Access Control

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Overview

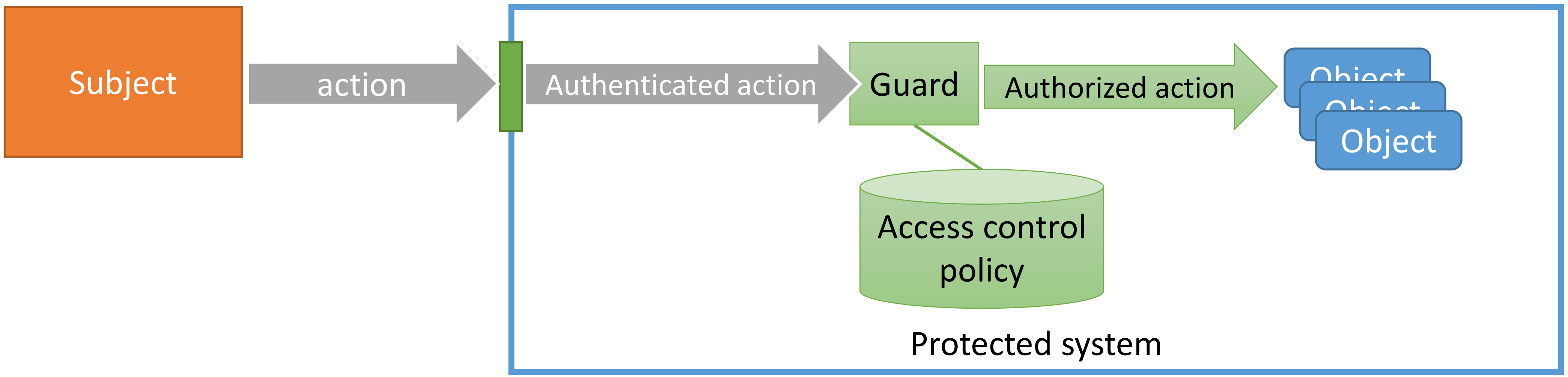
- Introduction
    - System model, security objective and attacker model
- Security automata
- Access control models
- Conclusions

Introduction

- Access control addresses the problem of specifying and enforcing rules on how a software application can be used
- We will assume that:
  - The software application has been adequately **isolated** such that interaction with the application is only possible through a well-defined interface
  - Users (subjects) interacting with the application have been adequately **authenticated** such that we know who is interacting over these interfaces
- We focus on enforcement by **run-time monitoring**

System model / attacker model

Security objective: the **guard** should block or allow actions as specified in the **access control policy**



Examples

Subject	Action	Guard	Protected objects
Host	Packet send	Firewall	Intranet hosts
Process	Open file	OS kernel	Files / OS resources / …
Java Module	Open file	Java Security Manager	Files / JVM resources
User	Query	DBMS	Databases / tables / …
User	Get page	Web server	Web site contents
…	…	…	…

Application-level access control

- There is a trend to move access checks into applications in addition to OS / network level access control
  - More context-sensitive policies
    - E.g. Friends-based access control in online social networks
    - E.g. Task-based or workflow-based access control
  - Policies are more user-oriented
  - Many resources that need protection are application resources
    - E.g. a shopping basket

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What should the guard do?

- A key question in access control is what the guard should do exactly
  - It should enforce some “access control policy”
  - But that policy should be configurable
    - By the owner of the protected system (“mandatory” policies)
    - But sometimes also by the users of the protected system (“discretionary” policies)
- We will introduce a general mechanism for specifying guard behavior
  - And then use it to specify some example guards
  - An **access control model** is a kind of “design pattern” for a guard

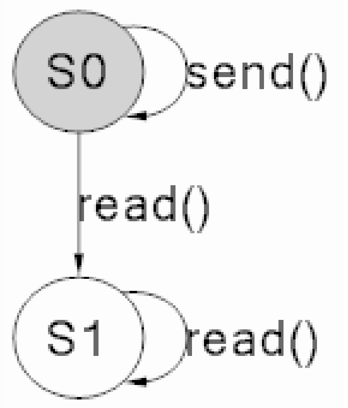
Specifying guard behavior

- We will consider guards that:
  - Can keep local state (the “protection state”)
  - On receipt of an authenticated action, the guard:
    - Decides whether to pass or drop it
      - Extensions are possible, for instance modify / sanitize the action
    - And possible updates its protection state
- Such guards can be generally modeled as **security automata**:
  - A state set, with an initial state
  - A transition relation defined by predicates on actions and current state

