Security Mechanisms
CS 239
Computer Security
Peter Reiher
January 24, 2007

Outline

- Security tools
- Access control

Tools for Security

- Physical security
- Access control
- Encryption
- Authentication
- Encapsulation
- Intrusion detection
- Common sense

Physical Security

- Lock up your computer
  – Actually, sometimes a good answer
- But what about networking?
  – Networks poke a hole in the locked door
- In any case, lack of physical security often makes other measures pointless

Access Controls

- Only let authorized parties access the system
- A lot trickier than it sounds
- Particularly in a network environment
- Once data is outside your system, how can you continue to control it?
  – Again, of concern in network environments

Encryption

- Algorithms to hide the content of data or communications
- Only those knowing a secret can decrypt the protection
- One of the most important tools in computer security

Encryption is Not a Panacea

- Encryption is usually breakable
  - Given enough time and resources
- Encryption can't protect everything
- Encryption is only as good as the security measures that use it
  - Key management often a weak point

Authentication

- Methods of ensuring that someone is who they say they are
- Vital for access control
- But also vital for many other purposes
- Often (but not always) based on encryption

Encapsulation

- Methods of allowing outsiders limited access to your resources
- Let them use or access some things
  - But not everything
- Simple, in concept
- Extremely challenging, in practice

Intrusion Detection

- All security methods sometimes fail
- When they do, notice that something is wrong
- And take steps to correct the problem
- Reactive, not preventative
  - But unrealistic to believe any prevention is certain
- Must be automatic to be really useful

Common Sense

- A lot of problems arise because people don't like to think
- The best security tools generally fail if people use them badly
- If the easiest way in is to fool people, that's what attackers will do

The Depressing Truth

- Ultimately, computer security is a losing battle
- Nothing will ever work 100%
- Nothing will work forever
- All your efforts will eventually be undone
- It's like housework – doing it doesn't make the house clean tomorrow, but not doing it guarantees the house is dirty today

Access Control

- Security could be easy
  - If we didn't want anyone to get access to anything
- The trick is giving access to only the right people
- How do we ensure that a given resource can only be accessed by the proper people?

Goals for Access Control

- Complete mediation
- Least privilege
- Useful in a networked environment
- Scalability
- Cost and usability

Access Control Mechanisms

- Directories
- Access control lists
- Capabilities
- Access control matrices

The Language of Access Control

- *Subjects* are active entities that want to gain access to something
  - E.g., users or programs
- *Objects* represent things that can be accessed
  - E.g., files, devices, database records
- *Access* is any form of interaction with an object
- An entity can be both subject and object

Directories

- Each user has a list of the items he can access
  - With the associated rights
- When a user wants to access an item, look it up in his directory

Problems With the Directory Approach

- Per-user directories get very large
  - Overhead and performance problems
- Universal revocation of access
- Pseudonym problems
- Works poorly in networks
- This method is not widely used

Access Control Lists

- For each protected resource, maintain a single list
- Each list entry specifies a user who can access the resource
  - And the allowable modes of access
- When a user requests access to a resource, check the access control list (ACL)

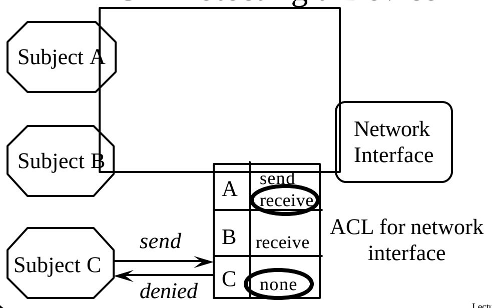
ACL Objects and Subjects

- In ACL terminology, the resources being protected are *objects*
- The entities attempting to access them are *subjects*
  - Allowing finer granularity of control than per-user

ACL Example

- An operating system example:
  - Using ACLs to protect a network interface device (an object)
- User (Subject) A is allowed to receive from and send to the device
- User (Subject) B may only receive from it
- User (Subject) C may not access it

An ACL Protecting a Device



Issues for Access Control Lists

- How do you know the requestor is who he says he is?
- How do you protect the access control list from modification?
- How do you determine what resources a user can access?

