CIS 551 / TCOM 401

Computer and Network Security

Spring 2008
Lecture 5

Today's Plan

- We've seen how worms and viruses spread.
- What can we do about it?
  - Proactive:
    - Produce good software (eliminate vulnerabilities)
    - Limit the damages that can be done
  - Reactive: install filtering configure firewalls to drop packets

- Today: access control
  - Firewall
  - OS provided file permissions, etc.

The "Gold" Standard

- *Au*thentication
  - Identify which principals take which actions
- *Au*dit
  - Recording the security relevant actions
- *Au*thorization
  - Determine what actions are permissible
  - This lecture is about authorization.
  - We'll get to authentication & audit later.

Authorization

- Authorization is the process of determining whether a principal is permitted to perform a particular action.
- Access control
  - Example: Read/Write/Execute permissions for a file system.
  - Example: Java applets have restricted authorization to perform network & disk I/O.
  - Example: Firewall determines which packets can flow into a network

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

Access Control Matrices

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*

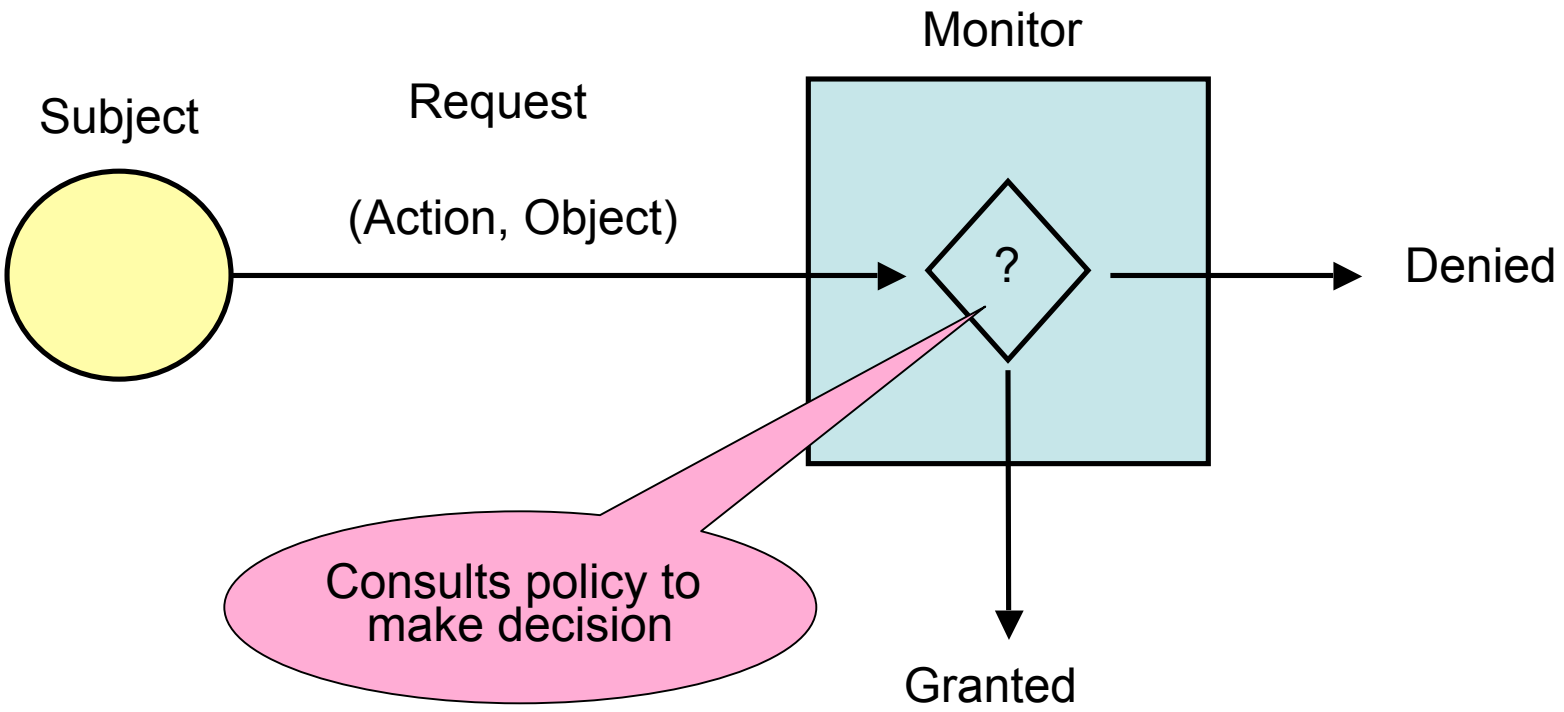
Rights and Actions

- 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)

