Advanced Systems Security: Principles

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Access Control – The Right Way

- We said that ordinary operating systems cannot control code controlled by an adversary
- Review formalisms developed for "protection"
  - and show how they are extended to enforce "security"
- Key concepts
  - Mandatory protection state
    - Adversary cannot modify access control policy
  - Reference monitor
    - Enforce access control comprehensively
  - Later: Security models

Protection System

- Manages the authorization policy for a system
  - It describes what operations each subject (via their processes) can perform on each object
- Consists of
  - **State:** *Protection state*
  - **State Ops:** *Protection state operations*

The Access Matrix

- An access matrix is one way to represent policy.
  - Frequently used mechanism for describing policy
- Columns are objects, subjects are rows.
- To determine if S_i has right to access object O_j, find the appropriate entry.
- Succinct descriptor for O (|S|*|O|) entries
- Matrix for each right.

	O_1	O_2	O_3
S_1	Y	Y	N
S_2	N	Y	N
S_3	N	Y	Y

Access Matrix Protection System

- Protection State
  - Current state of matrix
- Can modify the protection state
  - Via protection state operations
  - E.g., can create objects
  - E.g., owner can add a subject, operation mapping for their objects
- Lampson's "Protection" paper
  - Can even delegate authority to perform protection state ops

Protection System

- Why is Protection State insufficient to enforce security?
- Goal: a protection state in which we can determine whether an unauthorized operation will ever be allowed (Safety)

Protection System Problems

- Protection system approach is inadequate for security
  - Suppose a process runs bad code
- Processes can change their own permissions
  - Processes may become untrusted, but can modify policy
- Processes, files, etc. are created and modified
  - Cannot predict in advance (safety problem)
- What do we need to achieve necessary controls?

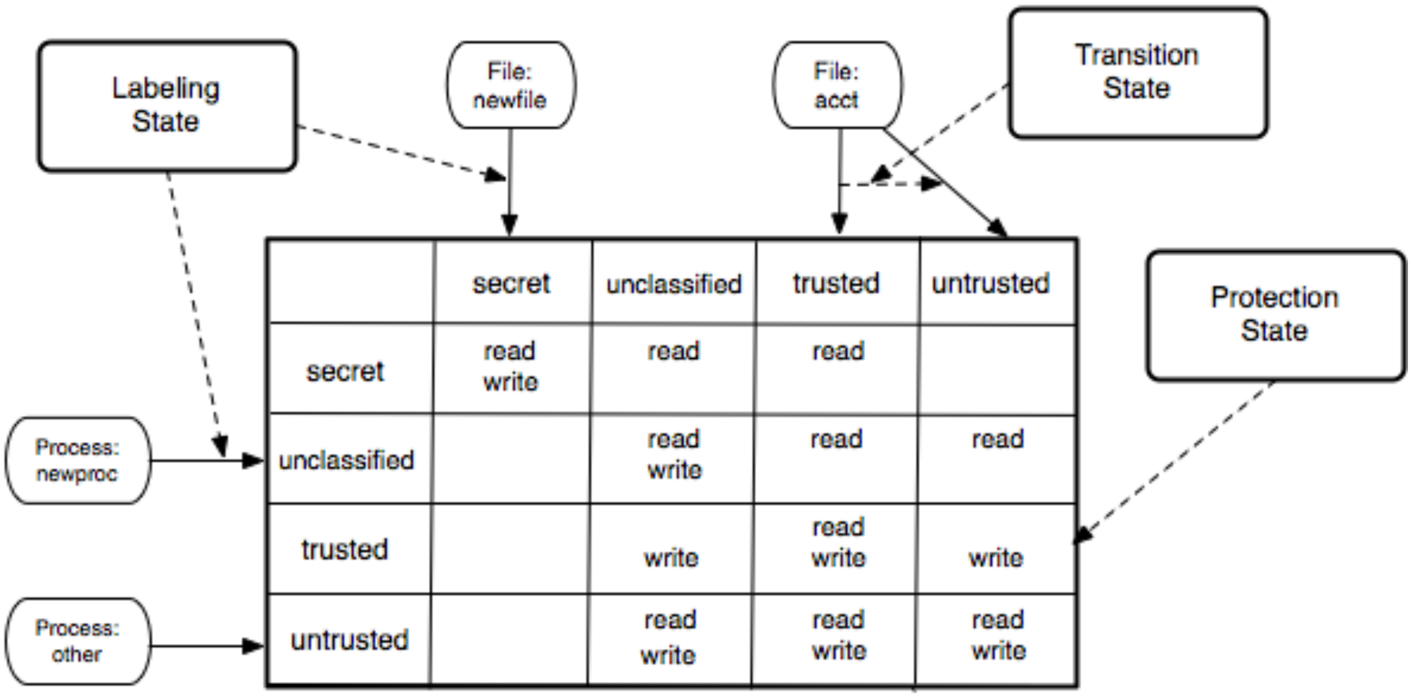
Define and Enforce Goals

- Claim: *If we can define and enforce a security policy that ensures security goals, then we can prevent such attacks*
- How do we know what policy will be enforced?
- How do we know the enforcement mechanism will enforce policy as expected?
  - Look into this today
- How do we know the policy expresses effective goals?
  - Will look into this in depth later

