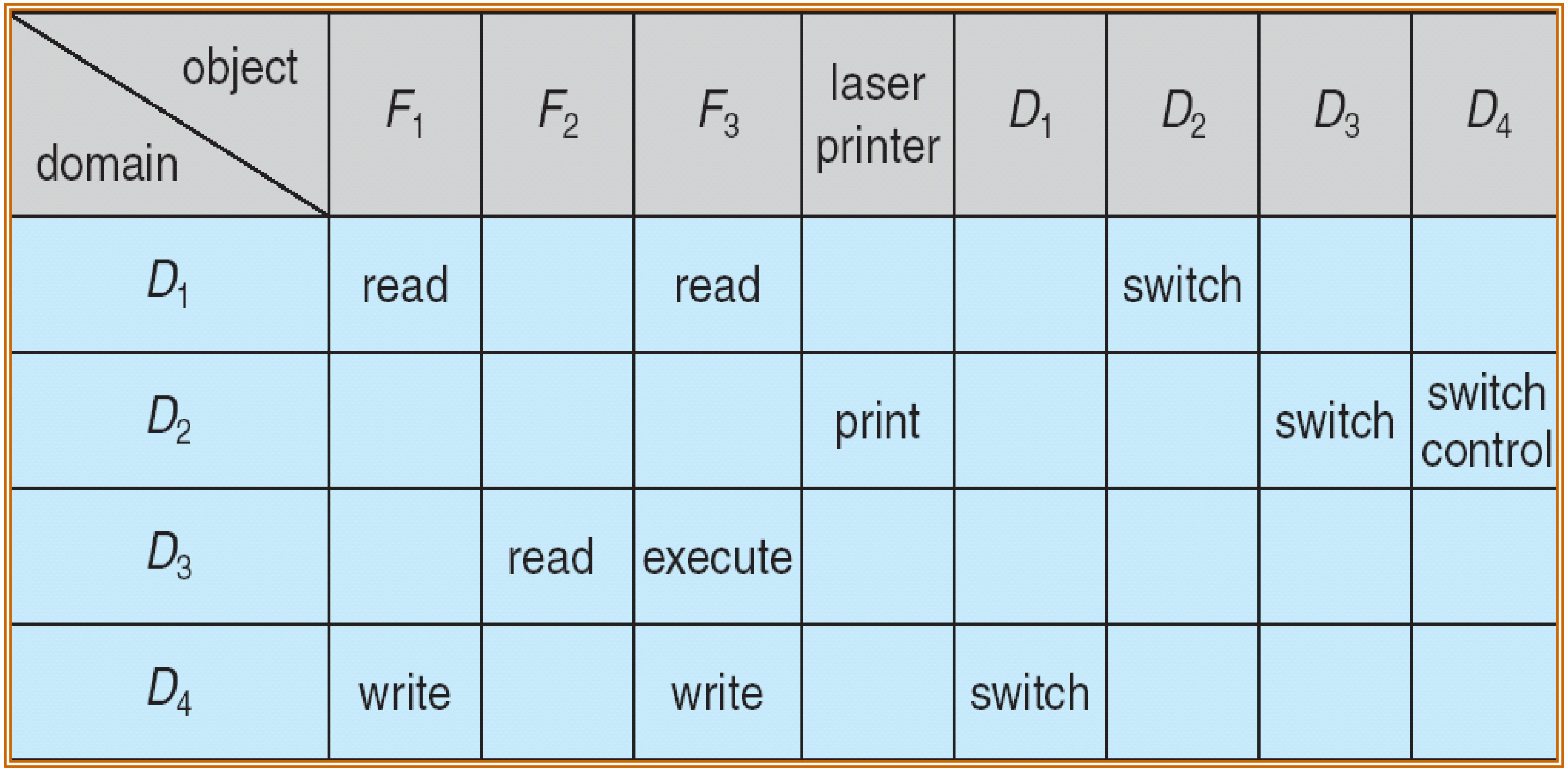
object domain	F_1	F_2	F_3
D_1	owner execute		write
D_2		read* owner	read* owner write
D_3	execute		