Specifying guard behavior

- Notation:
  - Security automaton is specified as a Scala object
    - State space is specified by declaration of typed state variables
  - Actions are specified as methods
    - Preconditions determine acceptability of action
    - Implementation body determines state update
- Example: no network send after file read

```scala
object ExPolicy {
  var hasRead = false;
  def send() {
    require (!hasRead);
  }
  def read() {
    hasRead = true;
  }
}
```



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  - Discretionary access control (DAC)
  - Lattice-based access control (LBAC)
  - Role-based access control (RBAC)
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Discretionary Access Control (DAC)

- Objective = creator-controlled sharing of information
  - I.e. *Discretionary*: creator can set policy
- Key Concepts
  - Protected system manages <u>*objects*</u>, passive entities requiring controlled access
  - Objects are accessed by means of <u>*operations*</u> on them
  - Every object has an <u>*owner*</u>
  - Owner can grant right to use operations to other users
- Variants:
  - Possible to pass on ownership or not?
  - Possible to delegate right to grant access or not?
  - Constraints on revocation of rights.
  - Possible to create subjects with lesser privileges.

Security automaton for DAC

```
import scala.collection.mutable._;
object DACPolicy {
  type U = String; // Users
  type O = String; // Objects
  type A = String; // Actions
  type R = (U,O,A); // Rights
  var users = Set[U]();
  var objects = Set[O]();
  var rights = Set[R](); // Access Control Matrix
  var ownerOf = Map[O,U]();
// Invariant: for (u,o,a) in rights, u is in users and o in objects

// Access checks
  def read(s: U, o:O) { require(rights.contains((s,o,"Read"))); }
  def write(s: U, o:O) { require(rights.contains((s,o,"Write"))); }
// Actions that impact the protection state
  def addRight(s: U, r:R) { r match { case (u,o,a) =>
    require(users.contains(u) & objects.contains(o) & ownerOf(o) == s);
    rights += r; }
  }
```

Security automaton for DAC (ctd)

```
  def deleteRight(s: U, r:R) { r match { case (u,o,a) =>
    require(ownerOf(o) == s);
    rights -= r; }
  }
  def addObject(s:U,o:O) {
    require(!objects.contains(o));
    objects += o;
    ownerOf += (o -> s);
  }
  def delObject(s:U,o:O) {
    require(objects.contains(o) & ownerOf(o) == s);
    objects -= o;
    ownerOf -= o;
    rights.retain( {case (u,o2,a) => o2 != o } );
  }
// Admin functions
  def addUser(s:U,u:U) {
    require(!users.contains(u)); // Possibly require s is an admin
    users += u;
  }
}
```

DAC Extensions

- Exercises: extend this simple specification with features such as:
  - Groups
  - Negative permissions
  - Mechanisms to start subjects with restricted privileges
  - …

