CSE 380
Computer Operating Systems

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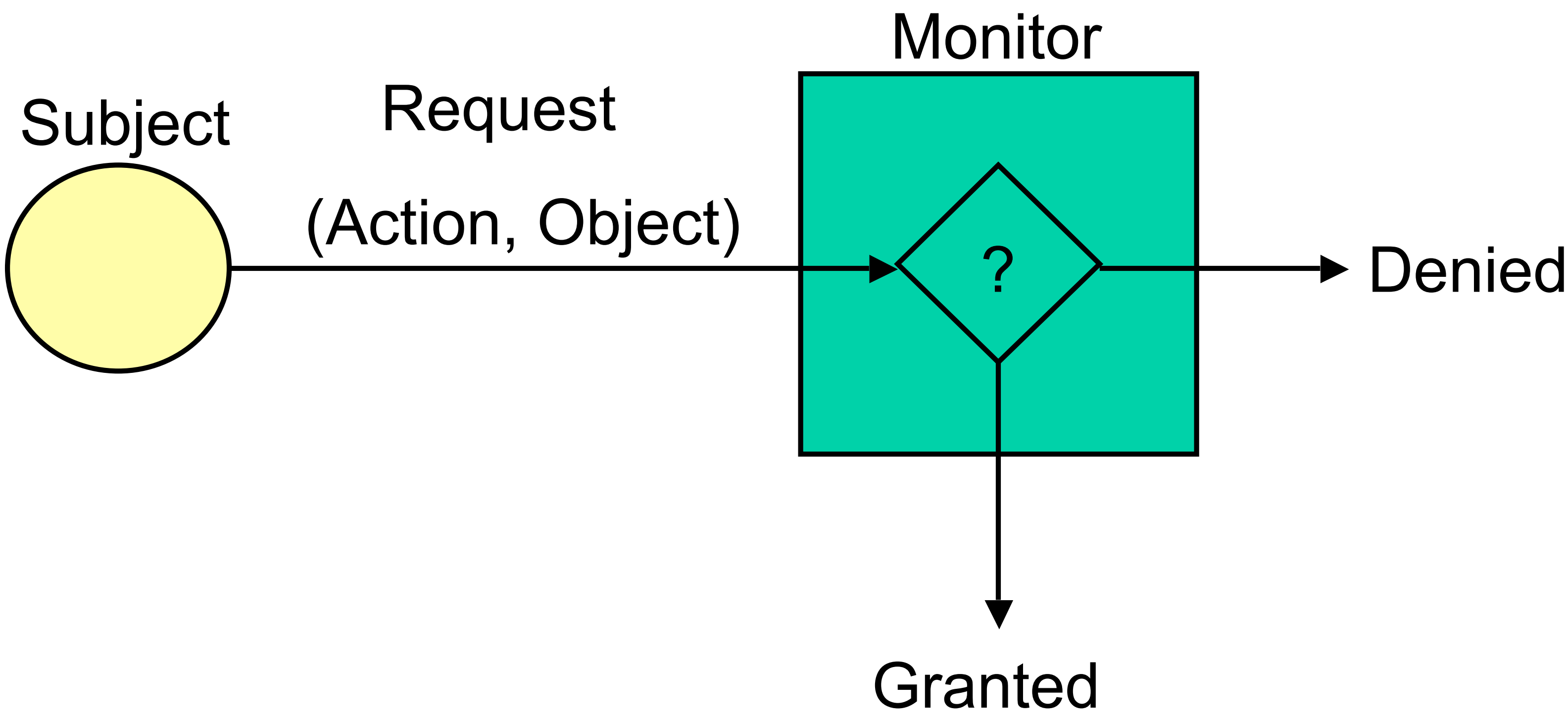
Lecture Note: Protection Mechanisms