(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)

Modified Access Matrix of Figure B

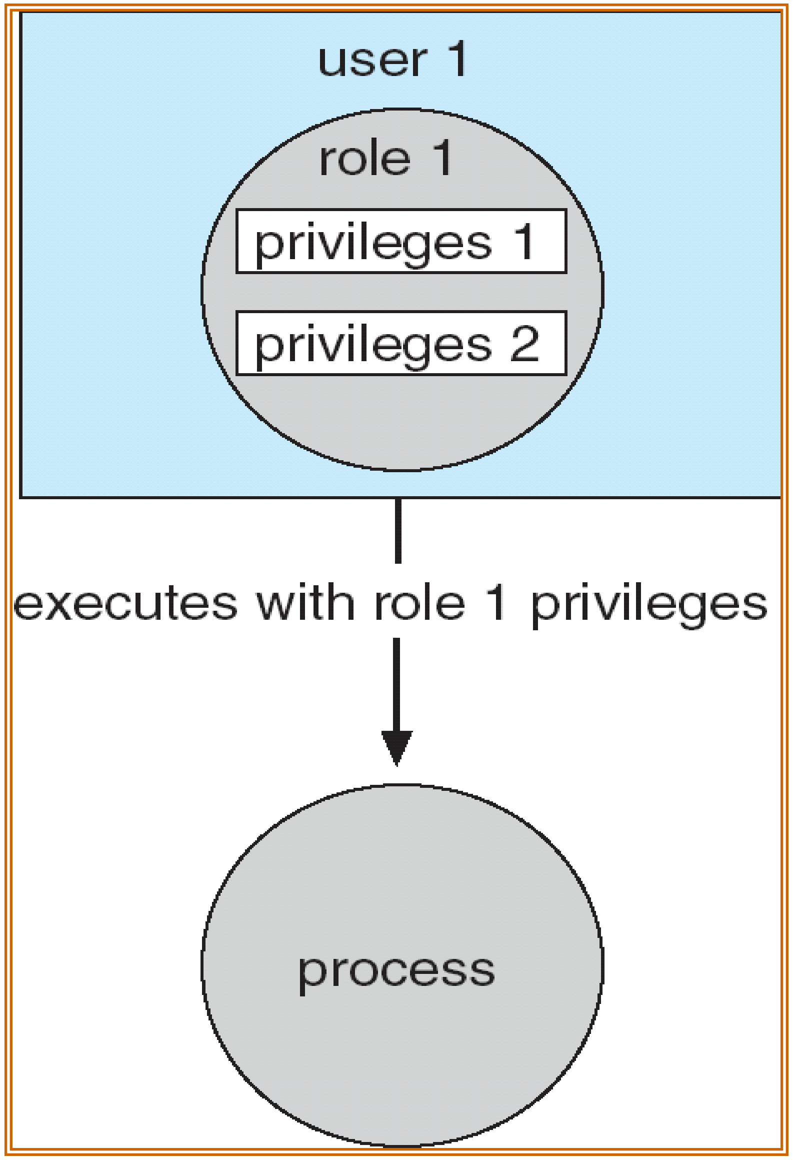


object / domain	F_1	F_2	F_3	laser printer	D_1	D_2	D_3	D_4
D_1	read		read			switch		
D_2				print			switch	switch control
D_3		read	execute					
D_4	write		write		switch			

Access Control

- Protection can be applied to non-file resources
- Solaris 10 provides **role-based access control** 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

Role-based Access Control in Solaris 10



Revocation of Access Rights

- *Access List* – Delete access rights from access list.
  - Simple
  - Immediate

- *Capability List* – Scheme required to locate capability in the system before capability can be revoked.
  - Reacquisition
  - Back-pointers
  - Indirection
  - Keys

Capability-Based Systems

- Hydra
  - Fixed set of access rights known to and interpreted by the system.
  - Interpretation of user-defined rights performed solely by user's program; system provides access protection for use of these rights.

