CS 591: Introduction to Computer Security

Lecture 2: Access Control

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Objectives

- Introduce the mechanism of Access Control
- Relate mechanism to Confidentiality, Integrity and Availability
- Introduce the Access Control Matrix Model and Protection State Transitions

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Alice and Bob

- Standard names for "agents" in a security or crypto scenario
- Also known as "A" and "B"

An Access Control Scenario

- Alice:
  1. New Secret foo
- Bob:
  2. If (cp foo afoo)
  3. then echo "success"
  4. else echo "fail"

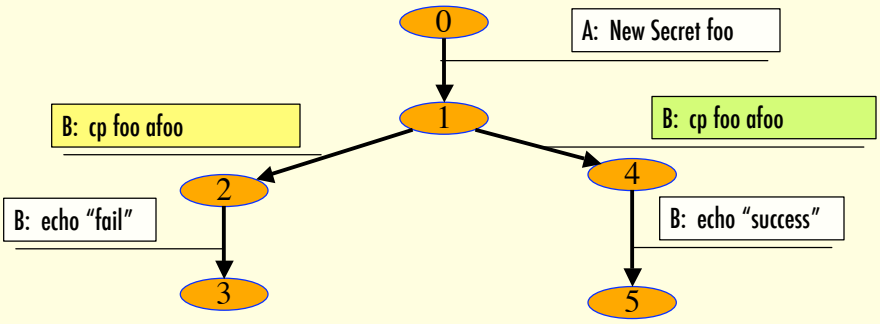
Intent:

•Bob's **cp** is attempting to violate Alice's expected access policy

•If **cp** succeeds then the principle of **confidentiality** is not satisfied

Q: Revise scenario to violate **availability**

Characterizing the Violation



Basic Abstraction: States and Transitions

Q: What are the States?

Q: What determines if we reach State 2 or 4 from State 1?

Q: If we reach State 5 was State 1 good?

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Secure and non-Secure States

Characterize states in a system as "Secure" and "non-Secure"

A system is **Secure** if every transition maps Secure states to Secure states

Consequence: In the scenario, security is compromised if Alice's "New secret foo" yields a state in which Bob can access foo.

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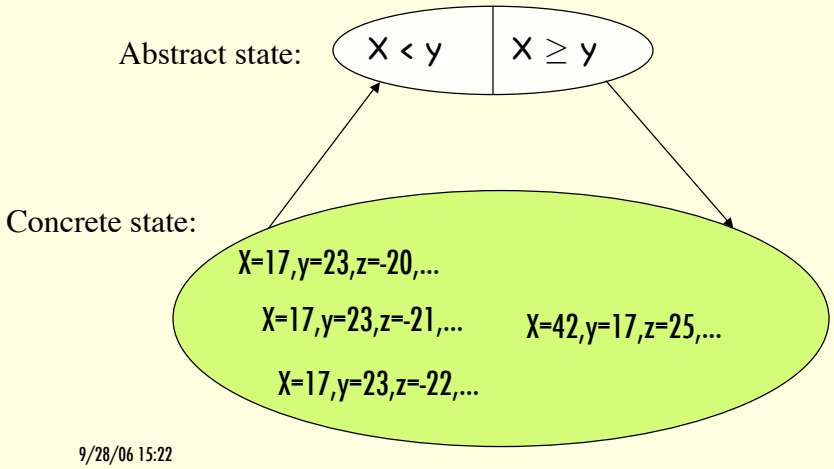
Abstraction



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Protection States

- An abstraction that focuses on security properties
- Primarily interested in characterizing Safe states
- Goal is to prove that all operations in the system preserve "security" of the protection state
- Access Control Matrix is our first Protection State model

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Access Control Matrix Model

- Lampson '71, refined by Graham and Denning ('71, '72)
- Concepts
  - **Objects**, the protected entities, O
  - **Subjects**, the active entities acting on the objects, S
  - **Rights**, the controlled operations subjects can perform on objects, R
  - **Access Control Matrix**, A, maps Objects and Subjects to sets of Rights
  - State: (S, O, A)

