CIS 551 / TCOM 401

Computer and Network Security

Spring 2009
Lecture 10

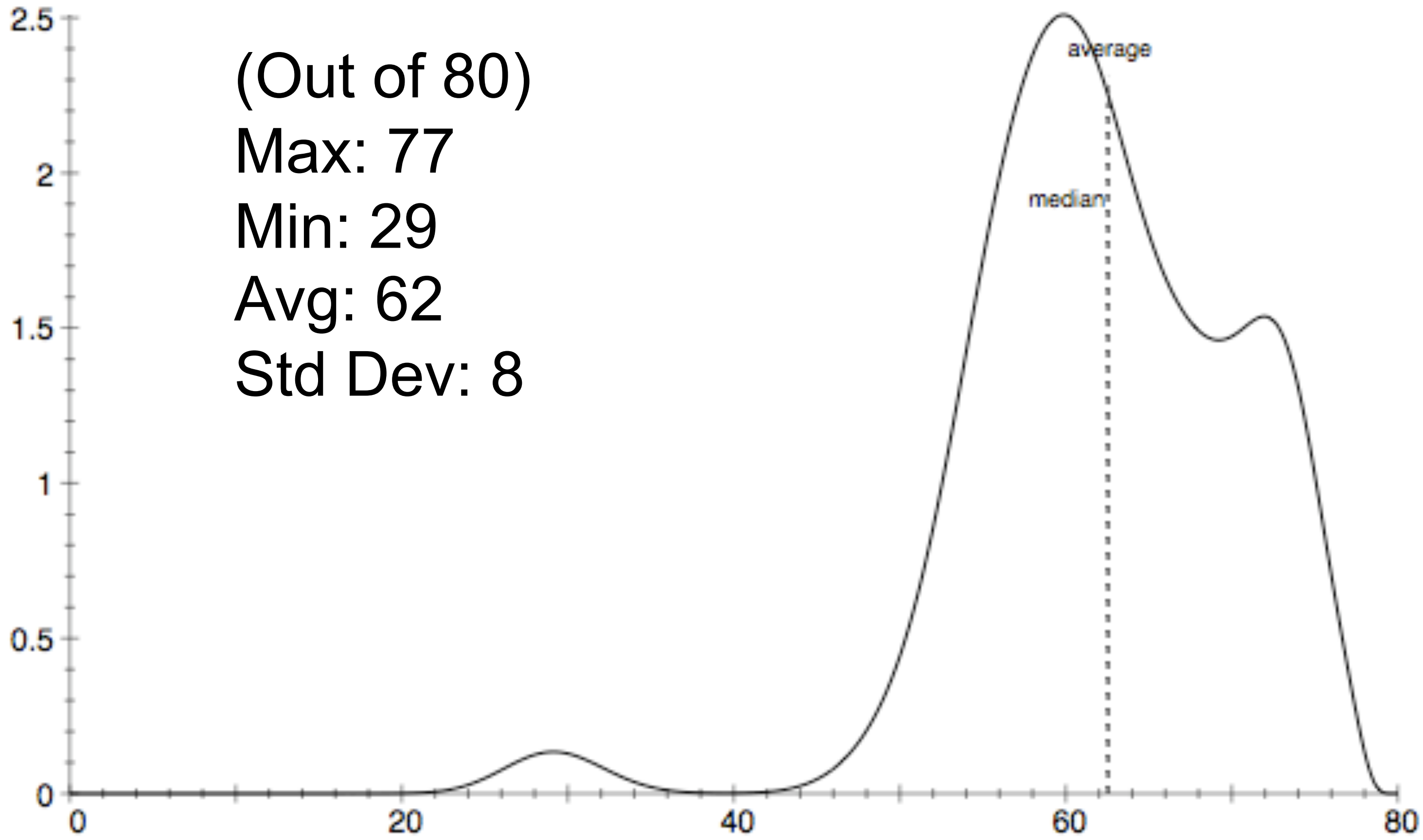
Announcements

- Plan for Today:
  - Return briefly to finish up attacker reconnaissance
  - Access Control

