System Protection

Michael Brockway

November 18, 2014

Contents

- What is Protection? - Principles
- Domains of Protection
- Access Matrix
- Implementation of Access Matrix
- Access Control
- Revocation of Access Rights
- Capability-Based Systems
- Language-Based Protection

References

- based on Operating System Concepts (8th Ed), Silberschatz et al, chapter 14. You are recommended to read this chapter of the module textbook.

What is Protection

Model: computer as a collection of objects, hardware, software

Each object has a unique name and can be accessed through a well-defined set of operations

The *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 privelege

- Programs, users, systems be given just enough privileges (and no more) to perform their tasks
- limits damage if the entity has a bug or is abused/misused accidentally/on purpose
- can be *static* during life of system or during life of process
- or *dynamic* (changed by process as needed): eg domain switching, privilege escalation
- A "Need to know" concept regarding access to data

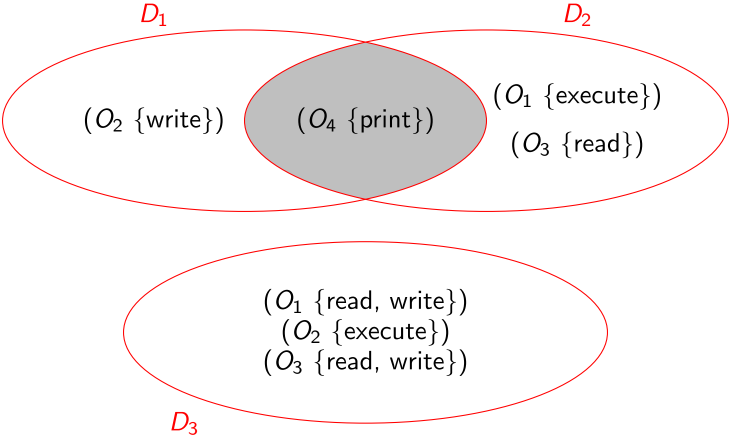
Can be

- Coarse-grained: priveleged given in large chunks: eg "admin" versus "ordinary user" rights
- ... or fine-grained: every file, program, has a set of permissions for every entity that may access it: more work for the system but more protective.

Domains

- A *domain* of protection is a set of *access rights* where
- an *access right* is a pair consisting of an *object* and a *rights set*
  - A set of permissions governing access to the object
- User domains, process domains, ...
- Each user or process associated with the domain has access to each object (file, program, system resource) determined by the rights set.

Domains - example



Domains in 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 = 1, then user-id is set to owner of the file being executed
  - When execution completes user-id is reset
- Domain switch is accomplished via passwords
  - Each file has associated with it a *domain bit* (setuid bit)
  - When file is executed and setuid = 1, then user-id is set to owner of the file being executed
  - `su` command temporarily switches to another user's domain when the other domain's password is provided.
- Domain switching via commands
  - `sudo` command prefix executes specified command in another domain, if original domain has the privilege or if password given.

Access Matrix

Protection by domains can be presented as a matrix:

- one row per domain
- one column per object
- $access[i,j]$ = set of operations a process executing in domain D_i can invoke on object O_j

Example

	O_1 (file)	O_2 (file)	O_3(file)	O_4 (printer)
D_1		write		print
D_2	execute		read	print
D_3	read, write	execute	read, write	
D_4		read	execute	

Access Matrix, ctd

- If a process in domain D_i tries to do *op* on object O_j, then need $op \in access[i, j]$
- User who creates object can define access column for that object
- Access matrix approach 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

Use of Access Matrix

Access matrix approach can be expanded to *dynamic* protection

- operations to add, delete access rights
- Special access rights:
  - owner of O_i
    - If D_k owns O_i (owner $\in$ $access[k, j]$) then a D_k process may grant or revoke permissions anywhere in column j.
  - copy *op* permission from row D_i to D_j
    - denoted by "*" below
    - limited to column(s) where copy permission given
  - control: D_i can modify D_j access rights
  - switch: from domain D_i to D_j
- Copy, Owner apply to any object
- Control applies to a domain object

Access Matrix - switch, control

Matrix as above, but with domains as objects

	O_1 (file)	O_2 (file)	O_3 (file)	O_4 (prtr)	D_1 (dom)	D_2 (dom)	D_3 (dom)	D_4 (dom)
D_1		write		print		switch		
D_2	exec		read	print			switch	switch control
D_3	read write	exec exec	read write					
D_4		read	exec		switch			

A process executing in a domain D has permission to switch to domain D' provided 'switch' permission appears in row D, column D'.