- Cambridge CAP System
  - Data capability - provides standard read, write, execute of individual storage segments associated with object.
  - Software capability -interpretation left to the subsystem, through its protected procedures.

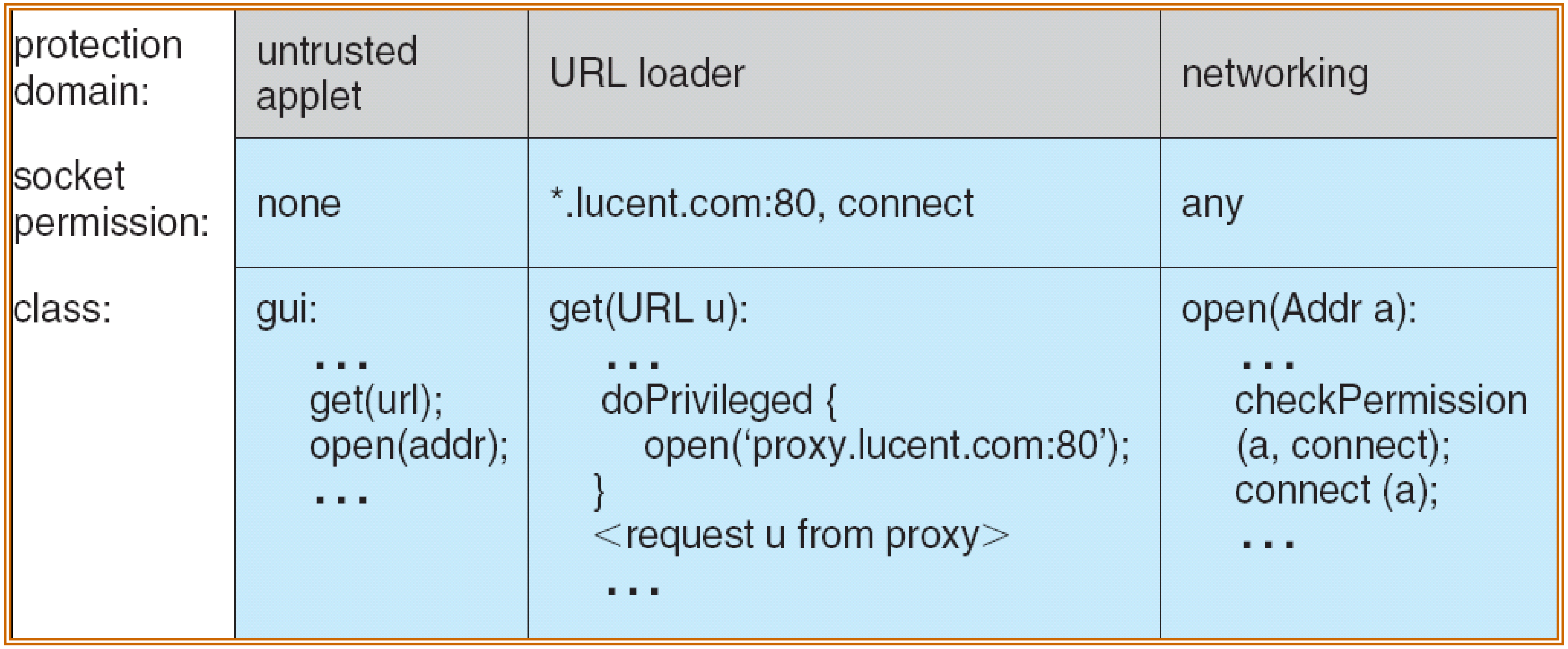
Language-Based Protection

- 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.

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); . . .