Lecture #8

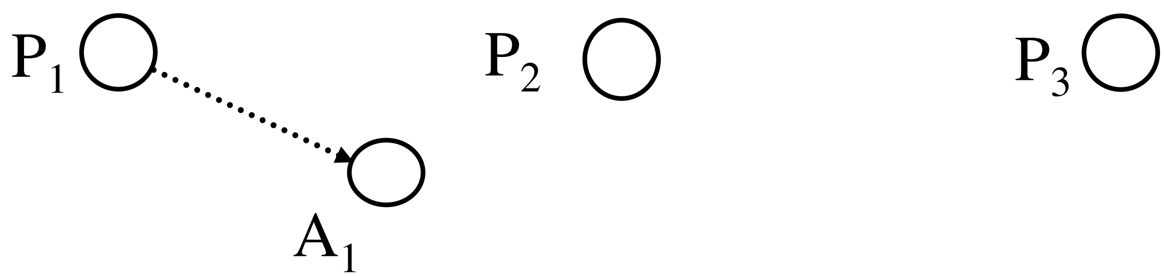
- Multiparent create
- Expressive power
- Typed Access Control Matrix (TAM)
- Overview of Policies
- The nature of policies
  - What they cover

Expressiveness

- Graph-based representation to compare models
- Graph
  - Vertex: represents entity, has static type
  - Edge: represents right, has static type
- Graph rewriting rules:
  - Initial state operations create graph in a particular state
  - Node creation operations add nodes, incoming edges
  - Edge adding operations add new edges between existing vertices

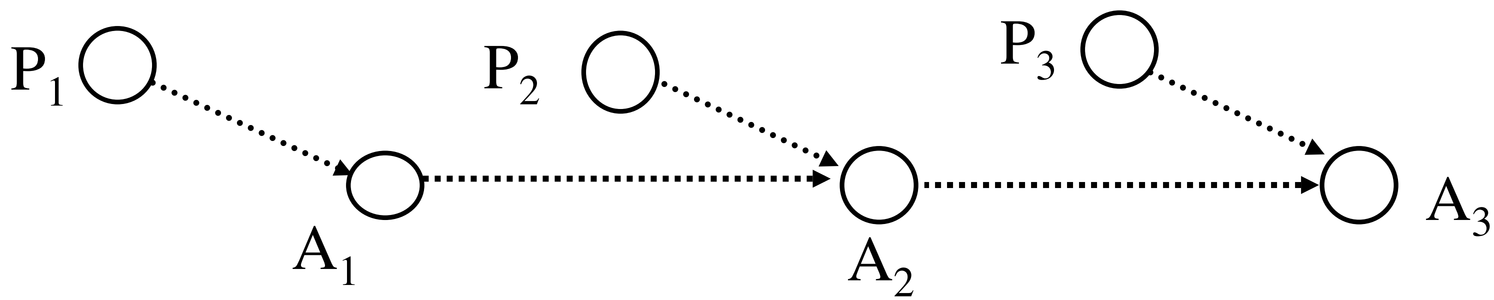
Example: 3-Parent Joint Creation

- Simulate with 2-parent
  - Nodes $\mathbf{P}_1$, $\mathbf{P}_2$, $\mathbf{P}_3$ parents
  - Create node **C** with type *c* with edges of type *e*
  - Add node $\mathbf{A}_1$ of type *a* and edge from $\mathbf{P}_1$ to $\mathbf{A}_1$ of type *e´*