Access Control Examples

- Assume OS is a subject with all rights
- To create a file f owned by Alice:
  - Create object f
  - Grant own to Alice with respect to f
  - Grant read to Alice with respect to f
  - Grant write to Alice with respect to f
- To start a login for Alice
  - Input and check password
  - Create a shell process p
  - Grant own_process to Alice with respect to p

Reference Monitors



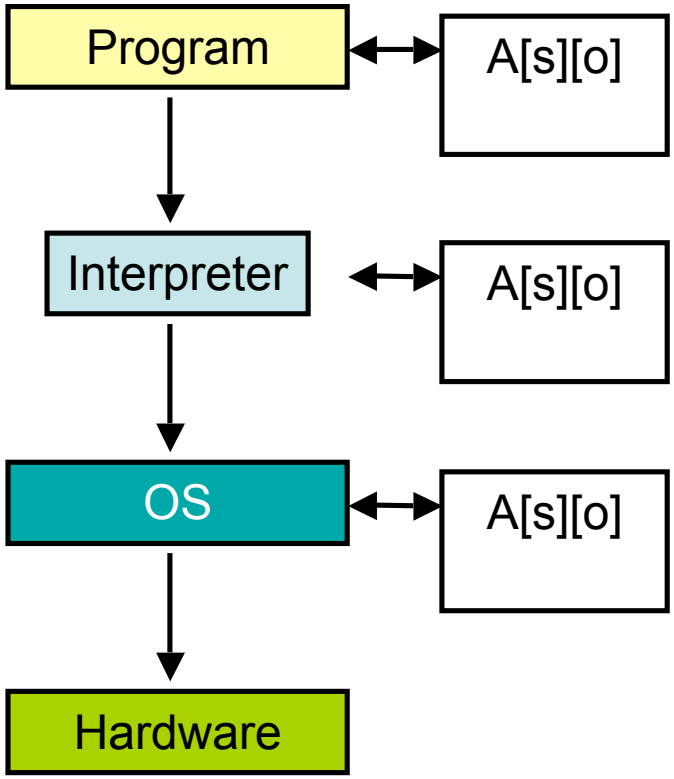
Reference Monitors

- Criteria
  - Correctness
  - Complete mediation (all avenues of access must be protected)
  - Expressiveness (what policies are admitted)
  - How large/complex is the mechanism?

- Trusted Computing Base (TCB)
  - The set of components that must be trusted to enforce a given security policy
  - Would like to simplify/minimize the TCB to improve assurance of correctness

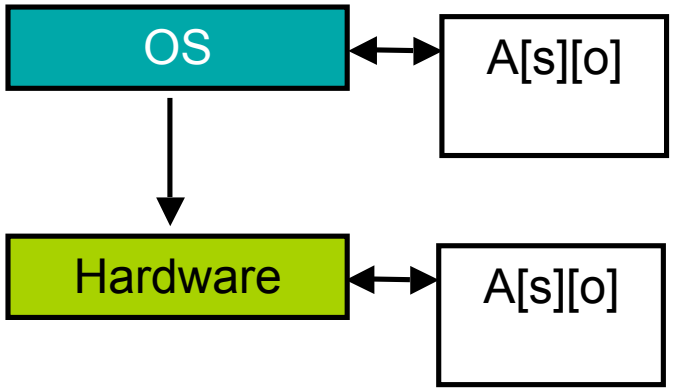
Software Mechanisms

- Interpreters
  - Check the execution of every instruction
  - Hard to mediate high-level abstractions
- Wrappers
  - Only “interpret” some of the instructions
  - What do you wrap?
  - Where do you wrap? (link-time?)
- Operating Systems
  - Level of granularity?
  - Context switching overheads?
- Example
  - Java and C# runtime systems



Hardware Mechanisms

- Multiple modes of operation
  - User mode (problem state)
  - Kernel mode (supervisor state)
- Specialized hardware
  - Virtual memory support (TLB's, etc.)
  - Interrupts



Protecting Reference Monitors

- It must not be possible to circumvent the reference monitor by corrupting it
- Mechanisms
  - Type checking
  - Sandboxing: run processes in isolation
  - 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)
  - Physical configuration (e.g. network topology)

Implementing Access Control

- Access control matrices
  - Subjects >> #users (say 1000s)
  - Objects >> #files (say 1,000,000s)
  - To specify “all users read f”
    - Change O(users) entries
- Matrix is typically sparse
  - Store only non-empty entries
- Special consideration for groups of users

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 x Rights) pairs.

