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
- Hard to prevent legitimate holder of a computer from using it as he wants
  - E.g., smart phone jailbreaks
- 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
  - But not a panacea
- Covered in more detail later in class

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 it’s 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

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
  - And at the right time and circumstances
- How do we ensure that a given resource can only be accessed when it should be?

Goals for Access Control

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

Access Control Mechanisms

- Access control lists
- Capabilities
- Access control matrices
  - Theoretical concept we won’t discuss in detail
- Role based access control

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

Mandatory vs. Discretionary Access Control

- Mandatory access control is dictated by the underlying system
  - Individual users can't override it
  - Even for their own data
- Discretionary access control is under command of the user
  - System enforces what they choose
  - More common than mandatory

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)

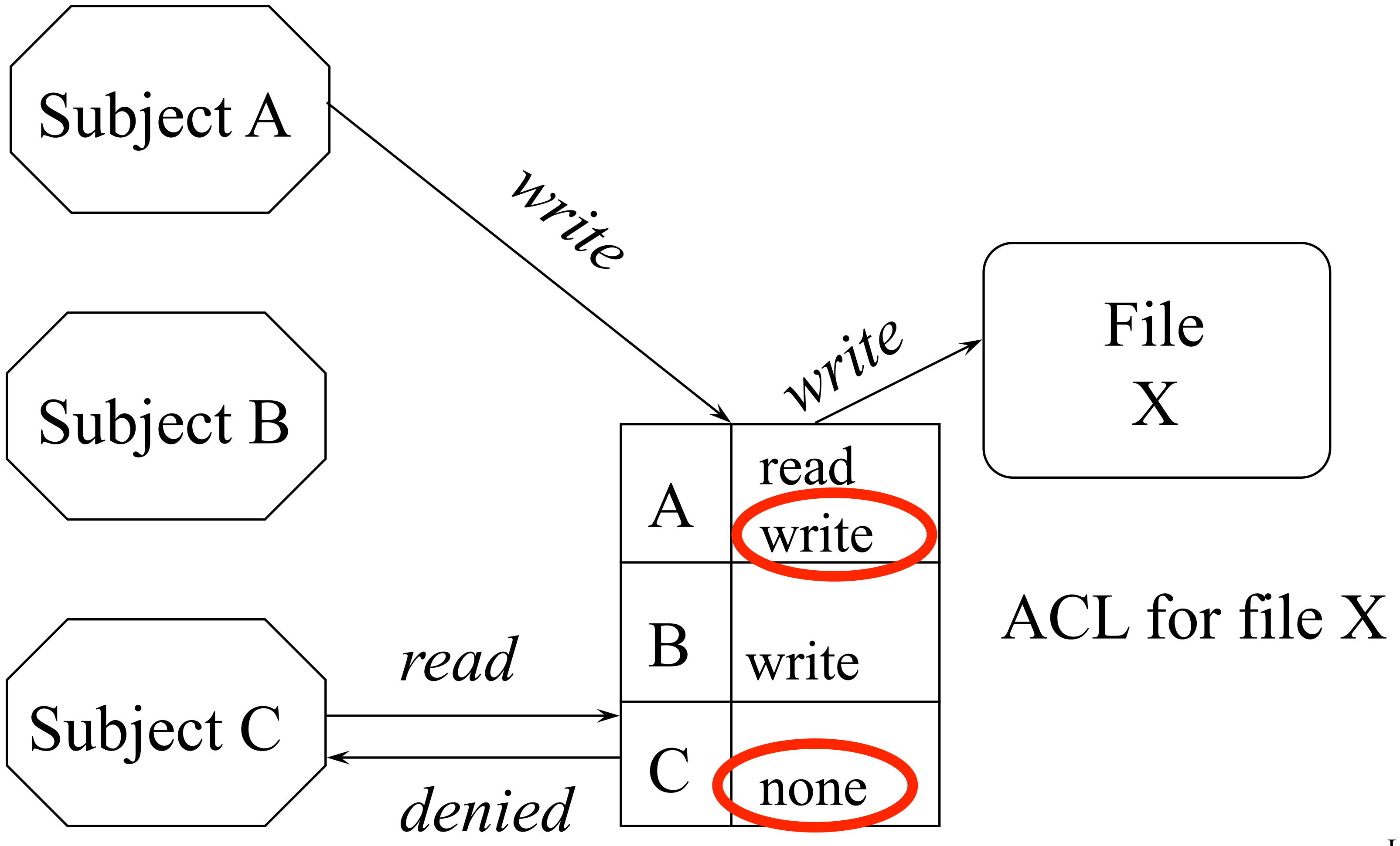
ACL Objects and Subjects

- 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 file
- User (Subject) A is allowed to read and write to the file
- User (Subject) B may only read from it
- User (Subject) C may not access it

An ACL Protecting a File



Issues for Access Control Lists

- How do you know that 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?
- Generally issues for OS design