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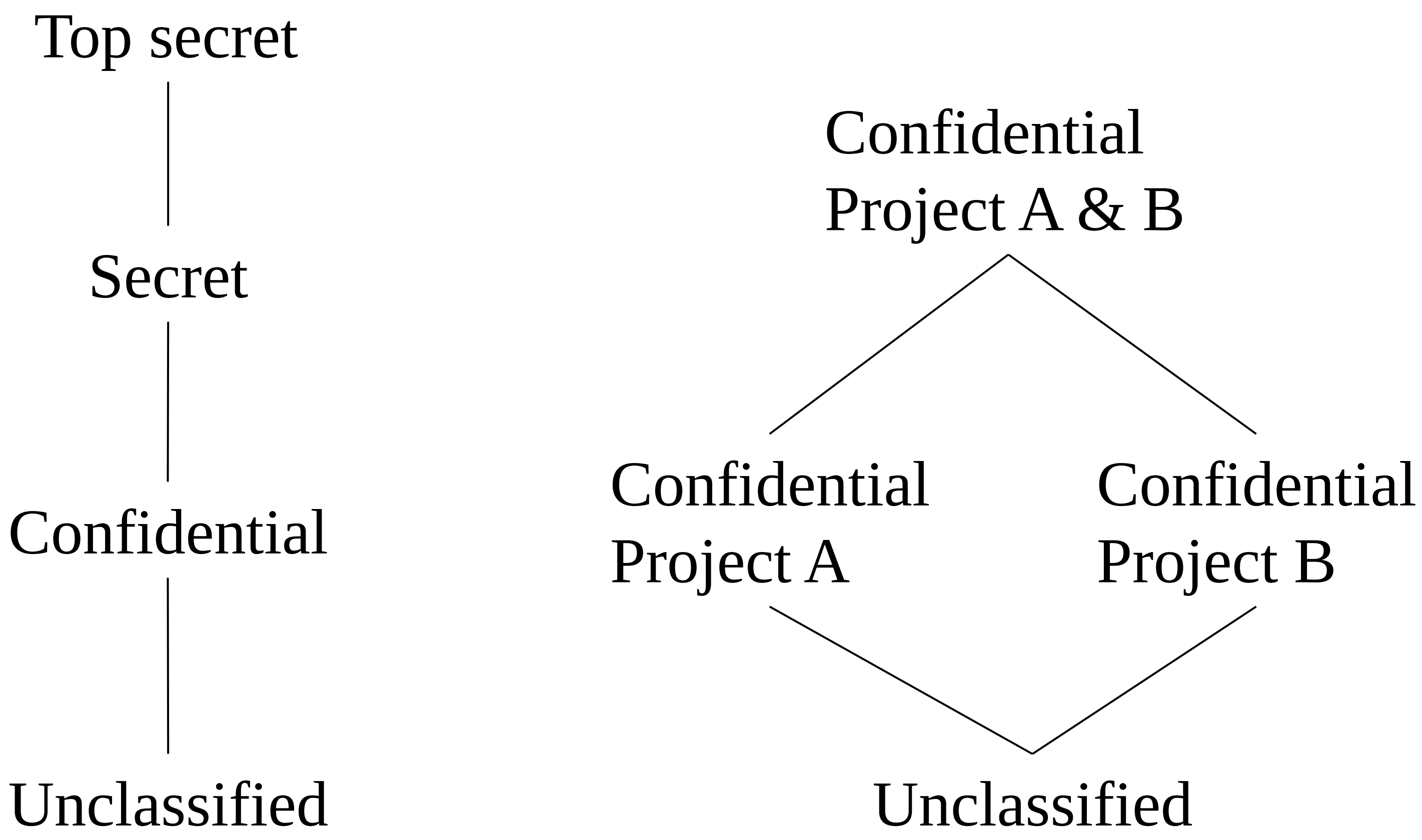
Lattice-based Access Control

- Objective = strict control of information flow
  - I.e. *Mandatory*: policy is not configurable by users
- Objective =
  - A lattice of *security labels* is given
  - Objects and users are tagged with security labels
  - Enforce that:
    - Users can only see information below their clearance
    - Information can only flow upward, even in the presence of Trojan Horses