Access Control Lists

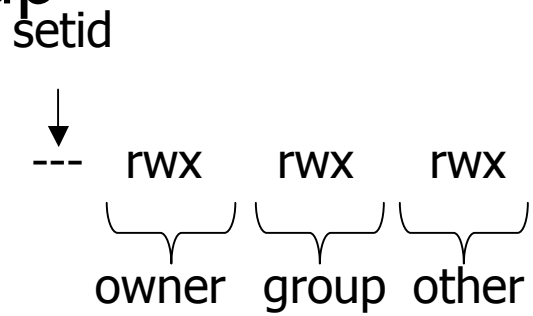
- Resolving queries is linear in length of the list
- Revocation w.r.t. a single object is easy
- “Who can access this object?” is easy
  - Useful for auditing
- Lists could be long
  - Factor into groups (lists of subjects)
  - Give permissions based on group
  - Introduces consistency question w.r.t.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

Representational Completeness

- Access Control Lists
  - Can represent any access control matrix
  - Potentially very large
  - Used in windows file system, NTFS
- Unix file permissions (next topic)
  - Fixed size
  - Can't naturally express some access control policies/matrices

Unix file security

- Each file has owner and group
- Permissions set by owner
  - Read, write, execute
  - Owner, group, other
  - Represented by vector of four octal values



- Only owner, root can change permissions
  - This privilege cannot be delegated or shared
- Setid bits – Discuss in a few slides

Question

- "owner" can have fewer privileges than "other"
  - What happens?
    - User gets access?
    - User does not?

- Prioritized resolution of differences

  if user = owner then *owner* permission

  else if user in group then *group* permission

  else *other* permission

Unix Policies Interact

/home/jeff/	jeff	jeff	-rwx ------
/home/jeff/.bashrc	jeff	jeff	-rwx r-- r--

- stevez cannot read /home/jeff/.bashrc
  - The confidentiality/availability of an object depends on policies other than it's own.
  - Such interactions make specifying policies hard.
  - Problem is not limited to unix (or file systems).

Setid bits on executable Unix file

- Three setid bits
  - Sticky
    - Off: if user has write permission on directory, can rename or remove files, even if not owner
    - On: only file owner, directory owner, and root can rename or remove file in the directory
  - Setuid – set EUID of process to ID of file owner
    - passwd owned by root and setuid is true
    - Jeff executes passwd: “passwd runs as root”
  - Setgid – set EGID of process to GID of file