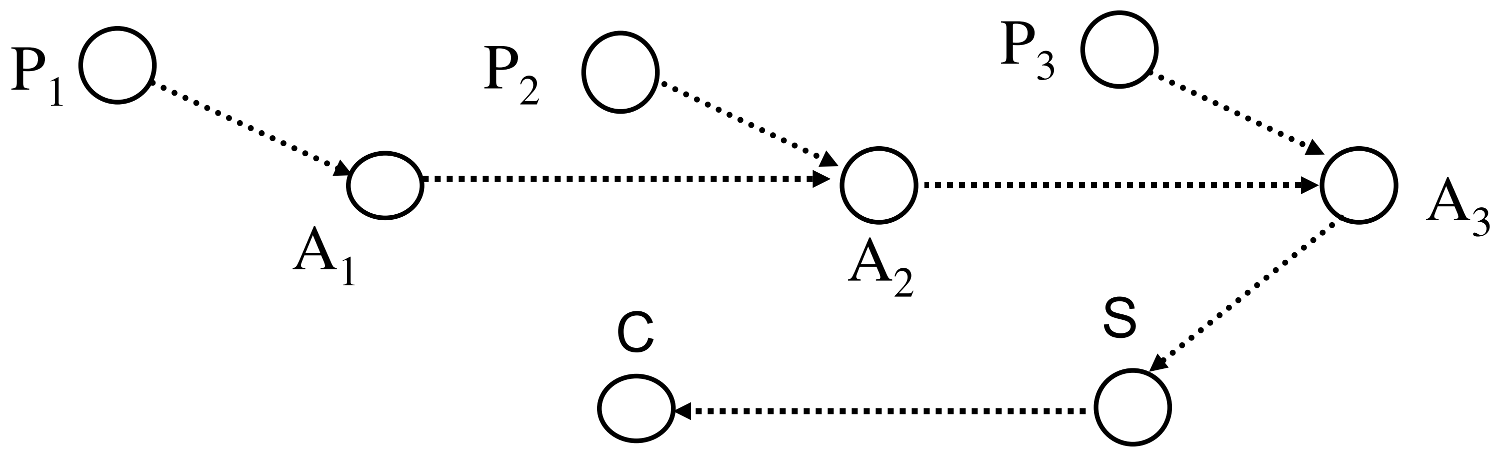
Next Step

- $\mathbf{A}_1$, $\mathbf{P}_2$ create $\mathbf{A}_2$; $\mathbf{A}_2$, $\mathbf{P}_3$ create $\mathbf{A}_3$
- Type of nodes, edges are *a* and *e*´