- Project 2 reminder
  - Due: Friday, March 6^{th} (right before Spring Break)

Midterm 1 Statistics

(Out of 80)
Max: 77
Min: 29
Avg: 62
Std Dev: 8



Detecting Attacks

- Attacks (against computer systems) usually consist of several stages:
  - Finding software vulnerabilities
  - Exploiting them
  - Hiding/cleaning up the exploit
- Attackers care about finding vulnerabilities:
  - What machines are available?
  - What OS / version / patch level are the machines running?
  - What additional software is running?
  - What is the network topology?
- Attackers care about not getting caught:
  - How detectible will the attack be?
  - How can the attacker cover her tracks?
- Programs can automate the process of finding/exploiting vulnerabilities.
  - Same tools that sys. admins. use to audit their systems…
  - A worm is just an automatic vulnerability finder/exploiter…

Attacker Reconnaissance

- Network Scanning
  - Existence of machines at IP addresses
  - Attempt to determine network topology
  - ping, tracert
- Port scanners
  - Try to detect what processes are running on which ports, which ports are open to connections.
  - Typical machine on the internet gets 10-20 port scans per day!
  - Can be used to find hit lists for flash worms
- Web services
  - Use a browser to search for CGI scripts, Javascript, etc.

Determining OS information

- Gives a lot of information that can help an attacker carry out exploits
  - Exact version of OS code can be correlated with vulnerability databases
- Sadly, often simple to obtain this information:
  - Just try telnet

```
playground~> telnet hpux.u-aizu.ac.jp
Trying 163.143.103.12 ...
Connected to hpux.u-aizu.ac.jp.
Escape character is '^]'.
HP-UX hpux B.10.01 A 9000/715 (ttyp2)

login:
```

Determining OS

- Or ftp:

```
$ ftp ftp.netscape.com 21
Connected to ftp.gftp.netscape.com.
220-36
220 ftpnscp.newaol.com FTP server (SunOS 5.8) ready.
Name (ftp.netscape.com:stevez):
331 Password required for stevez.
Password:
530 Login incorrect.
ftp: Login failed.
Remote system type is UNIX.
Using binary mode to transfer files.
ftp> system
215 UNIX Type: L8 Version: SUNOS
ftp>
```