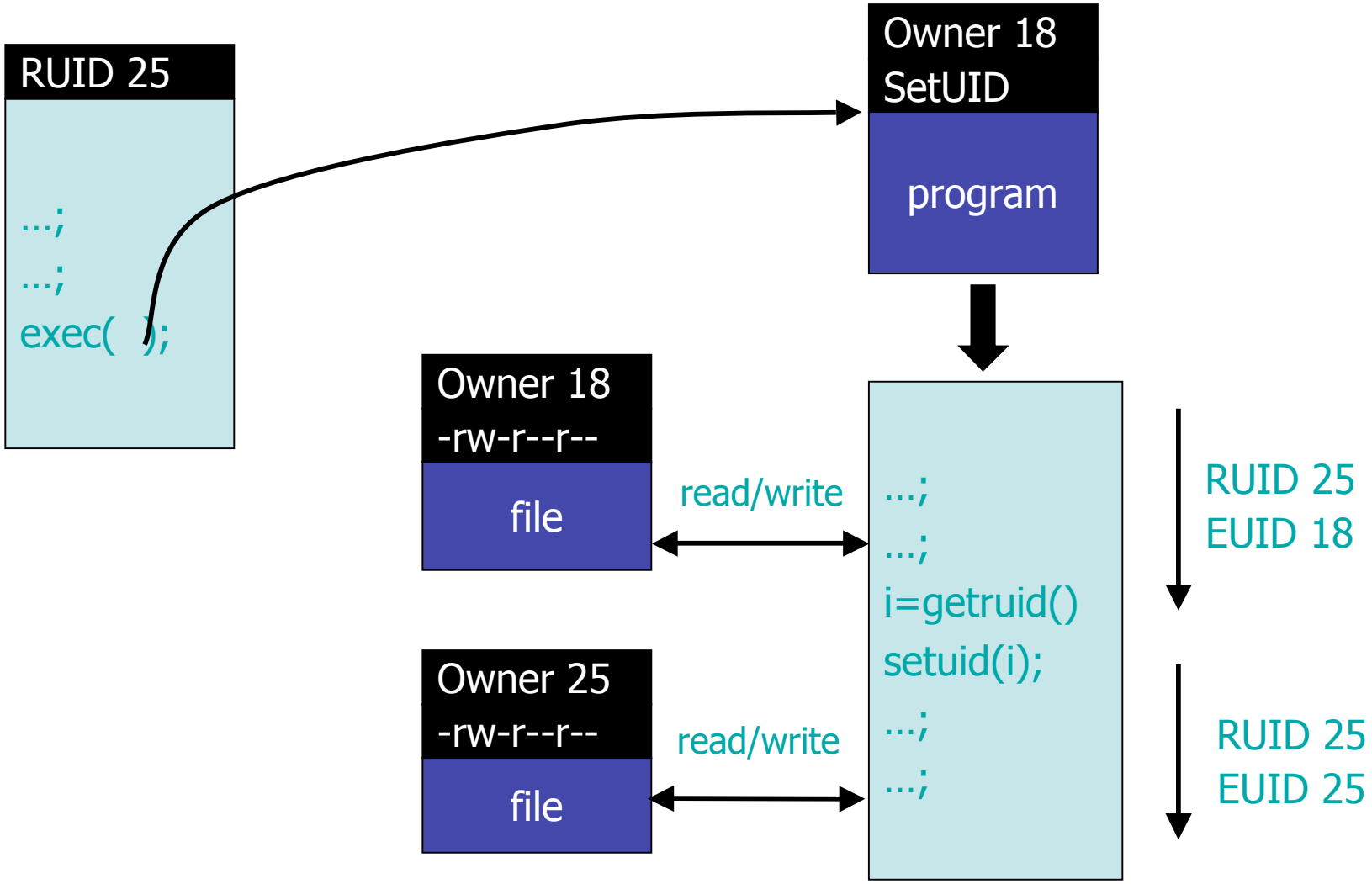
Effective User ID (EUID)

- Each process has three user IDs (more in Linux)
  - Real user ID (RUID)
    - same as the user ID of parent (unless changed)
    - used to determine which user started the process
  - Effective user ID (EUID)
    - from set user ID bit on program file, or system call
    - determines the permissions for process
      - file access and port binding
  - Saved user ID (SUID)
    - So previous EUID can be restored
- Real group ID, effective group ID, used similarly

Process Operations and IDs

- Root
  - ID=0 for superuser root; can access any file
- Fork and Exec
  - Inherit three IDs, except when executing a file with setuid bit on.
- Setuid system calls
  - seteuid(newid) can set EUID to
    - Real ID or saved ID, regardless of current EUID
    - Any ID, if EUID=0
- Details are actually more complicated
  - Several different calls: setuid, seteuid, setruid

Example


RUID 25
...;
...;
exec( );
Owner 18
SetUID
program
Owner 18
-rw-r--r--
file
read/write
Owner 25
-rw-r--r--
file
read/write
...;
...;
i=getruid()
setuid(i);
...;
...;
RUID 25
EUID 18
RUID 25
EUID 25

Setuid programming

- Can do anything that owner of file is allowed to do
- Be Careful!
  - Root can do anything; don't get tricked (no middle ground)
  - Principle of least privilege – change EUID when root privileges no longer needed
  - Be sure not to
    - Take action for untrusted user
    - Return secret data to untrusted user
- Setuid scripts
  - This is a bad idea
  - Historically, race conditions
    - Begin executing setuid program; change contents of program before it loads and is executed