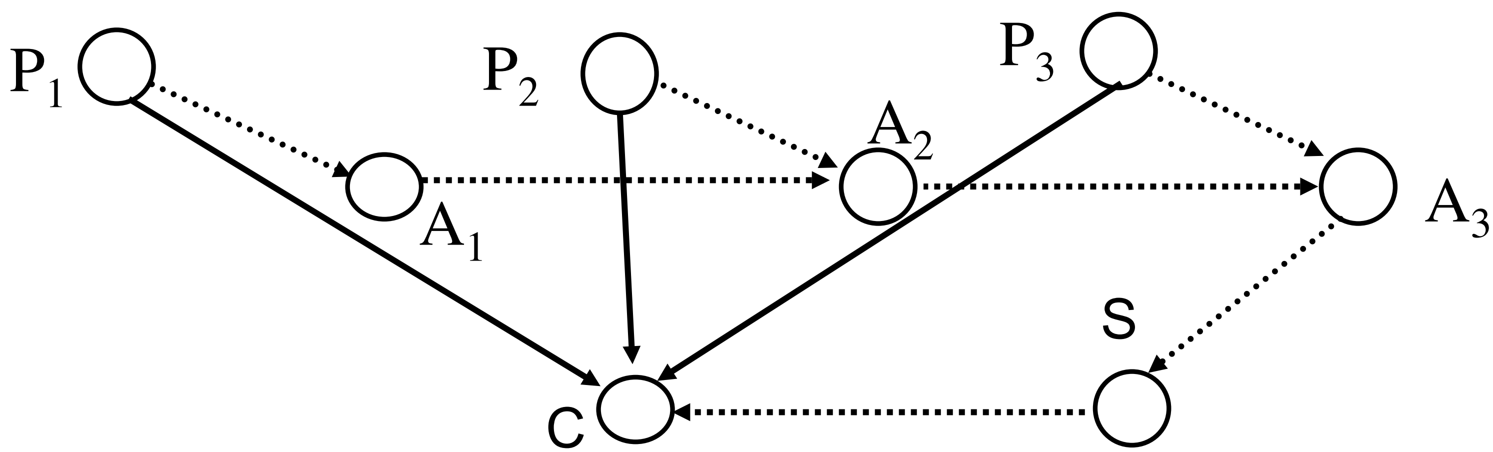
Next Step

- $\mathbf{A}_3$ creates **S**, of type *a*
- **S** creates **C**, of type *c*



Last Step

- Edge adding operations:
  - $\mathbf{P}_1 \rightarrow \mathbf{A}_1 \rightarrow \mathbf{A}_2 \rightarrow \mathbf{A}_3 \rightarrow \mathbf{S} \rightarrow \mathbf{C}$: $\mathbf{P}_1$ to $\mathbf{C}$ edge type *e*
  - $\mathbf{P}_2 \rightarrow \mathbf{A}_2 \rightarrow \mathbf{A}_3 \rightarrow \mathbf{S} \rightarrow \mathbf{C}$: $\mathbf{P}_2$ to $\mathbf{C}$ edge type *e*
  - $\mathbf{P}_3 \rightarrow \mathbf{A}_3 \rightarrow \mathbf{S} \rightarrow \mathbf{C}$: $\mathbf{P}_3$ to $\mathbf{C}$ edge type *e*



Definitions

- *Scheme*: graph representation as above
- *Model*: set of schemes
- Schemes A, B *correspond* if graph for both is identical when all nodes with types not in A and edges with types in A are deleted

Example

- Above 2-parent joint creation simulation in scheme *TWO*
- Equivalent to 3-parent joint creation scheme *THREE* in which $\mathbf{P}_1$, $\mathbf{P}_2$, $\mathbf{P}_3$, $\mathbf{C}$ are of same type as in *TWO*, and edges from $\mathbf{P}_1$, $\mathbf{P}_2$, $\mathbf{P}_3$ to $\mathbf{C}$ are of type e, and no types a and e' exist in *TWO*

Simulation

Scheme *A* simulates scheme *B* iff

- every state *B* can reach has a corresponding state in *A* that *A* can reach; and
- every state that *A* can reach either corresponds to a state *B* can reach, or has a successor state that corresponds to a state *B* can reach
  - The last means that *A* can have intermediate states not corresponding to states in *B*, like the intermediate ones in *TWO* in the simulation of *THREE*

Expressive Power

- If there is a scheme in *MA* that no scheme in *MB* can simulate, *MB* less expressive than *MA*
- If every scheme in *MA* can be simulated by a scheme in *MB*, *MB* as expressive as *MA*
- If *MA* as expressive as *MB* and *vice versa*, *MA* and *MB* equivalent

Example

- Scheme *A* in model *M*
  - Nodes $\mathbf{X}_1, \mathbf{X}_2, \mathbf{X}_3$
  - 2-parent joint create
  - 1 node type, 1 edge type
  - No edge adding operations
  - Initial state: $\mathbf{X}_1, \mathbf{X}_2, \mathbf{X}_3$, no edges
- Scheme *B* in model *N*
  - All same as *A* except no 2-parent joint create
  - 1-parent create
- Which is more expressive?

Can *A* Simulate *B*?

- Scheme *A* simulates 1-parent create: have both parents be same node
  - Model *M* as expressive as model *N*

Can *B* Simulate *A*?

- Suppose $\mathbf{X}_1$, $\mathbf{X}_2$ jointly create $\mathbf{Y}$ in *A*
  - Edges from $\mathbf{X}_1$, $\mathbf{X}_2$ to $\mathbf{Y}$, no edge from $\mathbf{X}_3$ to $\mathbf{Y}$
- Can *B* simulate this?
  - Without loss of generality, $\mathbf{X}_1$ creates $\mathbf{Y}$
  - Must have edge adding operation to add edge from $\mathbf{X}_2$ to $\mathbf{Y}$
  - One type of node, one type of edge, so operation can add edge between any 2 nodes