ACLs in Practice

- Unix file permissions are a limited form of an ACL
  - Only *owner*, *group*, and *all* can have ACL entries
  - Only read/write/execute controls are available
- Other systems (modern Windows, Linux, Solaris) have more general ACL mechanisms

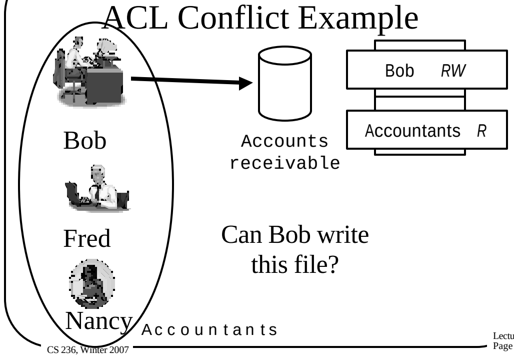
ACLs and Wildcards

- Can specify a whole range of subjects who share same access rights to object
- E.g., “all members of the software development team can read this file”
- Shortens the lists
- But leads to questions of conflicts

Conflicts in ACLs

- What if a given subject matches more than one rule in an ACL?

ACL Conflict Example



Can Bob write this file?

How To Handle ACL Conflicts

- Give most liberal rights
- Give most restrictive rights
- Deal with list in order
  - Giving first rights found
  - Or last rights found

Any of these solutions might be best in particular circumstances

Handling Conflicts in an Example System

- In standard Unix file access permissions, determine identity
  - Owner, group member, other
- Test only rights for the highest group
- If I own the file, test owner rights
  - Even if I’m in the group and group rights are more liberal

Pros and Cons of ACLs

+ Easy to figure out who can access a resource
+ Easy to revoke or change access permissions
– Hard to figure out what a subject can access
– Changing access rights requires getting to the object

Capabilities

- Each subject keeps a set of data items that specify his allowable accesses
- Essentially, a set of tickets
- Possession of the capability for an object implies that access is allowed

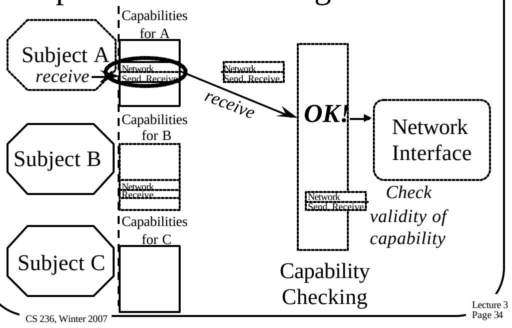
Properties of Capabilities

- Must be unforgeable
  - In single machine, keep under control of OS
  - What about in a networked system?
- In most systems, some capabilities allow creation of other capabilities
  - Process can pass restricted set of capabilities to a subprocess

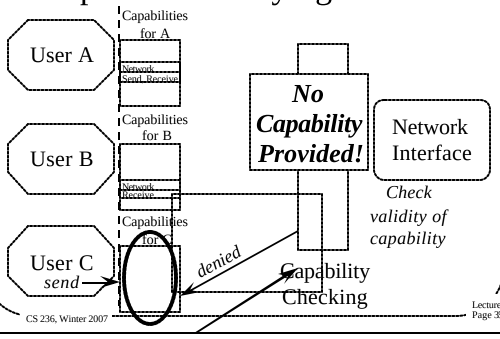
Capabilities and Domains

- The set of objects a subject can access at a given moment is its domain
  - The subject has a capability for each object in its domain
- Domains can be expanded by obtaining new capabilities
- New domains can be created for subprocesses
- Where do we keep capabilities?