Unix summary

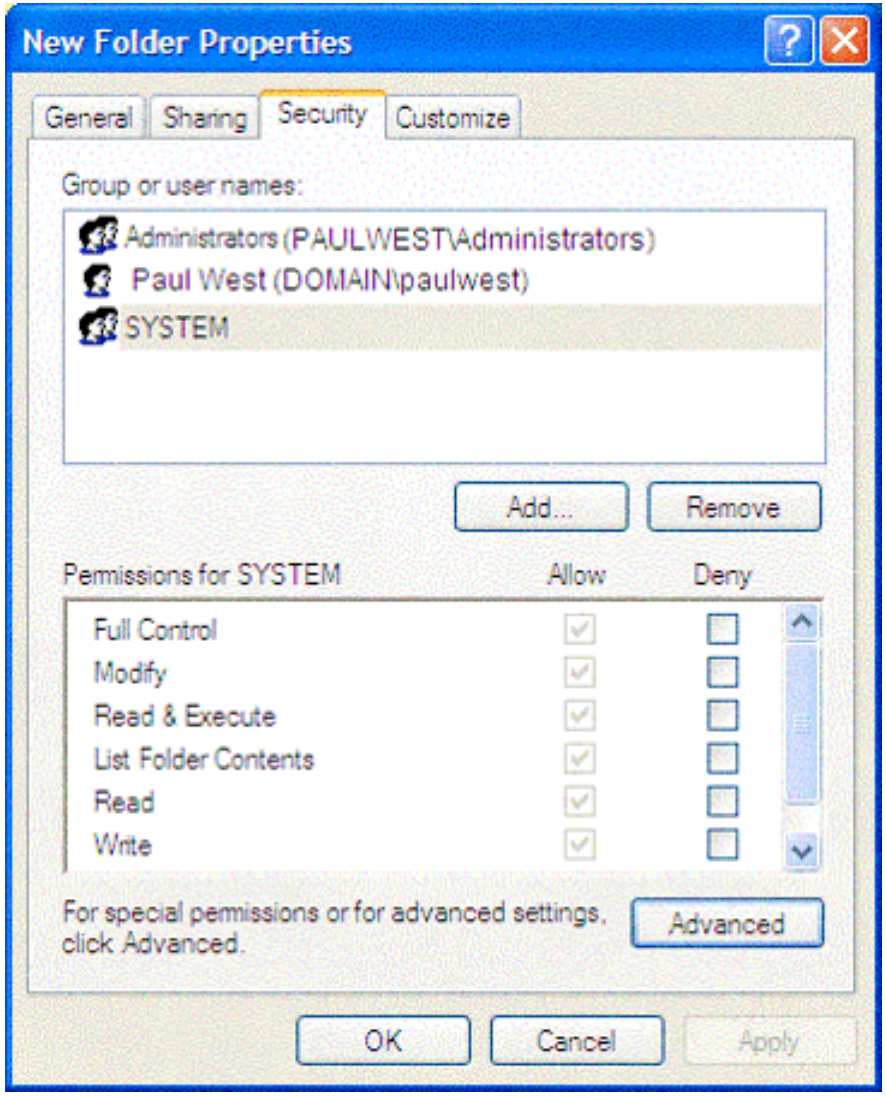
- We're all very used to this …
  - So probably seems pretty good
  - We overlook ways it might be better
- Good things
  - Some protection from most users
  - Flexible enough to make things possible
- Main bad thing
  - Too tempting to use root privileges
  - No way to assume some root privileges without all root privileges

Access control in Windows (NTFS)

- Some basic functionality similar to Unix
  - Specify access for groups and users
    - Read, modify, change owner, delete
  - ACLs used for fine grained control
- Some additional concepts
  - Tokens
  - Security attributes
- Generally
  - More flexibility than Unix
    - Can define new permissions
    - Can give some but not all administrator privileges

Sample permission options

- SID
  - "Security IDentifier"
  - Identity (like Unix UID)
    - SID revision number
    - 48-bit authority value
    - Globally unique
  - Describes users, groups, computers, domains, domain members



File Permission Inheritance

- Static permission inheritance (Win NT)
  - Initially, subfolders inherit permissions of folder
  - Folder, subfolder changed independently
  - *Replace Permissions on Subdirectories* command
    - Eliminates any differences in permissions
- Dynamic permission inheritance (Win 2000)
  - Child inherits parent permission, remains linked
  - Parent changes are inherited, except explicit settings
  - Inherited and explicitly-set permissions may conflict
    - Resolution rules
      - Positive permissions are additive (take union of all permissions)
      - Negative permission (deny access) takes priority

Security Descriptor

- Access Control List associated with an object
  - Specifies who can perform what actions on the object
- Several fields
  - Header
    - Descriptor revision number
    - Control flags, attributes of the descriptor
      - E.g., memory layout of the descriptor
  - SID of the object's owner
  - SID of the primary group of the object
  - Two attached optional lists:
    - Discretionary Access Control List (DACL)
      - Describes access policy
    - System Access Control List (SACL)
      - Describes audit/logging policy