Policy vs. Mechanism

- Access control policy is a *specification*
  - Given in terms of a model of the system
  - Subjects: do things (i.e. a process writes to files)
  - Objects: are passive (i.e. the file itself)
  - Actions: what the subjects do (i.e. read a string from a file)
  - Rights: describe authority (i.e. read or write permission)
- Mechanisms are used to *implement* a policy
  - Example: access control bits in Unix file system & OS checks
  - Mechanism should be general; ideally should not constrain the possible policies.
  - Complete mediation: every access must be checked

Reference Monitors



Example Reference Monitors

- Operating Systems
  - File system
  - Memory (virtual memory, separate address spaces)
- Firewalls
  - Regulate network access
- Java Virtual Machine
  - Regulates Java programs' resource usage

Access Control Matrix

A[s][o]	Obj_1	Obj_2	…	Obj_N
$Subj_1$	{r,w,x}	{r,w}	…	{}
$Subj_2$	{w,x}	{}	…	
…	…	…	…	
$Subj_M$	{x}	{r,w,x}	…	{r,w,x}

Each entry contains a set of rights.

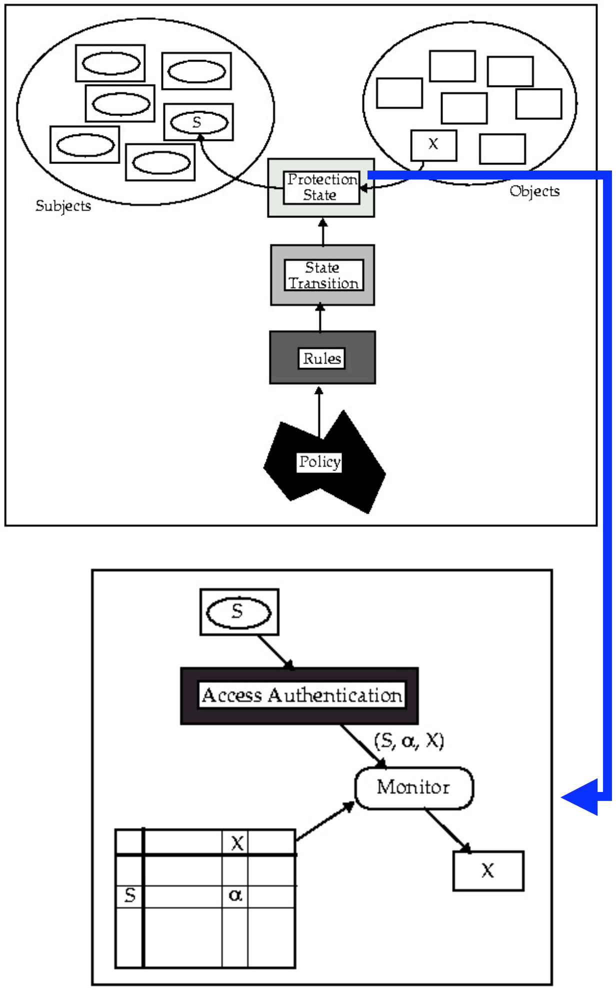
Access Control Checks

- Suppose subject s wants to perform action that requires right r on object o:

- If ($r \in A[s][o]$) then *perform action* else *access is denied*

Model for resource Protection

- A Protection System is composed of
  - **set of subjects:** processes executing in a specific protection domain
  - **set of objects:** all the passive elements of the system plus all the subjects
  - **set of rules specifying the protection policy**
- Protection Domain: Set of rights a process has at any given time
- Protection state is checked for each access of an object, X, by a subject, S
- Protection state can be conceptualized as an ***access matrix.***
- A[S,X] is a set that describes the access rights held by subject S to object X.