- $D_1 \to D_2$;
- $D_2 \to D_3$ or D_4;
- $D_4 \to D_1$

A process in D_2 may alter access rights throughout D_4.

Access Matrix - copy

	O_1 (file)	O_2 (file)	O_3 (file)
D_1	exec		write*
D_2	exec	read*	exec
D_3	exec		

A D_1 process may give write permission on file O_3 to a process in another domain. A D_2 process may give read permission on file O_2 to a process in another domain.

Thus, for instance, ...

	O_1 (file)	O_2 (file)	O_3 (file)
D_1	exec		write*
D_2	exec	read*	exec
D_3	exec	read	

A copy permission may (or may not) *propagate* – eg read* rather than read in (D_3, O_2)

Access Matrix - owner

	O_1 (file)	O_2 (file)	O_3 (file)
D_1	exec owner		write
D_2		read* owner	read* owner write
D_3	exec		

If owner $\in$ $access[D, O]$ then a process running in D may grant or revoke any permission in column O. Thus, for instance,

	O_1 (file)	O_2 (file)	O_3 (file)
D_1	exec owner		write
D_2		read* owner write*	read* owner write
D_3		write	write

Access Matrix - Implementation

- Generally, a *sparse* matrix
- One option - a global table
  - Store triples (domain, object, rights-set) in a single table
  - A requested operation M on object O within domain $D \rightarrow$ search table for (D, O, R) with $M \in R$.
  - The table probably too large to keep in memory
  - Managing groups of object with same permissions unwieldy - eg consider an object that all domains can read.
- Alternativey, keep *access lists* for objects
  - Each column implemented as an access list for one object
  - Each resulting per-object list is a set of pairs (domain, rights-set) defining all domains with non-empty set of access rights for the object
  - Easily extended to contain a 'default set': if $M \in$ default set, also allow access
  - Each column is an access control list for one object; each row a *capability list* for one domain.

Access Matrix - Implementation ctd

- Another option: A capability list for domains
  - domain based rather than object-based
  - A *capability list* for a domain is list of pair (object O, $\{$operations allowed $O\}$)
  - To execute operation M on object O, a process requests the operation and specifies capability as a parameter. Possession of capability $\Rightarrow$ access is allowed
  - Capability list associated with domain but never directly accessible by domain
    - Rather, it is protected object, maintained by OS and accessed indirectly
    - Like a "secure pointer"
    - The approach can be extended to applications
- Fourth option: Lock-key
  - Compromise between access lists and capability lists
  - Each object has list of unique bit patterns, *locks*
  - Each domain as list of unique bit patterns, *keys*
  - Process in domain can access object $\Leftrightarrow$ domain has key that matches one of the locks

Comparison of Implementations

Trade-offs ...

- 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: 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

Most systems use combination of access lists and capabilities: on First access to an object, the access list searched

- If allowed, capability created and attached to process; additional accesses need not be checked
- After last access, capability destroyed
- Example: File system with Access Lists per file

Revocation of Access

Options

- Immediate vs. delayed
- Selective vs. general
- Partial vs. total
- Temporary vs. permanent

Access List: Delete access rights from access list

- Simple: search access list and remove entry
- Immediate, general or selective, total or partial, permanent or temporary

Capability List: A scheme is required to locate capability in the system before capability can be revoked

- Reacquisition: periodic delete, with require and denial if revoked
- Back-pointers: set of pointers from each object to all capabilities of that object
- Indirection: capability points to global table entry which points to object: delete entry from global table, not selective
- Keys: unique bits associated with capability, generated when capability created

Language-based Protection

Specification of protection in a programming language allows the high-level description of policies for the allocation and use of resources.

The language implementation can provide software for protection enforcement when automatic hardware-supported checking is unavailable.

The implementation interpret protection specifications to generate calls on whatever protection system is provided by the hardware and the operating system.

Ref: Silberschatz et al §14.9

Protection in Java

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: ...

Protection in Java - Stack Inspection

<table>
<tr><td>protection domain:</td><td>untrusted applet</td><td>URL loader</td><td>networking</td></tr>
<tr><td>socket permission:</td><td>none</td><td>*.lucent.com:80, connect</td><td>any</td></tr>
<tr><td>class:</td><td>gui:
...
get(url);
open(addr);

...</td><td>get(URL u):
...
doPrivileged {
open
('proxy.lucent.com:80');
}
⟨request u from proxy⟩
...</td><td>open(Addr a):
...
checkPrmsn
(a, connect);

connect(a);
...</td></tr>
</table>