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

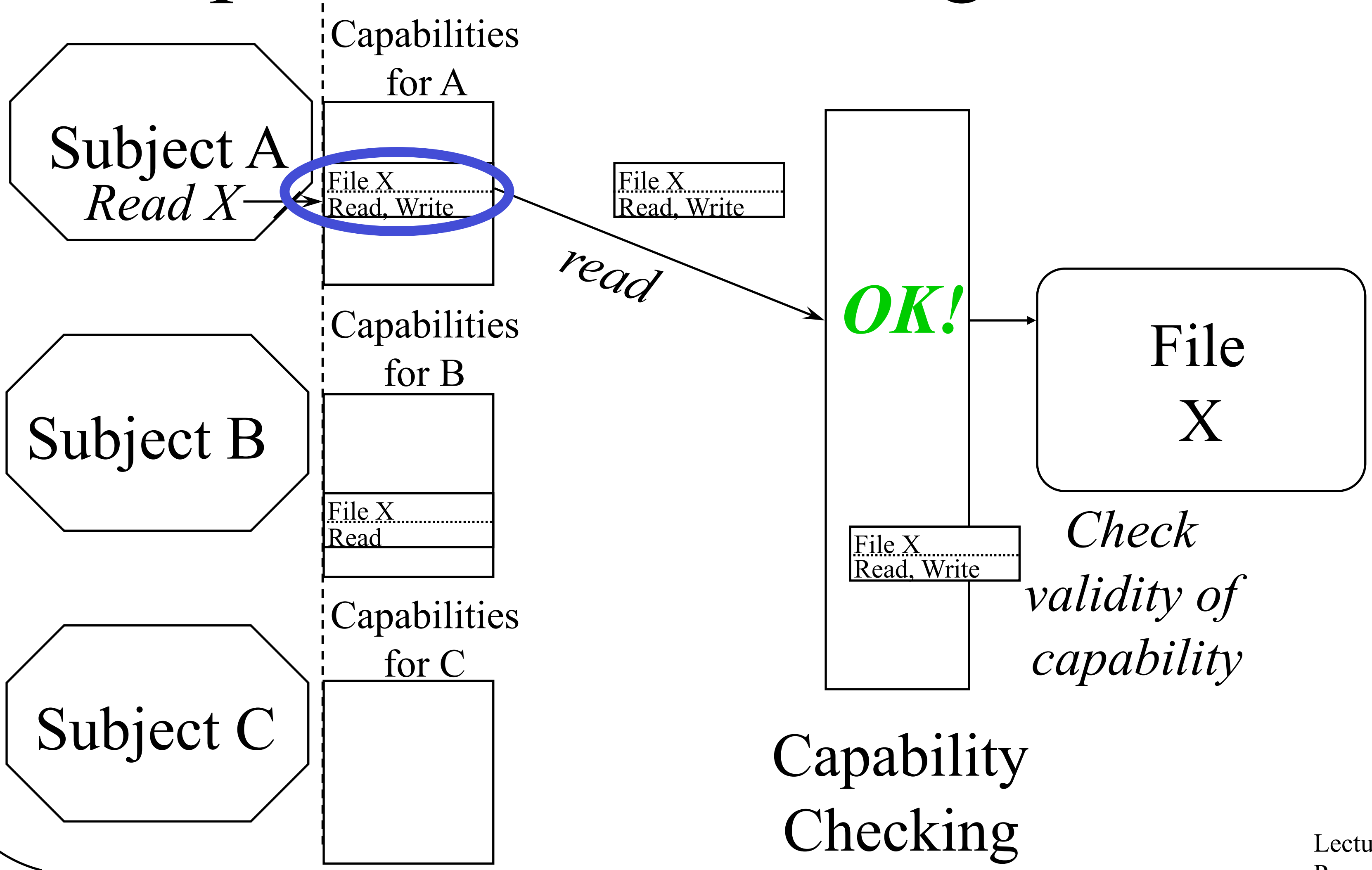
Capabilities

- 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

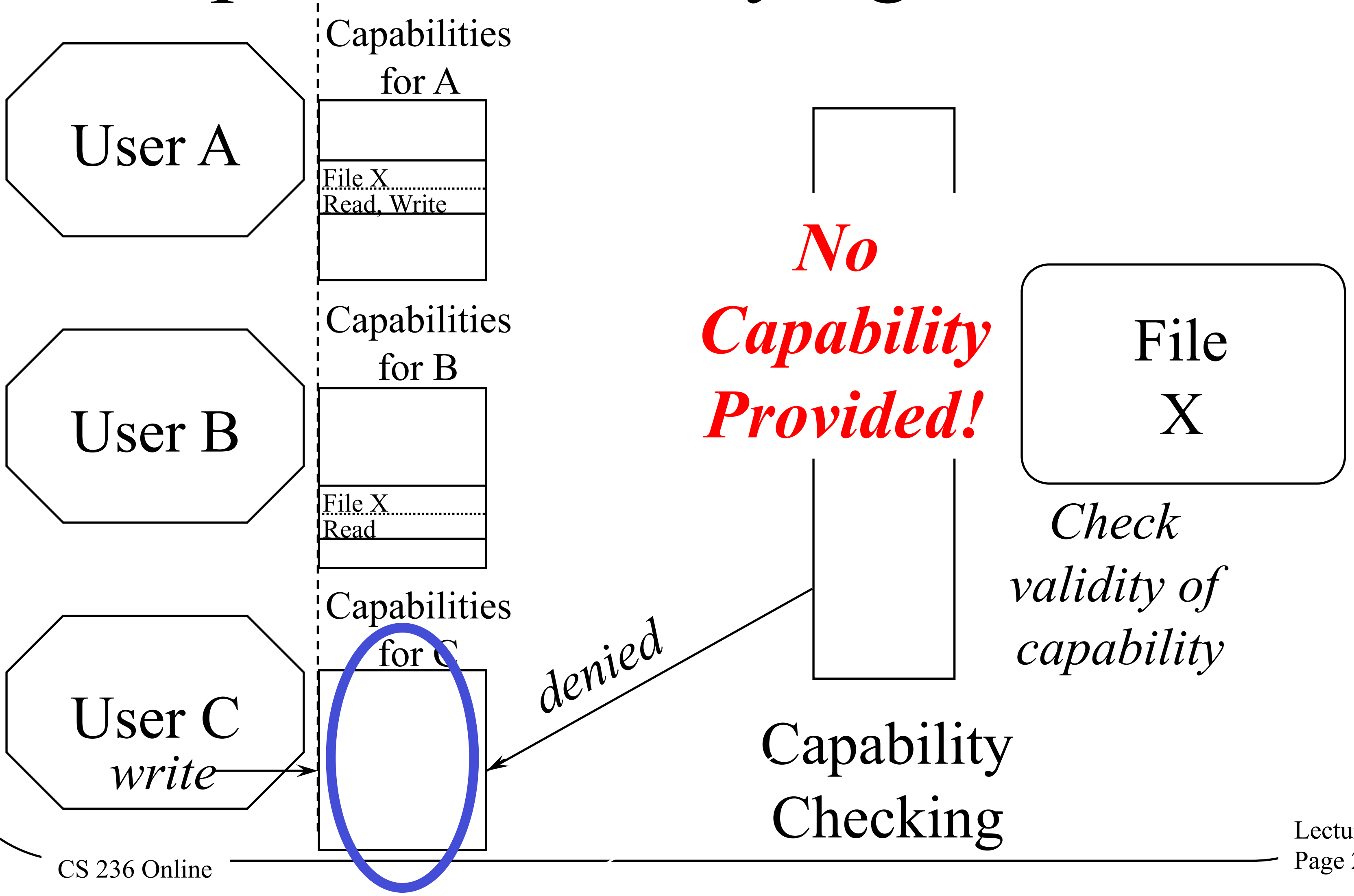
Properties of Capabilities

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

Capabilities Protecting a File

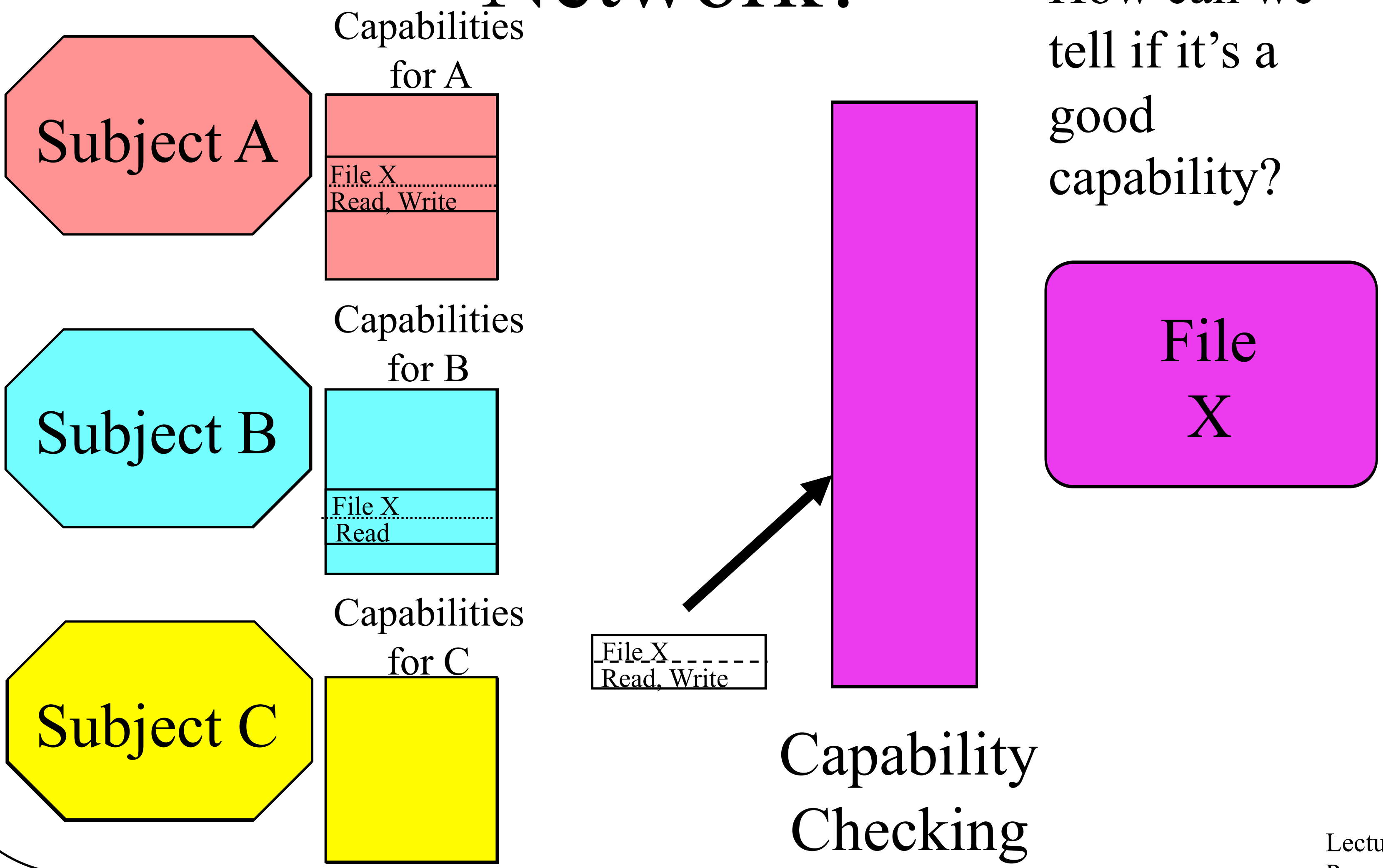


Capabilities Denying Access

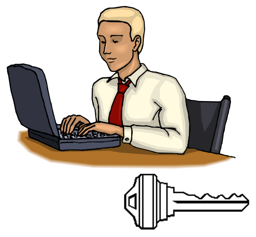


How Will This Work in a Network?

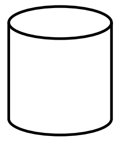
How can we tell if it's a good capability?



Revoking Capabilities



Fred



`Accounts receivable`