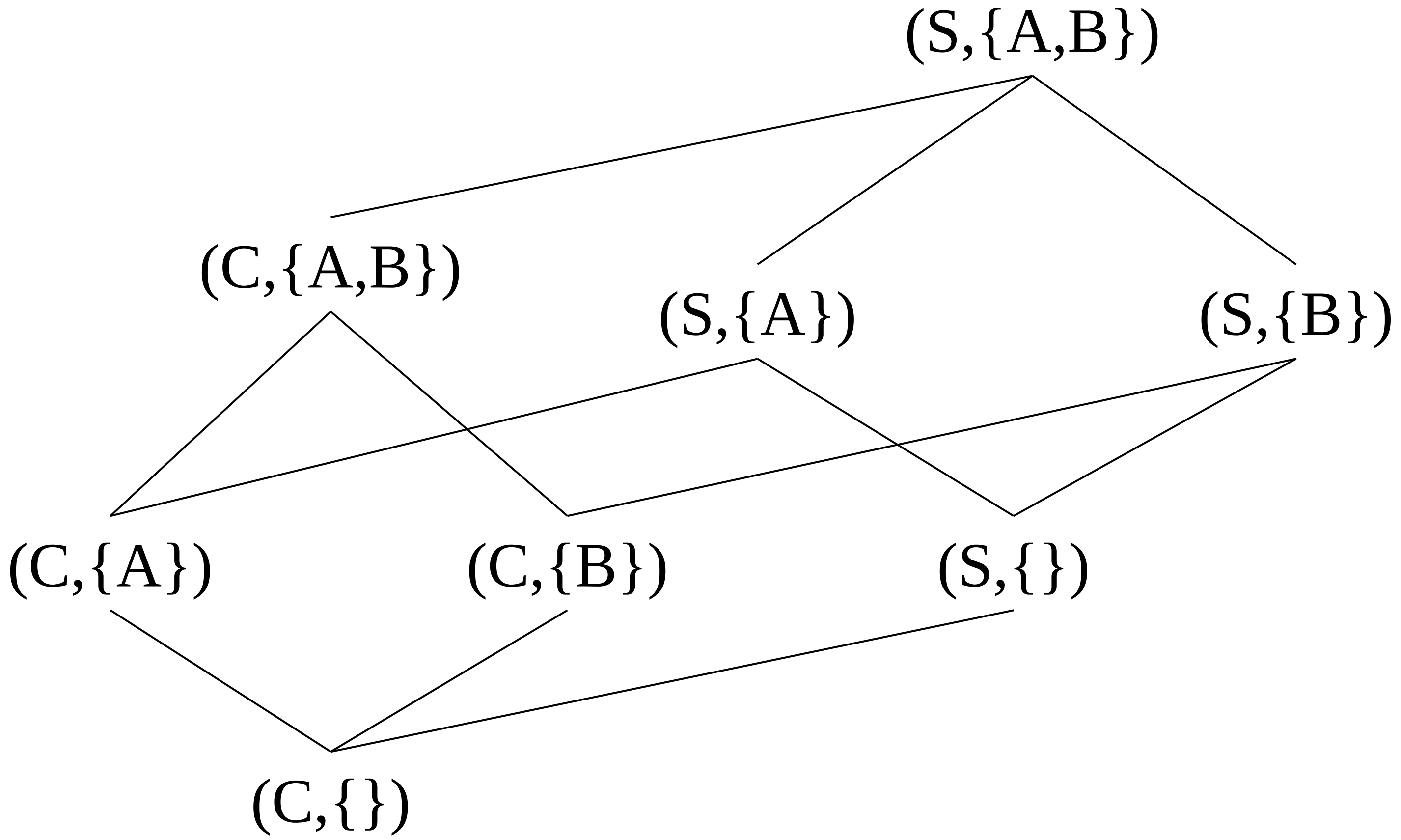
Example lattices



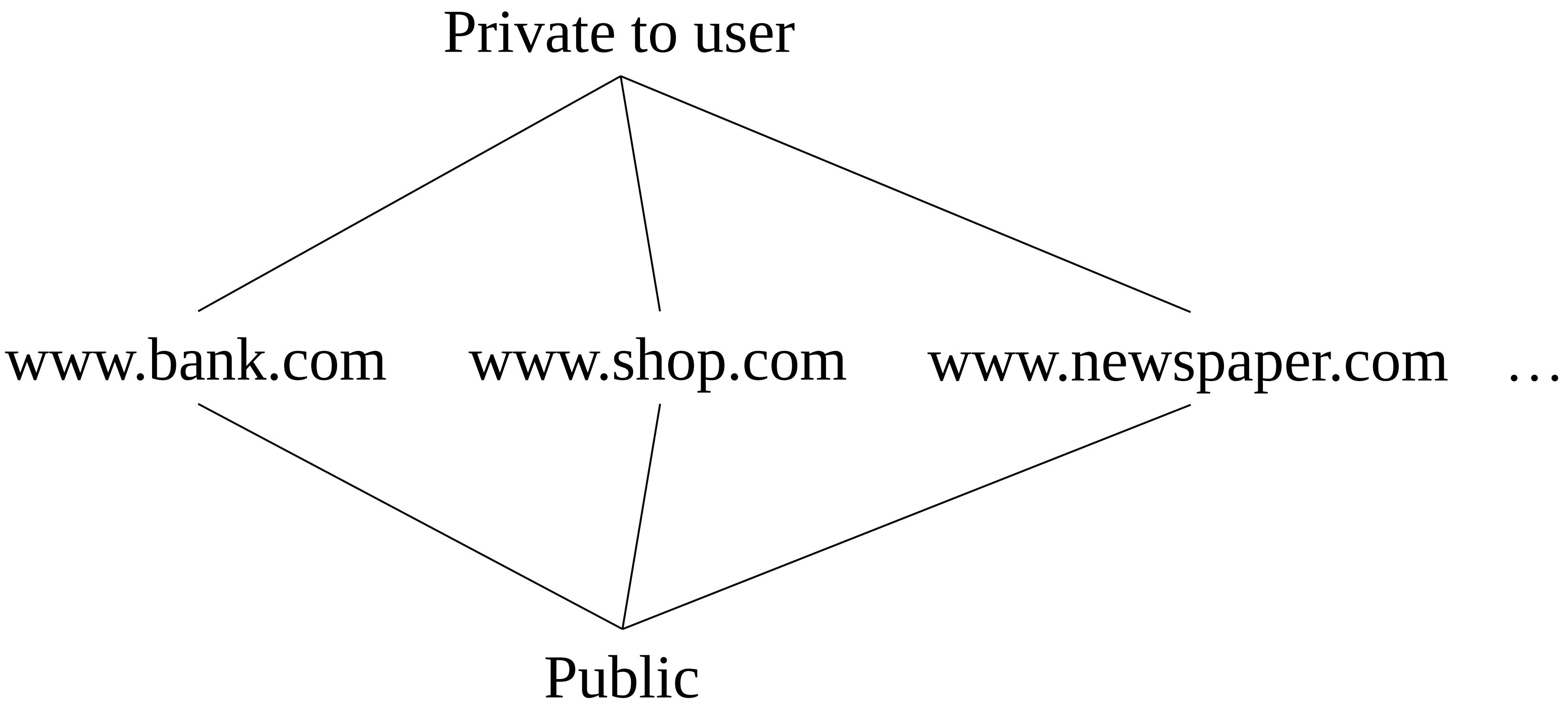
Typical construction of lattice

- Security label = (level, compartment)
- Compartment = set of categories
- Category = keyword relating to a project or area of interest
- Levels are ordered linearly
  - E.g. Top Secret – Secret – Confidential – Unclassified
- Compartments are ordered by subset inclusion