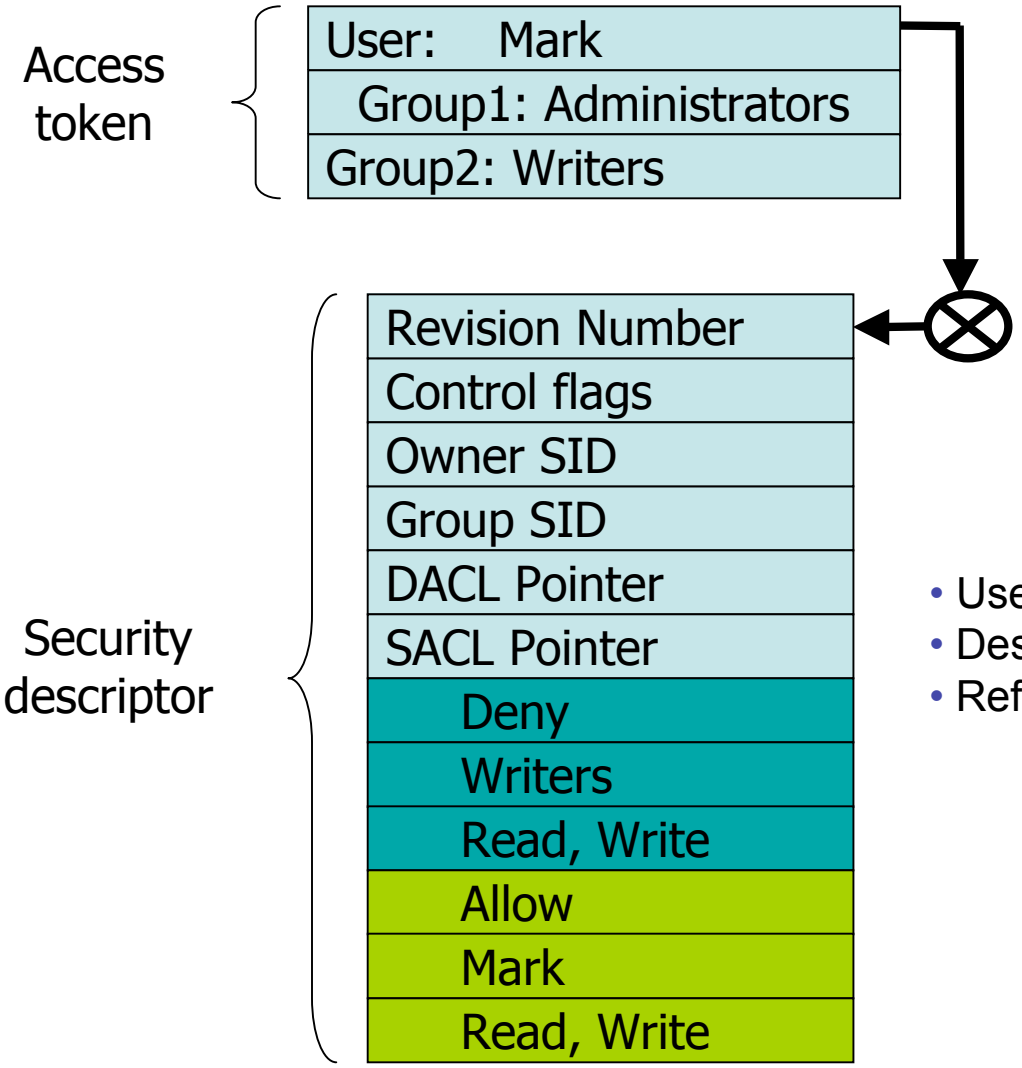
Tokens

- Security Reference Monitor
  - uses tokens to identify the security context of a process or thread
- Security context
  - privileges, accounts, and groups associated with the process or thread
- Impersonation token
  - thread uses temporarily to adopt a different security context, usually of another user
- Related to the EUID used in Unix.

Impersonation Tokens

- Windows equivalent of setuid
- Process uses security attributes of another
  - Client passes impersonation token to server
- Client specifies impersonation level of server
  - Anonymous
    - Token has no information about the client
  - Identification
    - server obtain the SIDs of client and client's privileges, but server cannot impersonate the client
  - Impersonation (= Anonymous + Identification)
    - server identify and impersonate the client
  - Delegation (= Impersonation + Authentication)
    - lets server impersonate client on local, remote system

Example access request



- User Mark requests write permission
- Descriptor denies permission to group
- Reference Monitor denies request

Windows Summary

- Good things
  - Very expressive
  - Don’t need full SYSTEM (e.g. root) privileges for many tasks
- Bad thing
  - More complex policies
    - Harder to implement: Larger TCB
    - Harder for users to understand