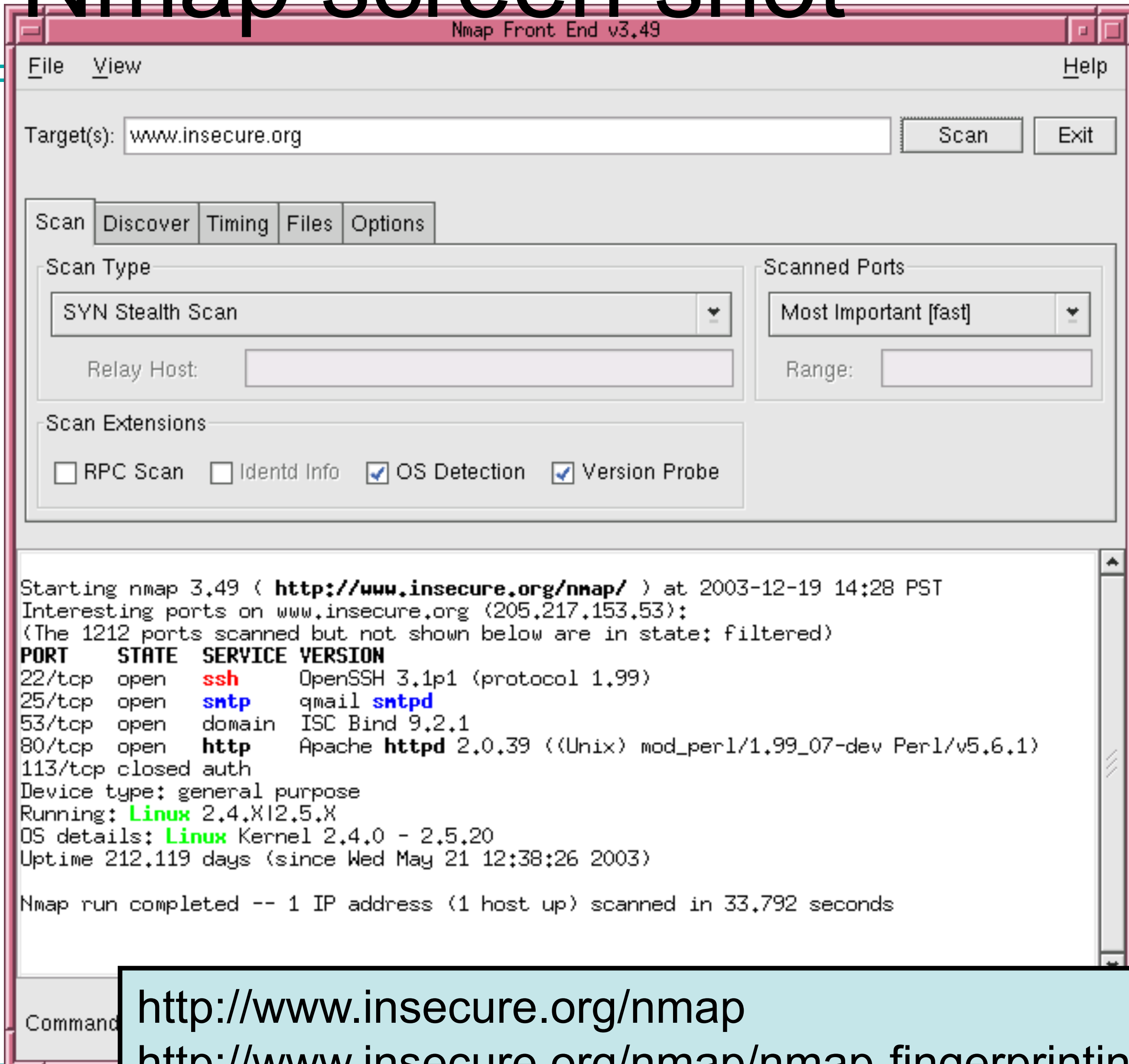
Determining OS

- Exploit different implementations of protocols
  - Different OS's have different behavior in some cases
- Consider TCP protocol, there are many flags and options, and some unspecified behavior
  - Reply to bogus FIN request for TCP port (should not reply, but some OS's do)
  - Handling of invalid flags in TCP packets (some OS's keep the invalid flags set in reply)
  - Initial values for RWS, pattern in random sequence numbers, etc.
  - Can narrow down the possible OS based on the combination of implementation features
- Tools can automate this process

Auditing: Remote auditing tools

- Several utilities available to “attack” or gather information about services/daemons on a system.
  - SATAN (early 1990’s):
    Security Administrator Tool for Analyzing Networks
  - SAINT - Based on SATAN utility
  - SARA - Also based on SATAN
  - Nessus - Open source vulnerability scanner
    - http://www.nessus.org
  - Nmap
- Commercial:
  - ISS scanner
  - Cybercop

Nmap screen shot



http://www.insecure.org/nmap
http://www.insecure.org/nmap/nmap-fingerprinting-article.html

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
- Restrict access to OS resources?
  - If one could prevent a worm or virus from tampering with the file system or restrict their access to other functionality, the damage they can do is limited.
- Today: access control more generally

Authorization

- A *principal* is an entity that has a bearing on the security properties of a system.
  - Example principals: Users, Hosts, Processes, “the Attacker”, etc.

- *Authorization* is the process of determining whether a principal is permitted to perform a particular action.
- *Access control* is necessary at many levels of abstraction in a computing system:
  - Firewalls are one example of an access control mechanism.
  - Others?

The “Gold” Standard

- *Au*thentication
  - Identify which principals take which actions
- *Au*thorization
  - Determine what actions are permissible
- *Au*dit
  - Recording the security relevant actions

- We discussed auditing in one context – there’s more to say about that later.
- This rest of this lecture is about authorization.
- We'll get to authentication in a few lectures.