Rights and Actions

- Besides read, write, execute actions there are many others:
- Ownership
- Creation
  - New subjects (i.e. in Unix add a user)
  - New objects (i.e. create a new file)
  - New rights: Grant right r to subject s with respect to object o (sometimes called delegation)
- Deletion of
  - Subjects
  - Objects
  - Rights (sometimes called revocation)

Protecting the Reference Monitor

- It must not be possible to circumvent the reference monitor by corrupting it
- Mechanisms
  - Type checking
  - Software fault isolation: rewrite memory access instructions to perform bounds checking
  - User/Kernel modes
  - Segmentation of memory (OS resources aren't part of virtual memory system)

Storing the Access Control Matrix

- Subjects >> # users
  - A row can correspond to a protection domain
  - Each subject runs within a protection domain
  - Example: User-ID and Group-ID in Unix determine domain
- Objects >> # files
  - Potentially could have permissions on any resource
- The matrix is typically sparse
  - Store only non-empty entries

Access Control Lists

A[s][o]	Obj_1	Obj_2	…	Obj_N
$Subj_1$	{r,w,x}	{r,w}	…	{}
$Subj_2$	{w,x}	{}	…	{r}
…	…	…	…	…
$Subj_M$	{x}	{r,w,x}	…	{r,w,x}

For each object, store a list of (Subject , Rights) pairs.

Access Control Lists

- Resolving queries is linear in length of the list
- Revocation w.r.t. a single object is easy
- "Who can access this object?" is easy
  - Useful for auditing
- Lists could be long
  - Factor into groups (lists of subjects)
  - Give permissions based on group
  - Introduces consistency question w.r.t. groups
- Authentication critical
  - When does it take place? Every access would be expensive.

Capabilities Lists

A[s][o]	Obj_1	Obj_2	…	Obj_N
$Subj_1$	{r,w,x}	{r,w}	…	{}
$Subj_2$	{w,x}	{}	…	{r}
…	…	…	…	…
$Subj_M$	{x}	{r,w,x}	…	{r,w,x}

For each subject, store a list of (Object, Rights) pairs.

Capabilities

- A capability is a (Object, Rights) pair
- Must be protected from tampering
  - Otherwise, subjects could get illegal access
- Authentication takes place when the capabilities are granted (not needed at use)
- Harder to carry out revocation (must find all entries where the object appears)
- Easy to audit a subject, hard to audit an object

Storing Capabilities Securely

- Special hardware: tagged words in memory
  - Can’t copy/modify tagged words
- Store the capabilities in protected address space
- Could use static scoping mechanism of safe programming languages.
  - Java’s “private” fields
- Could use cryptographic techniques
  - OS kernel could sign (Object, Rights) pairs using a private key
  - Any process can verify the capability

Unix Security

- Each user has a unique 16-bit UID
  - UID of root/superuser is 0
- Each user can belong to a group, each group has a unique 16-bit GID
- Protection domain of a process is determined by the (UID,GID) of the user that owns the process
- Every file has
  - UID and GID of the owner
  - Protection bits that can be set/changed by the owner
  - Devices handled as files (e.g. /dev/tty, /dev/lp)
- 9 bits specifying allowed read(r)/write(w)/execute(x) access for the owner, group, and everyone else
  - E.g. rw-r----- means owner can read/write and group can read

SETUID

- How to give temporary access to privileged resources?
- E.g. /dev/lp is owned by printer daemon (or by root), other processes need to write to it to send jobs to printer, but you do not want to set permission to rwxrwxrwx
- Solution: Each file/device has a SETUID bit
- When an executable program P with SETUID bit set to 1 is executed by a process Q, the protection domain of Q is changed to (UID,GID) of P (i.e. the owner of P)
  - If P's SETUID bit is 0, then protection domain of Q does not change

Sample Scenario

- /dev/lp is owned by root with protection rw-------
    - This is used to access the printer
- /bin/lp is owned by root with --x--x--x with SETUID=1
- User A issues a print command
- Shell (running with A's UID and GID) interprets the command and forks off a child process, say, P
- Process P has the same UID/GID as user A
- Child process P executes exec("/bin/lp",…)
- Now P's domain changes to root's UID
- Consequently, /dev/lp can be accessed to print
- When /bin/lp terminates so does P
- Parent shell never got the access to /dev/lp