Mandatory Protection System

- Is a *protection system* that can be modified only by *trusted administration* that consists of
  - A *mandatory protection state* where the protection state is defined in terms of an immutable set of *labels* and the *operations that subject labels can perform on object labels*
  - A *labeling state* that assigns system subjects and objects to those labels in the mandatory protection state
  - A *transition state* that determines the legal ways that subjects and objects may be relabeled
- MPS is *immutable* to user-space process

Mandatory Protection System



	secret	unclassified	trusted	untrusted
secret	read write	read	read	
unclassified		read write	read	read
trusted		write	read write	write
untrusted		read write	read write	read write

Mandatory Protection State

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- Immutable table of
  - Subject labels
  - Object labels
  - Operations authorized for former upon latter
- How can you use an MPS to control use of bad code?
  - E.g., Prevent modification of kernel memory?

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- How can you use an MPS to control use of bad code?
  - E.g., Prevent modification of kernel memory?
  - Subject labels for all subjects running "bad code" are not allowed modify kernel memory
    - Or that may run "bad code" (be compromised)
  - How do subjects (processes) get their labels?

Labeling State

- Immutable rules mapping
  - Subjects to labels (in rows)
  - Objects to labels (in columns)
- How can you use labeling state to control bad code?
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  - Subjects to labels (in rows)
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- How can you use labeling state to control bad code?
  - E.g., Prevent modification of kernel memory?
  - Assign all processes that may run bad code …
  - With a label that cannot modify kernel memory
  - What about objects created by these processes?

Protecting Good Code

- How can you use labeling state to prevent good code from going bad?

Protecting Good Code

- How can you use labeling state to prevent good code from going bad?
  - E.g., Prevent dependence on untrusted input?
  - Assign object labels to all objects that may be adversary-controlled
  - Do not grant subject labels that should run good code access to those labels
  - Verify that you are running good code (how?) and assign to one of these protected subject labels
  - What integrity model does this approximate?

Protecting Good Code

- What if good code needs to access some adversary-controlled resources?

Mandatory Protection State

- What if good code needs to access some adversary-controlled resources?
  - (1) if a process reads adversary-controlled object label, remove privileged permissions (e.g., to modify kernel memory)
  - (2) if a process reads adversary-controlled object label, remove permission to write to any object that may be accessed by a subject whose label grants privileged permissions
- How do we achieve this change with the MPS?

Transition State

- Immutable rules mapping
  - Subject labels to conditions that change their subject labels
  - Object labels to conditions that change their object labels
- How can you use labeling state to control bad code?
  - E.g., Achieve (1) and (2)

Transition State

- Immutable rules mapping
  - Subject labels to conditions that change their subject labels
  - Object labels to conditions that change their object labels
- How can you use labeling state to control bad code?
  - E.g., Achieve (1) and (2)
  - Change subject label of subject accessing adversary-controlled resources to remove these permissions
  - What integrity model does this approximate?

Transition State

- Is it possible to launch processes with more permissions than the invoker with MPS?

Managing MPS

- Challenge
  - Determining how to set and manage an MPS in a complex system involving several parties
- Parties
  - What does programmer know about deploying their program securely?
  - What does an OS distributor know about running a program in the context of their system?
  - What does an administrator know about programs and OS?
  - Users?

Managing MPS

- Current methods use dynamic analysis to setup MAC policies – run the program and collect the permissions used
  - Really a functional policy