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*

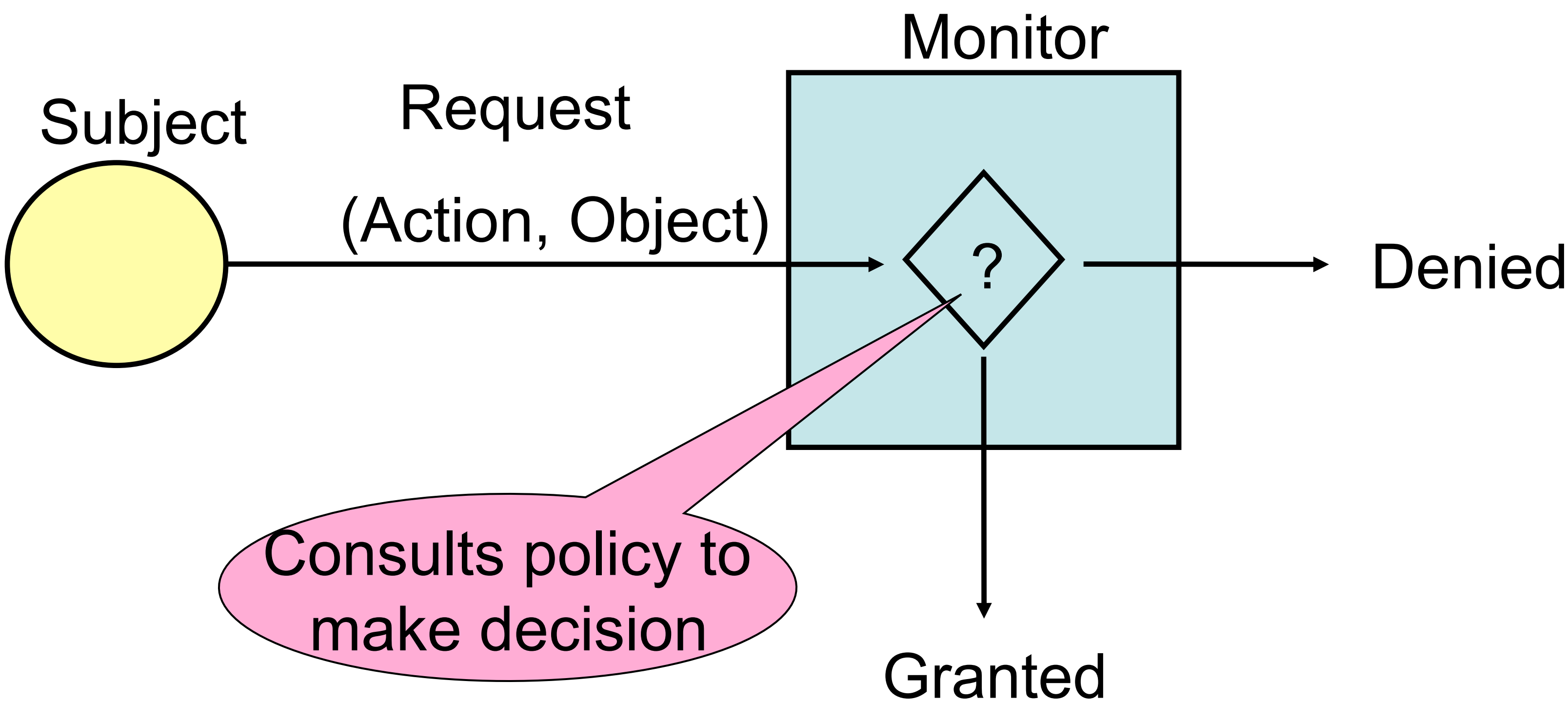
Rights

- Besides read, write, execute rights 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