How do we take away Fred's capability?

Nancy

Without taking away Nancy's?

Options for Revoking Capabilities

- Destroy the capability
  - How do you find it?
- Revoke on use
  - Requires checking on use
- Generation numbers
  - Requires updating non-revoked capabilities

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

Distributed Access Control

- ACLs still work OK
  - Provided you have a global namespace for subjects
  - And no one can masquerade
- Capabilities are more problematic
  - Security relies on unforgeability
  - Provided by cryptographic methods
  - Prevents forging, not copying

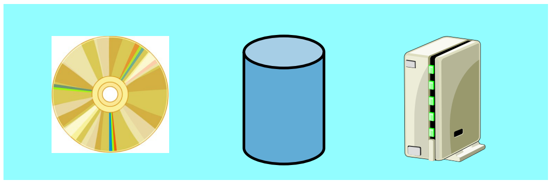
Role Based Access Control

- An enhancement to ACLs or capabilities
- 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
- Available in some form in most modern operating systems

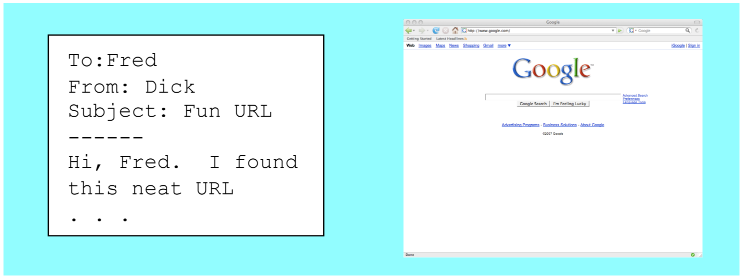
A Simple Example

Fred is a system administrator

But Fred is a also a normal user



Fred should operate under one role while doing system administration



```
To:Fred
From: Dick
Subject: Fun URL
------
Hi, Fred.  I found
this neat URL
. . .
```

And another role while doing normal stuff

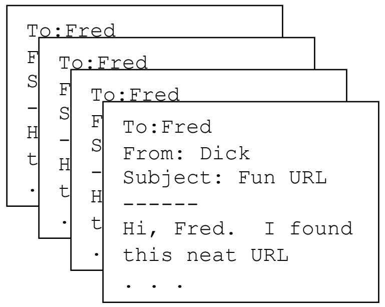
Continuing With Our Example

He decides to upgrade the C++ compiler

Fred logs on as "fred"

He reads his email

So he changes his role to "sysadmin"



```
To:Fred
From: Dick
Subject: Fun URL
------
Hi, Fred.  I found
this neat URL
. . .
```

Then he has the privileges to upgrade the compiler

But may have lost the privileges to read "fred's" email

Result: Evil malware in fred's email 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
- Generally, these cause usability and management problems

Reference Monitors

- Whatever form it takes, access control must be instantiated in actual code
  - Which 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