No

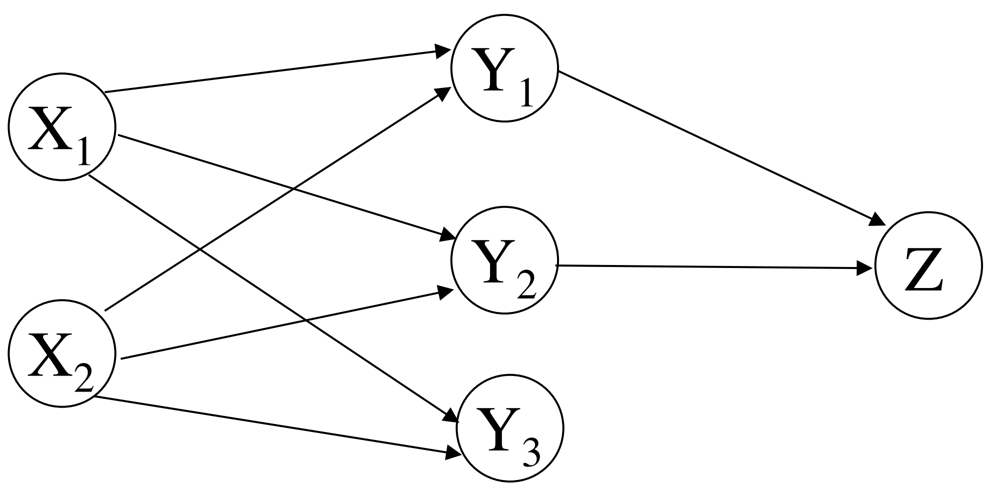
- All nodes in *A* have even number of incoming edges
  - 2-parent create adds 2 incoming edges
- Edge adding operation in *B* that can edge from $\mathbf{X}_2$ to **C** can add one from $\mathbf{X}_3$ to **C**
  - *A* cannot enter this state
    - *A*, cannot have node (**C**) with 3 incoming edges
  - *B* cannot transition to a state in which **Y** has even number of incoming edges
    - No remove rule
- So *B* cannot simulate *A*; *N* less expressive than *M*

Theorem

- Monotonic single-parent models are less expressive than monotonic multiparent models
- Proof by contradiction
  - Scheme A is multiparent model
  - Scheme B is single parent create
  - Claim: B can simulate A, without assumption that they start in the same initial state
    - Note: example assumed same initial state

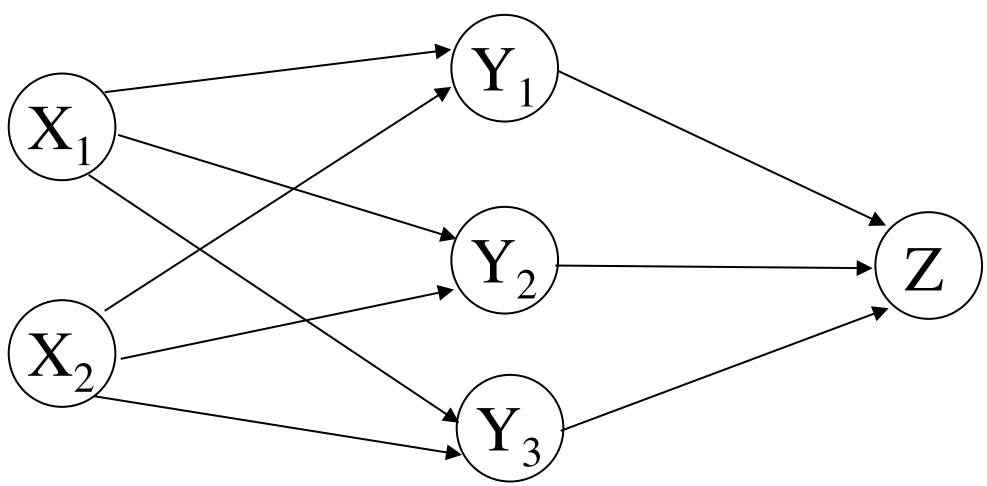
Outline of Proof

- $\mathbf{X}_1$, $\mathbf{X}_2$ nodes in *A*
  - They create $\mathbf{Y}_1$, $\mathbf{Y}_2$, $\mathbf{Y}_3$ using multiparent create rule
  - $\mathbf{Y}_1$, $\mathbf{Y}_2$ create $\mathbf{Z}$, again using multiparent create rule
  - *Note*: no edge from $\mathbf{Y}_3$ to $\mathbf{Z}$ can be added, as *A* has no edge-adding operation



Outline of Proof

- **W**, $\mathbf{X}_1$, $\mathbf{X}_2$ nodes in *B*
  - **W** creates $\mathbf{Y}_1$, $\mathbf{Y}_2$, $\mathbf{Y}_3$ using single parent create rule, and adds edges for $\mathbf{X}_1$, $\mathbf{X}_2$ to all using edge adding rule
  - $\mathbf{Y}_1$ creates **Z**, again using single parent create rule; now must add edge from $\mathbf{X}_2$ to **Z** to simulate *A*
  - Use same edge adding rule to add edge from $\mathbf{Y}_3$ to **Z**: cannot duplicate this in scheme *A*!