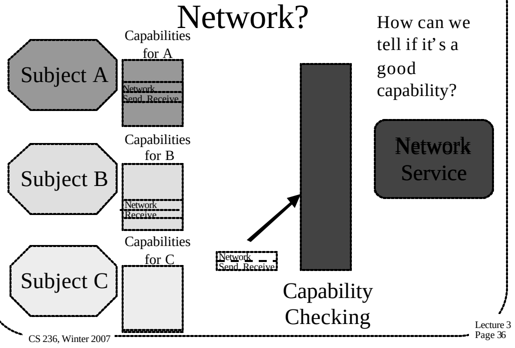
Capabilities Protecting a Device



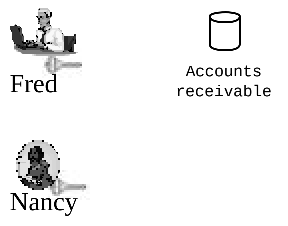
Capabilities Denying Access



How Will This Work in a Network?



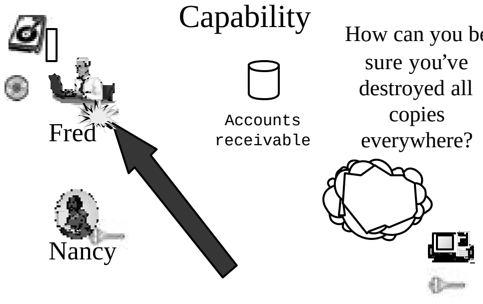
Revoking Capabilities



How do we take away Fred's capability?

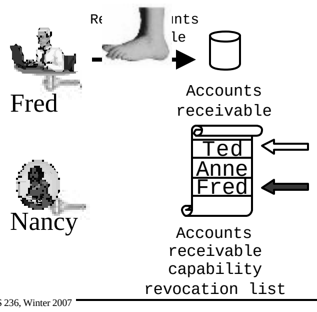
Without taking away Nancy's?

Revocation By Destroying the Capability



How can you be sure you've destroyed all copies everywhere?

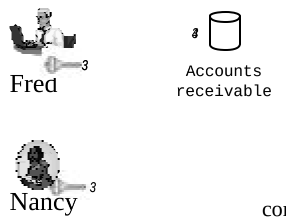
Revocation By Invalidation on Use



Costs time to check revocation list

Especially if list gets long

Revocation By Generation Numbers



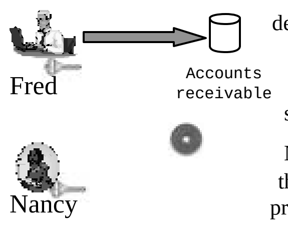
If generation numbers match, the capability is still valid

To invalidate capability, increase generation number

Requires some control of capabilities

Selective revocation is hard

Revocation by Indirection Through a Token



To revoke, destroy the token

Selective revocation somewhat slow

Nancy must go through the slow procedure again to set up a new token

Pros and Cons of Capabilities

+ Easy to determine what a subject can access
+ Potentially faster than ACLs (in some circumstances)
+ Easy model for transfer of privileges
– Hard to determine who can access an object
– Requires extra mechanism to allow revocation
– In network environment, need cryptographic methods to prevent forgery

ACLs, Capabilities, Complete Mediation, & Performance

- Ideally, every data access should have access control independently applied
- Practicality of doing so depends on the performance costs
- What does it cost to use ACLs?
  - Capabilities?

Performance Issues of Access Control

- What if the status of the access control mechanism changed between when last checked and current access?
- Common case is nothing changes
- Different approaches possible
  - Actually check changeable data structure on each access
  - Give process something cheap and revocable that allows access

Access Control in the Distributed World

- ACLs still work OK
  - Provided you have a global namespace for subjects
  - And no one can masquerade
- Capabilities are more problematic
  - Their security relies on unforgeability

Using Cryptographic Capabilities

- Can cryptography make capabilities unforgeable?
- It can make it impossible to create them from nothing
  - And only usable by their owner
- But it can't make them uncopyable
- So cryptographic capability systems must assume they can be freely copied

Access Control Matrices

- A very general access control concept
- In principle, ACLs are a 1-D list of who is permitted to access one object
- And capabilities are a 1-D list of what one subject can access
- Access control matrices are a 2-D description of access rights

Access Control Matrix Example

Objects

	File A	File B	Network	Printer
User 1	rw	r		w
User 2	r		sr	w
Sysadmin	rw	rw	sr	rw configure
Guest			sr	

