CMSC 412
Fall 2004

Protection and Security

Protection and Security

- Protection
  - Mechanisms supporting policies to control access to system resources
  - Protection policies essentially aim to prevent unauthorized access, modification, or destruction of data and resources.
- Security
  - Mechanisms to prevent external circumvention of the protection system

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.

Objects and Operations

- Objects are both hardware and software entities, at different levels of abstraction
  - CPU
  - Memory
  - File
  - Process
- Each object has type-specific operations
  - CPU can be executed
  - Memory can be read or written
  - Program files can be read, written, executed

Privileged Operations

- Even if an object supports a particular operation, we may not want to allow it for all processes
  - Only Alice can read her files
  - Only process P can read memory block M
  - Only the kernel can execute the INB instruction

1st Principle of Security Design

Least Privilege *("need to know"): each principal is given the minimum access needed to accomplish its task. [Saltzer & Schroeder '75]*

Examples:

+ Administrators don't run day-to-day tasks as root. So "**`rm -rf /`**" won't wipe the disk.
- fingerd runs as root so it can access different users' .plan files. But then it can also "**`rm -rf /`**".

Policies should Support LP

- Should be possible to specify different sets of permitted operations for the same objects
  - Like a role, or domain of authority.
- Should be easy to switch between roles, to control "dangerous" operations
  - System calls

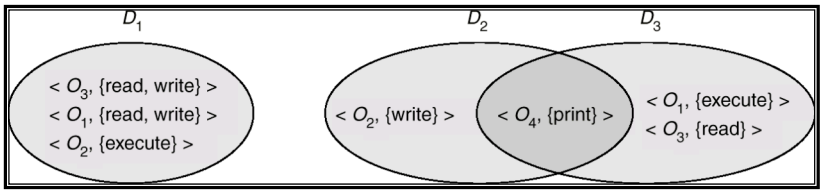
Least Privilege Elsewhere

Least Privilege shows up in almost all engineering design patterns.

- SE & Languages: abstract data types, strong interfaces, encapsulation, black-box principle, etc.

Domains

- Access-right = <*object-id*, *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 Use

- A process P executing "within" domain D is granted all of the access rights specified by the domain.
- For simplicity, we think of a process only ever within one domain at a time
- To change its rights, we may allow
  - A process to switch domains as it runs
  - A domain to expand its access rights

Domains in UNIX

- Two broad domains:
  - User
  - Supervisor
    - Switch from user to supervisor via system calls
- User domains further subdivided
  - Domain = user-id

Domains in UNIX

- User domain switch via file system
  - Each file has associated *setuid* bit.
  - When file is executed and *setuid* is set, then user-id is set to owner of the file being executed. When execution completes user-id is reset.
- … or by message passing
  - Send a message to a more privileged process to perform an operation on your behalf

Domains in UNIX

- User domain access rights expanded and contracted through the file system
  - Adding a user-id to a group permits it to access files at the group's privileges
  - Changing the access rights of a file may allow other domains to access it

Access Matrix

- A protection policy can be viewed 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
- Policy is established by the OS, and the users. Matrix (mechanism) is enforced by the OS and the hardware.

Access Matrix

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	

Figure A

Use of Access Matrix

- If a process in Domain D_i tries to do *op* on object O_j, then *op* must be in *Access(i,j)*.
- Can be expanded to dynamic protection.
  - Operations to add, delete access rights.
  - Special access rights:
    - *owner of* O_i
    - *copy right from* O_i *to* O_j
    - *control – D_i can modify D_j access rights*
    - *transfer – switch rights from domain D_i to D_j*

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 and *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 and *Owner* Rights

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

(a)

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

(b)

Modified Access Matrix of Figure B (*control* rights)

domain \ object	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			

Problems with Access Control

- Must be enforced at every step
  - What if process P opens and begins reading a file for which it has been given access, but then that access is revoked?
- Does not dictate information propagation, only initial access
  - What if process P copies an authorized file F to a location accessible by Q, a process not allowed to access F?

Access Control Lists

- **Access-control list** (ACL) implements each column in the matrix. Defines which domain can perform what operation on each object.

  Object O: Domain 1 = Read, Write
  Domain 2 = Read
  Domain 3 = Read

  Object P: …

- For each operation OP on O, find it's ACL, ensure the current domain D has permission to perform OP.

Capability List

- **Capability List** implements each row in the matrix.
- A **capability** is like a key that permits some set of operations on an object.
  - To perform operation OP on object O, the process must present a capability C that states it may do so. The object and the capability may be synonymous.
- Each domain is granted a list of capabilities

Acquiring Capabilities?

- Can be implicit, based on the domain in which a process executes
- Can be explicit, based on actions
  - For example, UNIX file descriptors are capabilities granted based on traditional access control via **open**
- Capabilities, once acquired, must be tamper-proof
  - Hardware or software-based

Revocation of Access Rights

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

Capability Unforgeability

- In Hydra and CAP, unforgeability is implemented via (special) hardware
  - In CAP, capabilities are stored in capability segments. Their meaning is determined by a parent process (e.g., the OS kernel) to whose memory they do not have access.
- In Eros, it is implemented on commodity hardware
  - Using virtual memory protection, as with UNIX
- We can also implement this via language-based protection.

Language-Based Protection

- Implement these systems in the programming language, rather than the OS
  - Provides more flexibility: objects are application-specific (high-level) rather than system-specific (low-level).
  - Problem of protection: how to avoid circumventing security checks? Used **type-safety** and **verification**.

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);
			. . .

2nd Principle of Security Design

Keep the Trusted Computing Base small.

Trusted Computing Base (TCB):

- the parts of a system that must work correctly to ensure the proper functioning of the system.
- e.g., the OS Kernel & Hardware.

Smaller, simpler systems tend to have fewer bugs and bad interactions.

- so keep the kernel small and simple.

"Small TCB" is a basic principle in *all* software.

Who do you trust?

- It's easy to get paranoid
- Do I trust a login prompt?
- Do I trust the OS that I got from the vendor?
- Do I trust the system staff?
  - should I encrypt all my files?
- Networking
  - do you trust the network provider?
  - do you trust the phone company?
- How do you bootstrap security?
  - need one "out of band" transfer to get going