Meaning

- Scheme *B* cannot simulate scheme *A*, contradicting hypothesis
- ESPM more expressive than SPM
  - ESPM multiparent and monotonic
  - SPM monotonic but single parent

Typed Access Matrix Model

- Like ACM, but with set of types T
  - All subjects, objects have types
  - Set of types for subjects TS
- Protection state is (S, O, τ, A)
  - τ: $O \rightarrow T$ specifies type of each object
  - If $\mathbf{X}$ subject, $\tau(\mathbf{X}) \in TS$
  - If $\mathbf{X}$ object, $\tau(\mathbf{X}) \in T - TS$

Create Rules

- Subject creation
  - **create subject** *s* **of type** *ts*
  - *s* must not exist as subject or object when operation executed
  - $ts \in TS$
- Object creation
  - **create object** *o* **of type** *to*
  - *o* must not exist as subject or object when operation executed
  - $to \in T - TS$

Create Subject

- Precondition: $s \notin S$
- Primitive command: **create subject** s **of type** t
- Postconditions:
  - $S' = S \cup \{ s \}$, $O' = O \cup \{ s \}$
  - $(\forall y \in O)[\tau'(y) = \tau(y)]$, $\tau'(s) = t$
  - $(\forall y \in O')[a'[s, y] = \varnothing]$, $(\forall x \in S')[a'[x, s] = \varnothing]$
  - $(\forall x \in S)(\forall y \in O)[a'[x, y] = a[x, y]]$

Create Object

- Precondition: $o \notin O$
- Primitive command: **create object** o **of type** t
- Postconditions:
  - $S' = S, O' = O \cup \{ o \}$
  - $(\forall y \in O)[\tau'(y) = \tau(y)], \tau'(o) = t$
  - $(\forall x \in S')[a'[x, o] = \varnothing]$
  - $(\forall x \in S)(\forall y \in O)[a'[x, y] = a[x, y]]$

Definitions

- MTAM Model: TAM model without **delete**, **destroy**
  - MTAM is Monotonic TAM
- $\alpha(x_1{:}t_1, ..., x_n{:}t_n)$ create command
  - t_i child type in α if any of **create subject** x_i **of type** t_i or **create object** x_i **of type** t_i occur in α
  - t_i parent type otherwise

Cyclic Creates

command *havoc*($s : u$, $p : u$, $f : v$, $q : w$)

  create subject p **of type** u;

  create object f **of type** v;

  enter *own* **into** $a[s, p]$;

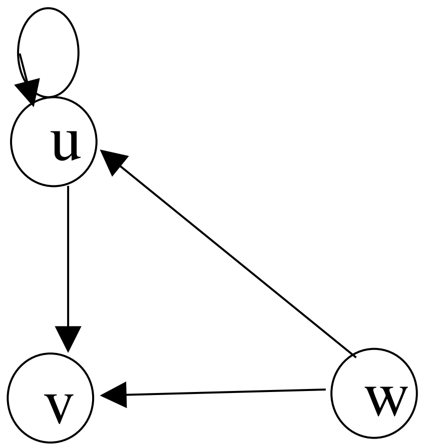
  enter r **into** $a[q, p]$;

  enter *own* **into** $a[p, f]$;

  enter r **into** $a[p, f]$

end

Creation Graph



- u, v child types
- u, w parent types
- Graph: lines from parent types to child types
- This one has cycles

Acyclic Creates

command $havoc(s : u, p : u, f : v, q : w)$

  create object f **of type** v;

  enter own **into** $a[s, p]$;