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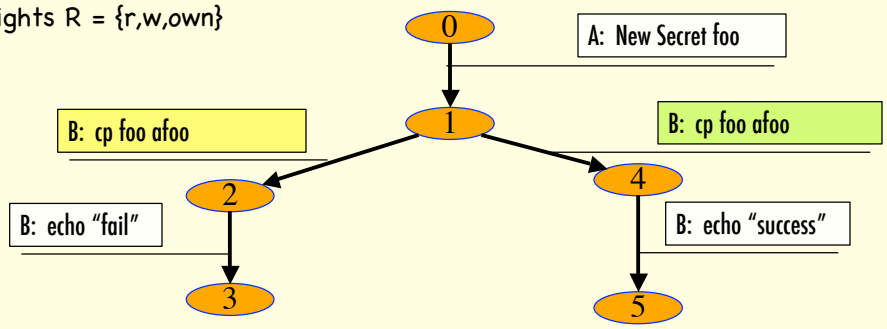
Confidentiality Scenario

Initial State
Subjects S_0 = {A,B}
Objects O_0 = {}
AC Matrix A_0 = {}

Rights R = {r,w,own}

$(S_0, O_0, A_0) \vdash_{\text{A: New Secret foo}} (S_1, O_1, A_1)$

$(S_1, O_1, A_1) \vdash_{\text{B: cp foo afoo}} (S_1, O_1, A_1)$



Intended State 1
Subjects S_1 = {A,B}
Objects O_1 = {foo}
AC Matrix A_1 = {(A,foo,[r,w,own]),
(B,foo,[])}

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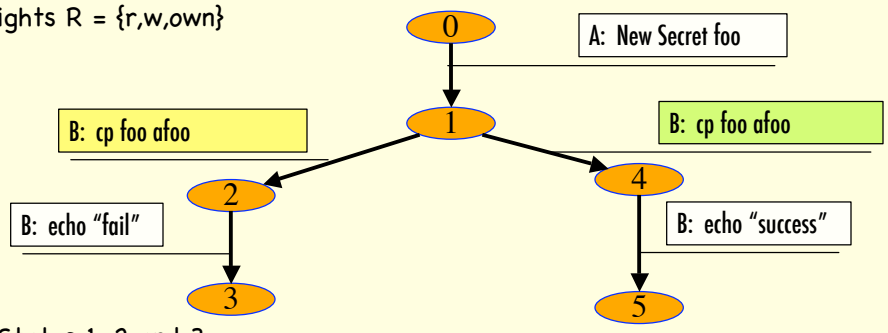
Confidentiality Scenario

Initial State
- Subjects S_0 = {A,B}
- Objects O_0 = {}
- AC Matrix A_0 = {}

Rights R = {r,w,own}

Is there a representation for Protection States 4 and 5?



States 1, 2 and 3
- Subjects S_1 = {A,B}
- Objects O_1 = {foo}
- AC Matrix A_1 = {(A,foo,[r,w,own]), (B,foo,[]) }

Critical issue is definition of $\vdash_{cp}$ … …

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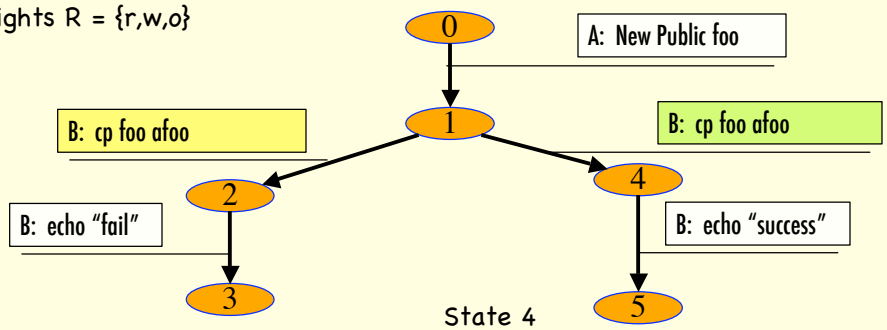
Availability Scenario