Example lattice



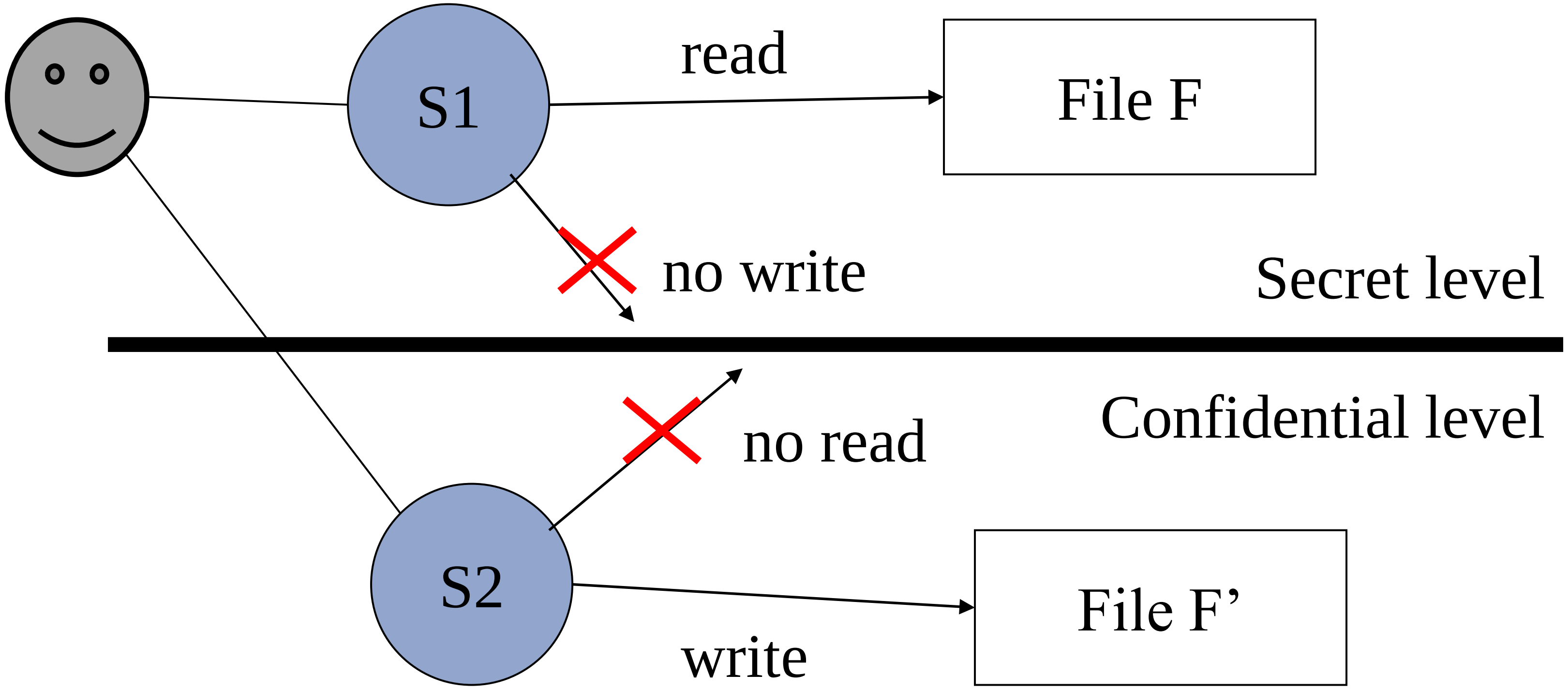
Web-based example



LBAC

- Key concepts of the model:
  - Users initiate *subjects* or *sessions*, and these are labeled on creation
  - Users of clearance L can start subjects with any label L’ $\leq$ L
  - Enforced rules:
    - Simple security property: subjects with label L can only read objects with label L’ $\leq$ L (**no read up**)
    - *-property: subjects with label L can only write objects with label L’ $\geq$ L (**no write down**)
  - The *-property addresses the Trojan Horse problem

LBAC and the Trojan Horse problem



Security automaton for LBAC

```
import scala.collection.mutable._;
object LBACPolicy {
  type U = String; // Users
  type O = String; // Objects
  type L = String; // Labels - in reality should be a more interesting lattice
  type S = Object; // Sessions

// Stable part of the protection state
  var users = Set[U]("alice","bob"); // some example users
  var ulabel = Map[U,L](("alice" -> "A"),("bob" -> "B"));
// Dynamic part of the protection state
  var objects = Set[O]();
  var sessions = Set[S]();
  var slabel = Map[S,L]();
  var olabel = Map[O,L]();

// No read up
  def read(s: S, o:O) { require(slabel(s) >= olabel(o)); }
// No write down
  def write(s: S, o:O) { require(slabel(s) <= olabel(o)); }
```

Security automaton for LBAC (ctd)

```
// Managing sessions and objects
  def createSession(u:U,l:L) {
    require(ulabel(u) >= l);
    val s = new S();
    sessions += s;
    slabel += ( s -> l );
  }
  def addObject(s:S,o:O,l:L) {
    require(!objects.contains(o) & slabel(s) <= l);
    objects += o;
    olabel += (o -> l);
  }
}
```

LBAC Extensions

- Exercises: extend this simple LBAC model with:
  - Declassification
  - Dynamic labels
  - Integrity protection instead of confidentiality protection
  - …

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Role-Based Access Control (RBAC)

- Main objective: *manageable* access control
  - Mandatory, policy setting by some administrator
- Key concepts of the model:
  - A **role**:
    - many-to-many relation between users and permissions
    - Corresponds to a well-defined job or responsibility
    - Think of it as a named set of permissions that can be assigned to users
  - When a user starts a session, he can activate some or all of his roles
  - A session has all the permissions associated with the activated roles

Security automaton for RBAC

```
import scala.collection.mutable._;
object RBACPolicy {
  type U = String; // Users
  type R = String; // Roles
  type P = String; // Permissions
  type S = Object; // Sessions

// Stable part of the protection state
  var users = Set[U]("alice","bob");
  var roles = Set[R]("teacher", "researcher");
  var perms = Set[P]("accesslib","bookroom");
  var ua = Map[U,Set[R]](("alice" -> Set("teacher")),("bob" -> Set("teacher","researcher")));
  var pa = Map[R,Set[P]](("teacher" -> Set("bookroom")),("researcher" -> Set("accesslib")));
// Dynamic part of the protection state
  var sessions = Set[S]();
  var session_roles = Map[S,Set[R]]();
  var session_user = Map[S,U]();

// Access checks
  def checkAccess(s: S, p:P) {
    require(session_roles(s).exists(r => pa(r).contains(p)) ); }
```