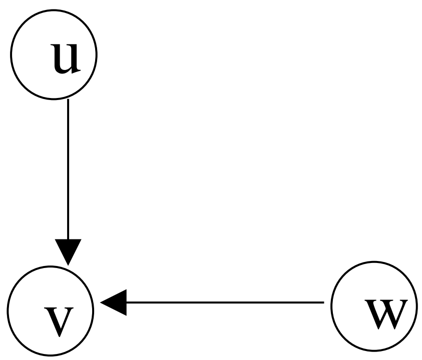
  enter r **into** $a[q, p]$;

  enter own **into** $a[p, f]$;

  enter r **into** $a[p, f]$

end

Creation Graph



- v child type
- u, w parent types
- Graph: lines from parent types to child types
- This one has no cycles

Theorems

- Safety decidable for systems with acyclic MTAM schemes
  - In fact, it's *NP-hard*
- Safety for acyclic ternary MATM decidable in time polynomial in the size of initial ACM
  - "Ternary" means commands have no more than 3 parameters
  - Equivalent in expressive power to MTAM

Comparing Security Properties

- Generalize what we have done earlier
  - Property we looked at is safety question
  - Others of interest are bounds on determining safety, what actions a specific subject can take, etc.
- Also eliminate the requirement of monotonicity
- Key idea: access requests are queries

Scheme (Alternate Definition)

Σ set of states

Q set of querties

e: $\Sigma \times Q \rightarrow \{$ true, false $\}$ (*entailment relation*)

T set of transition rules

Access control scheme is (Σ, Q, e, T)

Note

- We write $\sigma \vdash_\tau \sigma'$ for τ changing the system from state σ to state σ'
- We write $\sigma \mapsto_\tau \sigma'$ for τ *allowing* the system to change from state σ to state σ'
  - It doesn't actually change the state

Example: Take-Grant

- Σ set of all possible protection graphs
- Q set of queries

  { *can•share*(α, $\mathbf{v}_1$, $\mathbf{v}_2$, G_0) }
- *e*: e(σ_0, q) = true if q holds; false if not
- T set of sequences of take, grant, create, remove rules

So take-grant is an access control scheme

Security Analysis Instance

- (Σ, Q, e, T) access control scheme
- Security analysis instance is (σ, q, τ, Π) where:
  - $\sigma \in \Sigma, q \in Q, \tau \in T$
  - Π is $\forall$ or $\exists$
- Π is $\exists$: does there exist a state σ' such that $\sigma \mapsto^* \sigma'$ and $e(\sigma', q) = \text{true}$
- Π is $\forall$: for all states σ' such that $\sigma \mapsto^* \sigma'$, is $e(\sigma', q) = \text{true}$

Multiple Queries

- (Σ, Q, e, T) access control scheme
- *Compositional security analysis instance* is $(\sigma, \phi, \tau, \Pi)$ where ϕ is a propositional logic formula of queries from Q

Mapping from A to B

- A *mapping* from $A = (\Sigma^A, Q^A, e^A, T^A)$ to $B = (\Sigma^B, Q^B, e^B, T^B)$ is a function

$$f : (\Sigma^A \times T^A) \cup Q^A \; (\Sigma^B \times T^B) \cup Q^B$$

- Idea:
  - Each query in A corresponds to one in B
  - Each state, transition pair in A corresponds to a pair in B

Security-Preserving Mappings

- $f : A \rightarrow B$
- *Image of a security analysis instance* (σ^A, q^A, τ^A, Π) *under* f is (σ^B, q^B, τ^B, Π), where:
  - $f((\sigma^A, \tau^A)) = (\sigma^B, \tau^B)$ and $f(q^A) = q^B$
- f is *security-preserving* if every security analysis instance in A is true iff its image in B is true

Strongly Security-Preserving

- Like security-preserving, but for compositional security analyses instances
- That is, for the image, instead of $f(q^A) = q^B$ we have $f(\phi^A) = \phi^B$

Two Mapped Models

- Consider access control schemes A and B with a mapping $f : A \rightarrow B$
- Security properties deal with answers to queries about states and transitions
- Given 2 corresponding states and 2 corresponding sequences of transitions, corresponding queries must give same answer!