User 2's Capabilities

Subjects

File B's ACL

Pros and Cons of Access Control Matrices

+ Makes all access issues explicit and easy to find
+ Easy to tell who can access a resource, and what resources anyone can access

– Matrix very sparse, so inefficient

– Hard to achieve good performance

• More important conceptually than in implementations

Role Based Access Control

- Not really an alternative to ACLs , capabilities, access control matrix
- Rather, a more complex way of looking at access control subjects
- Commonly used in systems that care about security
  - Available in Solaris, SE Linux, modern Windows systems

The Idea Behind Role Based Access Control

- Each user has certain roles he can take while using the system
- At any given time, the user is performing a certain role
- Give the user access to only those things that are required to fulfill that role

A Simple Example

- Fred is a system administrator
  - Which requires him to install programs, examine logs, etc.
- Fred also reads email, looks at web sites, etc., like any other user
- Fred should operate under one role while doing normal work
  - And a different role while performing administrative tasks

Continuing With the Example

- Fred logs on as "fred"
- He reads his email as "fred"
- He decides to upgrade the C++ compiler
  - So he changes roles to "administrator"
- When he's done, he returns to the role of "fred"

What Has Been Gained?

- While reading mail and surfing the web, Fred isn't able to upgrade the C++ compiler
  - He doesn't have the access rights
- So if he accidentally downloads malicious code, it can't "upgrade" the compiler

Changing Roles

- Role based access control only helps if changing roles isn't trivial
  - Otherwise, the malicious code merely changes roles before doing anything else
- Typically requires providing some secure form of authentication
  - Which proves you have the right to change roles
  - Usually passwords, but other methods possible

Practical Limitations on Role Based Access Control

- Number of roles per user
- Problems of disjoint role privileges
- System administration overheads

Number of Roles Per User

- Each new role requires new authentication
- Less secure if the authentication is the same for each role
  - E.g., Unix `sudo`, which only requires your basic password
- How many passwords will people remember?
  - And how often will they be happy to type them?

Problems of Disjoint Roles

- Each role should have disjoint privileges
  - More secure if roles aren't supersets of other roles
- May cause difficulties if certain operations require privileges from different roles

Problems of System Administration

- Access control is only useful if the permissions are set correctly for each subject and object
- The more subjects there are, the more work system administrators must do
  - Since each subject needs to get only the proper privileges

Reference Monitors

- Whatever form it takes, access control must be instantiated in actual code
  - That checks if a given attempt to reference an object should be allowed
- That code is called a reference monitor
- Obviously, good reference monitors are critical for system security

Desirable Properties of Reference Monitors

- Correctness
- Proper placement
- Efficiency
- Simplicity
- Flexibility

An Example Reference Monitor

- The Linux code that mediates file access
- Applied on relatively few of the file system calls
  - Open, execute, directory traversal, a few others
  - Not on read and write

Another Example Reference Monitor

- A firewall
- It examines every packet for certain characteristics
- Typically, either any subject can do something or no subject can
- But sometimes packets from particular source addresses can do more
  - Essentially, the source address identifies a privileged subject

Thinking More Broadly About Access Control

- From one perspective, access control is the core of all computer security
- All security is about who can access what
- So where do security problems come from?
  - Not applying access control
  - Not applying access control properly

What Is the Most Common Access Control Mechanism?

- The null mechanism
- Let anyone do anything they want
- Sounds terrible, but it's actually the key to the success of computers and networks

Why Is Null Access Control Ever Good?

- Any user can run an instruction on a CPU without necessarily checking access control
- Any packet can be handled by a router without checking access control
- The trick is to apply access control when it's most important
  - And to apply it properly

Problems Arising From Null Access Control

- Spam
- Distributed denial of service
  - And most other denials of service
- Buffer overflows
- Worms

Proper Application of Access Control

Where do problems actually arise?

1. Not applying access control when you should
2. Improper configuration of access control
3. Bugs in access control mechanisms

Conclusion

- Much of security relates to allowing some people access to some resources
- While preventing the same access to others
- Without some method of determining who should access what . . .

You can’t do that