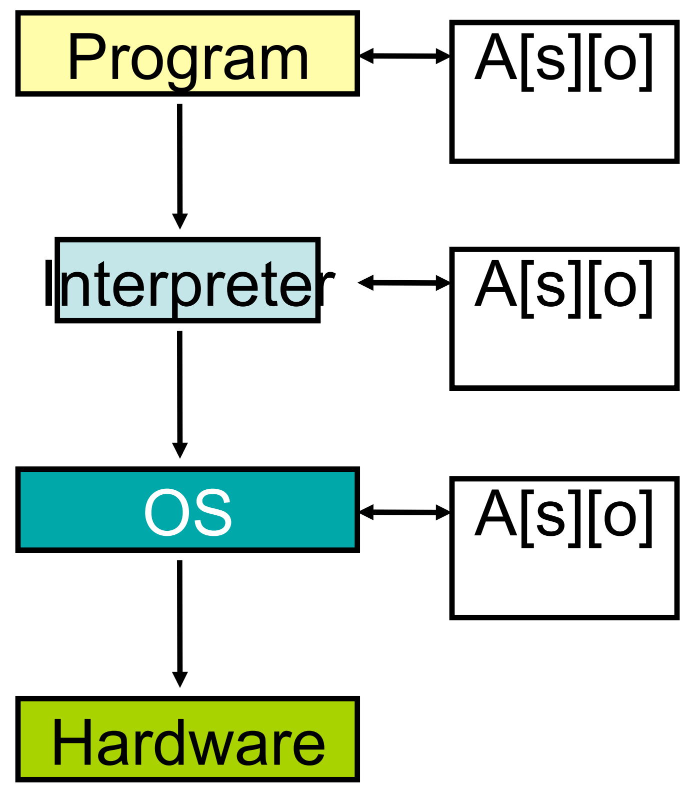


Reference Monitors

- 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

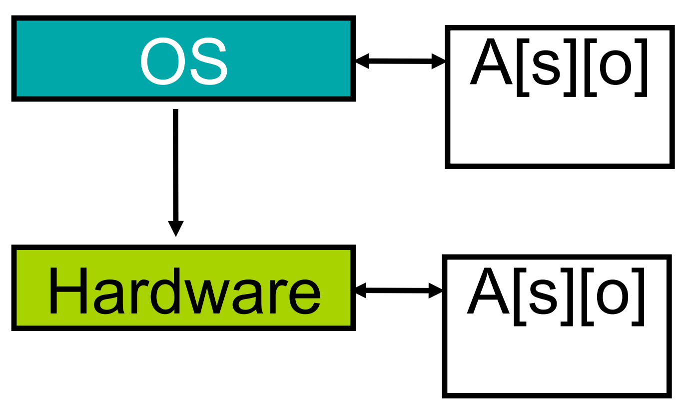
Software Mechanisms

- 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

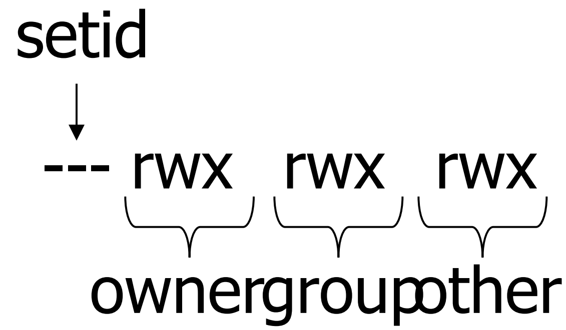
- Resolving queries is linear in length of the list
- Revocation w.r.t. a single object is easy
- "Who can access this object?" is easy
  - Useful for auditing
- Lists could be long
  - Factor into groups (lists of subjects)
  - Give permissions based on group
  - Introduces consistency question w.r.t.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