Initial State
- Subjects S_0 = {A,B}
- Objects O_0 = {}
- AC Matrix A_0 = {}

Rights R = {r,w,o}

$(S_0, O_0, A_0) \vdash_{\text{A: New Public foo}} (S_1, O_1, A_1)$

$(S_1, O_1, A_1) \vdash_{\text{B: cp foo afoo}} (S_4, O_4, A_4)$



State 1
- Subjects S_1 = {A,B}
- Objects O_1 = {foo}
- AC Matrix A_1 = {(A,foo,[r,w,o]), (B,foo,[r])}

State 4
- Subjects S_4 = S_1
- Objects O_4 = $O_1 \cup$ {afoo}
- AC Matrix A_4 = {(A,foo,[r,w,o]), (B,foo,[r]), (A,afoo,[]), (B,afoo,[r,w,o])}

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Voting Machine

- How can a voting machine be modeled with subjects, objects, and rights?
- In what ways do the rights change dynamically?

A Domain-Specific Language for Access Control

- Harrison, Ruzzo, and Ullman defined a set of primitive commands
  - Create subject s
  - Create object o
  - Enter r into a[s,o]
  - Delete r from a[s,o]
  - Destroy subject s
  - Destroy object o
- We will use this DSL of primitive commands to model the system in our example

Heads up:
We have 2 languages: HRU primitives and the example!

HRU Semantics

$(S, O, A) \vdash_{\text{Create subject } s} (S \cup \{s\}, O, A)$

$(S, O, A) \vdash_{\text{Create object } o} (S, O \cup \{o\}, A)$

$(S, O, A) \vdash_{\text{Enter } r \text{ into } a[s,o]} (S, O, A')$
where $A'[s,o] = A[s,o] \cup \{r\}$

$(S, O, A) \vdash_{\text{Delete } r \text{ from } a[s,o]} (S, O, A')$
where $A'[s,o] = A[s,o] - \{r\}$

$(S, O, A) \vdash_{\text{Destroy subject } s} (S - \{s\}, O, A\downharpoonright)$

$(S, O, A) \vdash_{\text{Destroy object } o} (S, O - \{o\}, A\downharpoonright)$
where $A\downharpoonright$ is the appropriate restriction of A

Molecules from Atoms

- This DSL gives us atomic transitions
- To model a system we combine these atomic operations into commands
- A system model in this framework is the set of commands that implement the system primitives

Modeling the Example

- Interface
  - X: New Secret <f>
  - X: New Public <f>
  - X: Cp <f> <f>
  - X: If <command> then <command> else <command>
- Assumptions
  - X ranges over {A,B}

Example

```
Initialize ()
   create subject A
   create subject B
end
New.Secret (x,f)
   create object f
   enter own into a[x,f]
   enter r into a[x,f]
   enter w into a[x,f]
end
```

```
New.Public (x,f)
   create object f
   enter own into a[x,f]
   enter r into a[A,f]
   enter r into a[B,f]
   enter w into a[x,f]
End
```

Example (cont)

Conditional command

```
Cp(x,src,dest)
   if r ∈ a[x,src]
   then
      create object dest
      enter own into a[x,dest]
      enter w into a[x,dest]
      ?
End
```

Modeling helps us be precise: Is the new file "public" or "secret"?

Modeling if

- How do we model the **if** statement in our scenario?
- We assumed Unix like "exit status"
- Could enrich model to have statements have value
- Does that add value?

Modeling if (cont)

- To establish system security we must model all sequences of commands
- What matters is that **cp** won't reveal Alice's secret
- Since we are considering **all** sequences of non-conditional commands we don't need to model

  If c1 then c2 else c3

  since we model both

  c1; c2

  c1; c3
- Why doesn't this argument apply to primitive commands?