Equivalent Under Mapping

- $A = (\Sigma^A, Q^A, e^A, T^A)$
- $B = (\Sigma^B, Q^B, e^B, T^B)$
- $f : A \rightarrow B$
- σ^A, σ^B *equivalent under mapping* f when $e^A(\sigma^A, q^A) = e^B(\sigma^B, q^B)$

State-Matching Reduction

- f is *state-matching reduction* if, for every $\sigma^A \in \Sigma^A$ and $\tau^A \in T^A$, $(\sigma^B, \tau^B) = f((\sigma^A, \tau^A))$ has the following properties:
  - $\forall(\sigma'^A \in \Sigma^A)$ such that $\sigma^A \mapsto_\tau^* \sigma'^A$, there is a state $\sigma'^B \in \Sigma^B$ such that $\sigma^B \mapsto_\tau^* \sigma'^B$, and σ'^A and σ'^B are equivalent under the mapping f
  - $\forall(\sigma'^B \in \Sigma^B)$ such that $\sigma^B \mapsto_\tau^* \sigma'^B$, there is a state $\sigma'^A \in \Sigma^A$ such that $\sigma^A \mapsto_\tau^* \sigma'^A$, and σ'^A and σ'^B are equivalent under the mapping f

Theorem

- A mapping $f : A \rightarrow B$ is strongly security-preserving iff f is a state-matching reduction

Expressive Power

If access control model *MA* has a scheme that cannot be mapped into a scheme in access control model *MB* using a state-matching reduction, then model *MB* is *less expressive than* model MA. If every scheme in model *MA* can be mapped into a scheme in model *MB* using a state-matching reduction, then model *MB* is *as expressive as* model *MA*. If *MA* is as expressive as *MB*, and *MB* is as expressive as *MA*, the models are *equivalent*.

- Note it does not require schemes to be monotonic!

Security Policies

- Overview
- The nature of policies
  - What they cover
  - Policy languages
- The nature of mechanisms
  - Types
  - Secure *vs*. precise
- Underlying both
  - Trust

Overview

- Policies
- Trust
- Nature of Security Mechanisms
- Policy Expression Languages
- Limits on Secure and Precise Mechanisms

Security Policy

- Policy partitions system states into:
  - Authorized (secure)
    - These are states the system can enter
  - Unauthorized (nonsecure)
    - If the system enters any of these states, it's a security violation
- Secure system
  - Starts in authorized state
  - Never enters unauthorized state

Confidentiality

- X set of entities, I information
- I has *confidentiality* property with respect to X if no $x \in X$ can obtain information from I
- I can be disclosed to others
- Example:
  - X set of students
  - I final exam answer key
  - I is confidential with respect to X if students cannot obtain final exam answer key

Integrity

- X set of entities, I information
- I has *integrity* property with respect to X if all $x \in X$ trust information in I
- Types of integrity:
  - trust I, its conveyance and protection (data integrity)
  - I information about origin of something or an identity (origin integrity, authentication)
  - I resource: means resource functions as it should (assurance)

Availability

- X set of entities, I resource
- I has *availability* property with respect to X if all $x \in X$ can access I
- Types of availability:
  - traditional: x gets access or not
  - quality of service: promised a level of access (for example, a specific level of bandwidth) and not meet it, even though some access is achieved

Policy Models

- Abstract description of a policy or class of policies
- Focus on points of interest in policies
  - Security levels in multilevel security models
  - Separation of duty in Clark-Wilson model
  - Conflict of interest in Chinese Wall model

Types of Security Policies

- Military (governmental) security policy
  - Policy primarily protecting confidentiality
- Commercial security policy
  - Policy primarily protecting integrity
- Confidentiality policy
  - Policy protecting only confidentiality
- Integrity policy
  - Policy protecting only integrity

Integrity and Transactions

- Begin in consistent state
  - "Consistent" defined by specification
- Perform series of actions (*transaction*)
  - Actions cannot be interrupted
  - If actions complete, system in consistent state
  - If actions do not complete, system reverts to beginning (consistent) state

Trust

Administrator installs patch

1. Trusts patch came from vendor, not tampered with in transit
2. Trusts vendor tested patch thoroughly
3. Trusts vendor's test environment corresponds to local environment
4. Trusts patch is installed correctly

Trust in Formal Verification

- Gives formal mathematical proof that given input i, program P produces output o as specified
- Suppose a security-related program S formally verified to work with operating system O
- What are the assumptions?