Reference Monitor

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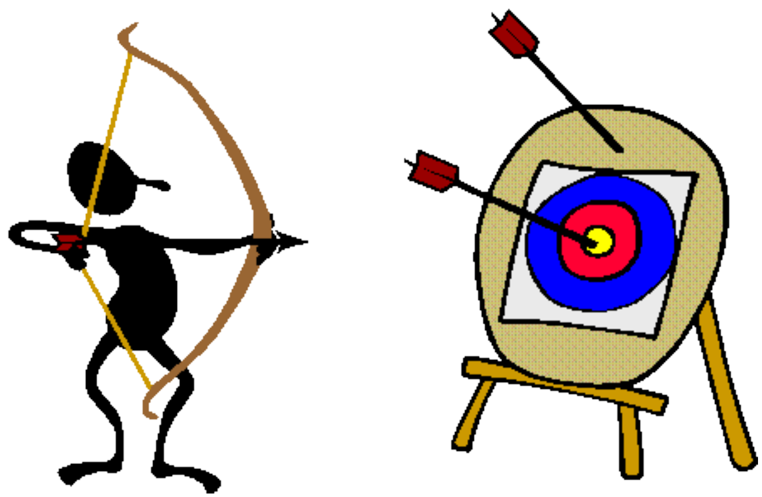
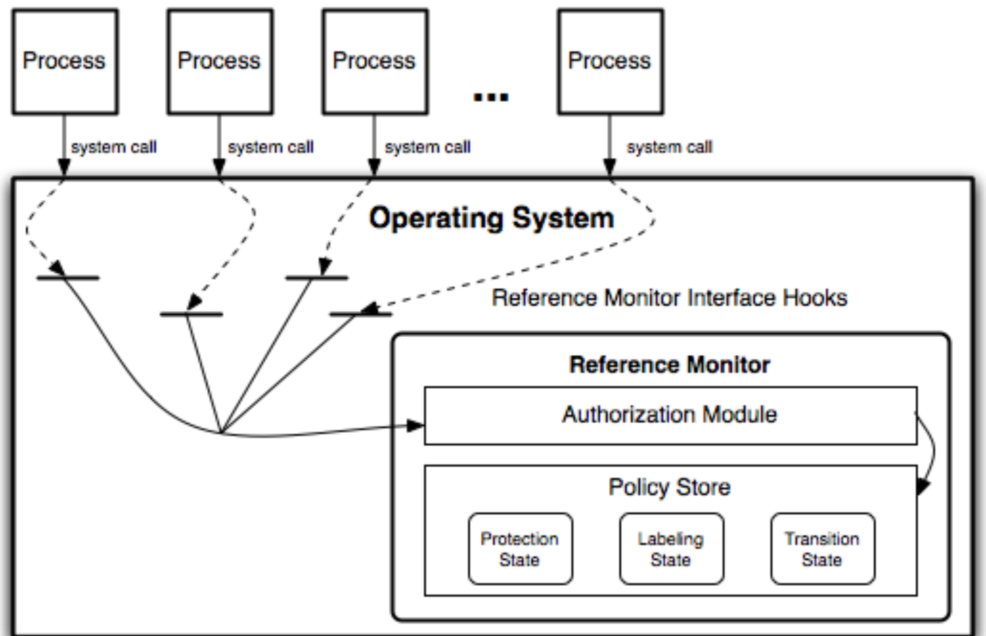
- Purpose: Ensure enforcement of security goals
  - Define goals in the mandatory protection system
  - Reference monitor ensures enforcement



- *Every component that you depend upon to enforce your security goals must be a reference monitor*

Reference Monitor

- Components
  - Reference monitor interface (e.g., LSM)
  - Reference validation mechanism (e.g., SELinux)
  - Policy store (e.g., policy database)



Reference Monitor Guarantees

- **Complete Mediation**
  - The reference validation mechanism must always be invoked
- **Tamperproof**
  - The reference validation mechanism must be tamperproof
- **Verifiable**
  - The reference validation mechanism must be subject to analysis and tests, the completeness of which must be assured

Complete Mediation

- Every security-sensitive operation must be mediated
  - What's a "security-sensitive operation"?

Complete Mediation

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  - What's a "security-sensitive operation"?
  - E.g., operation that may not be authorized for every subject
- How do we validate complete mediation?

Complete Mediation

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- Every security-sensitive operation must be mediated
  - What's a "security-sensitive operation"?
  - E.g., operation that may not be authorized for every subject
- How do we validate complete mediation?
  - Every security-sensitive operation must be identified
  - E.g., ensure every execution of that operation is checked
- **Mediation**: Does interface mediate?
- **Mediation**: On all resources?
- **Mediation**: Verifably to enforce security goals?

Tamperproof

- Prevent modification by untrusted entities
  - Prevent modification of what?

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  - Code and data that can affect reference monitor
- How to detect tamperproofing?

Tamperproof

- Prevent modification by untrusted entities
    - Prevent modification of what?
    - Code and data that can affect reference monitor
- How to detect tamperproofing?
    - Check for strong integrity guarantees (Biba)
    - Challenge: Often some untrusted operations are present
- **Tamperproof**: Is reference monitor protected?
- **Tamperproof**: Is system TCB protected?

Verification

- Determine correctness of code and policy
  - What defines correct code?
  - What defines a correct policy?
- Test and analyze reference validation mechanism
  - Does code/policy do its job correctly?
  - For all executions (completeness must be assured)
- **Verifiable**: Is TCB code base correct?
- **Verifiable**: Does the MPS enforce the system's security goals?

Evaluation

- **Mediation**: Does interface mediate?
- **Mediation**: On all resources?
- **Mediation**: Verifably?
- **Tamperproof**: Is reference monitor protected?
- **Tamperproof**: Is system TCB protected?
- **Verifiable**: Is TCB code base correct?
- **Verifiable**: Does the MPS enforce the system's security goals?

Take Away

- Mandatory Protection System
  - Means to define security goals that applications cannot impact
- Reference Monitor Concept
  - Requirements for a reference validation mechanism that can correctly enforce an MPS
  - NOTE: This will be a major focus of this course
- *Until we come up with coherent approach to validating MPS meets security goals and validating reference monitor guarantees, we will continue to have insecure systems*
  - That is the challenge of systems security research