Security automaton for RBAC (ctd)

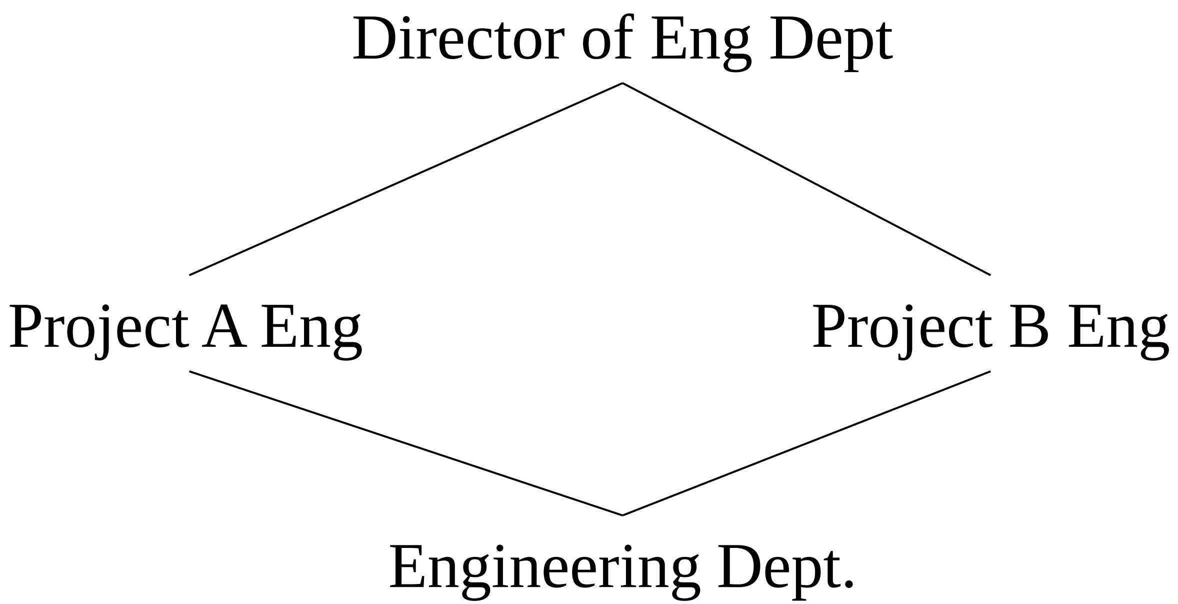
```
// Managing sessions
  def createSession(u:U,rs:Set[R]) {
    require(rs.subsetOf(ua(u)));
    val s = new S();
    sessions += s;
    session_roles += ( s -> rs );
    session_user += (s -> u);
  }

  def dropRole(s:S,r:R) {
    require(session_roles(s).contains(r));
    session_roles(s) -= r;
  }

  def activateRole(s:S,r:R) {
    require(ua(session_user(s)).contains(r));
    session_roles(s) += r;
  }
}
```

RBAC - Extensions

- Hierarchical roles: senior role inherits all permissions from junior role



RBAC - Extensions

- Constraints:
  - Static constraints
    - Constraints on the assignment of users to roles
    - E.g. Static separation of duty: nobody can both:
      - Order goods
      - Approve payment
  - Dynamic constraints
    - Constraints on the simultaneous activation of roles
    - E.g. to enforce least privilege

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Other models

- Lattice-based access control for integrity
  - Labels represent a level of *trustworthiness* of the integrity of information
    - Information should only flow from high-integrity objects to low-integrity objects – not the other way around
- Dynamic access control models
  - Where the protection state changes with work being done
    - E.g. enforcing a workflow, enforcing Chinese walls

Conclusions

- Think of all these models as *design patterns* for policies
  - Specific applications will generally need a custom policy
  - **Exercise**: come up with policies for
    - A discussion forum
    - A social network site
    - …
- Security automata are a good tool to reason about and specify your policies
  - Some limited forms of automatic analysis might even be possible
    - E.g. safety analysis: can this user ever access this object?
    - But many of these questions will be undecidable in general