Conditional Commands

- To obtain results in Chapter 3 we place technical restrictions on HRU conditional commands
- Condition must be "positive"
  - $r \in a[s,o]$
  - Cf. negative: $r \notin a[s,o]$
- Conjunctions of conditions are allowed
  - $r \in a[s,o] \wedge r' \in a[s',o']$
- Disjunctions are unnecessary
  - All atomic actions are idempotent
  - if $\phi \vee \psi$ then C $\equiv$ if ϕ then C; if ψ then C

Access Control Matrix

- Very high fidelity model
- Every user and process can be modeled as a subject
- Every file and process can be modeled as an object
- Does it scale?
- Is it useful?

Access Control Matrix

- The access control matrix model is a critical reference point
  - most systems can be modeled within the framework
  - most mechanisms are an imperfect approximation of the Access Control Matrix

Foundational Results

- Can we use an algorithm to test if a system is secure?
  - What do we mean by "system"?
  - What do we mean by "secure"?

Aside: Safety and Liveness

- Safety property: A bad thing does not happen
  - E.g. A memory safe program will not dereference a "bad" pointer
- Liveness property: A good thing will happen eventually
  - E.g. Every runnable process will eventually be scheduled

Security: safe or live?

- Availability is often a liveness property
- Confidentiality is often cast as a safety property
- Integrity can be both
  - The processor will execute the instruction stream is a liveness property
  - All memory will be accessed consistent with the protection state is a safety property

Bounding the Problem

- "Mono-operational" commands
  - If each system level command in the modeled system is implemented by a single HRU primitive the system is "mono-operational"
- General case
  - In the general case the commands of the system being modeled are implemented by arbitrary combinations of HRU primitives
- Cast Problem as Safety Property
  - *Bad things don't happen*

What is secure?

- Must designate a "bad thing" and then prove it doesn't happen
- Definition: A right *r* is leaked if it is added to an element of the access control matrix that does not already contain it
  - In our example "new secret foo" leaks rights "own, r and w" if foo did not already exist
- Definition: A system is safe with respect to right *r* if it does not leak the right *r*

Follow Bishop

If time permits in this lecture jump to Bishop's slide #03-04

Conclusion

- Modeling is the process of abstracting to the essence of the property of concern
- Security Modeling exploits "protection state" abstractions
- Access Control Matrix is a "best" model for file and process granularity modeling
- With virtually any realistic system the general security question will be undecidable

Looking Forward

- Complete Chapter 3
- Start Chapter 4, Security Policies

Backup Materials

A scenario from the text

- Bishop models a language with interface:
  - Create.file(p,f)
  - Spawn.process(p,q)
  - Make.owner(p,f)
  - Grant.read.file.1(p,f,q)
  - Grant.read.file.2(p,f,q)
  - Grant.write.file.1(p,f,q)
  - Grant.write.file.2(p,f,q)
- Some of his examples follow

Commands

```
Command create.file (p,f)
   create object f;
   enter own into a[p,f];
   enter r into a[p,f];
   enter w into a[p,f];
end
```

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Commands (cont)

```
Command spawn.process(p,q)
   create subject q;
   enter own into a[p,q];
   enter r into a[p,q];
   enter w into a[p,q];
   enter r into a[q,p];
   enter w into a[q,p];
End
```

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Conditional Commands

Command grant.read.file.1(p,f,q)
  if own in a[p,f]
  then
    enter r into a[q,f]
End

Root Agent

Create subjects voter, tallyAgent, reporter
Create objects vote, state, tally, voterCard
Initialize tally=0
Enter

Voter Agent

```
Repeat Indefinitely:
   Present credential;
   If credential accepted then
     Prepare ballot;
     Confirm vote;
   Withdraw credential
```


Tally Agent

```
While (mode = election) do
   On credential presented do
     If credential valid then
         Enable voting;
         On vote commit do atomic
             add vote to tally
             invalidate credential
```