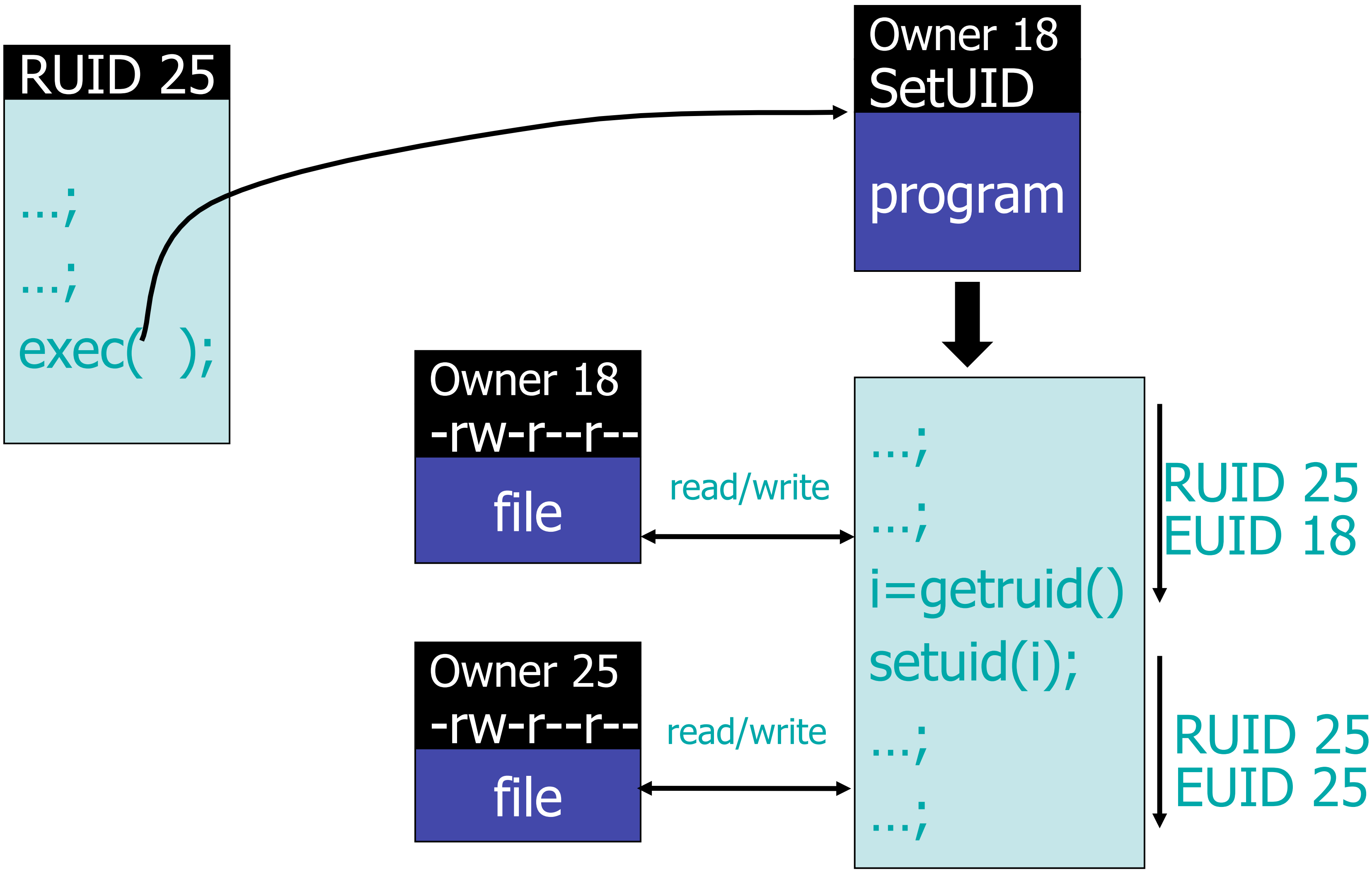
Effective User ID (EUID)

- 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

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 x Rights) pairs.

Capabilities

- A capability is a (Object, Rights) pair
  - Used like a movie ticket e.g.:
    ("Cloverfield", {admit one, 7:00pm show})
- Should be unforgeable
  - Otherwise, subjects could get illegal access
- Authentication takes place when the capabilities are granted (not needed at use)
- Harder to do revocation (must find all tickets)
- Easy to audit a subject, hard to audit an object

Implementing Capabilities

- Must be able to name objects
- Unique identifiers
  - Must keep map of UIDs to objects
  - Must protect integrity of the map
  - Extra level of indirection to use the object
  - Generating UIDs can be difficult
- Pointers
  - Name changes when the object moves
  - Remote pointers in distributed setting
  - Aliasing possible

Unforgeability of Capabilities

- 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
  – Example: Kerberos