CS 591: Introduction to Computer Security

Lecture 4: Bell LaPadula

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Objectives

- Introduce the Bell LaPadula framework for confidentiality policy
- Discuss realizations of Bell LaPadula

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References:

- Bell retrospective
- Bishop Chapter 5
- Anderson

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Background

- Clearance levels
  - Top Secret
    - In-depth background check; highly trusted individual
  - Secret
    - Routine background check; trusted individual
  - For Official Use Only/Sensitive
    - No background check, but limited distribution; minimally trusted individuals
    - May be exempt from disclosure
  - Unclassified
    - Unlimited distribution
    - Untrusted individuals

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Background

- Clearance levels are only half the story
  - They give a level of trust of the subject
- The “need to know” policy provides an orthogonal structure called compartmentalization
- A category (or compartment) is a designation related to the “need to know” policy
- Examples:
  - NUC: Nuclear
  - EUR: Europe
  - ASI: Asia

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Categories and Coalitions

- Categories can be critical in complex coalitions
- The US may have two allies that do not wish to share information (perhaps Israel and Saudi Arabia)
- Policy must support:
  - Top Secret, Israel
  - Top Secret, Saudi Arabia
  - Top Secret, Israel and Saudi Arabia
    - (probably very few people in this set)

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Classification Systems

- Both notions of classification induce a partial order
  - TS is more trusted that S
  - You can only see information if you are cleared to access all categories that label it
- Mathematicians Bell and LaPadula picked a lattice structure as a natural model for security levels

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Partially Ordered Set

- A Set S with relation ≤ (written (S, ≤) is called a partially ordered set if ≤ is
  - Anti-symmetric
    - If a ≤ b and b ≤ a then a = b
  - Reflexive
    - For all a in S, a ≤ a
  - Transitive
    - For all a, b, c. a ≤ b and b ≤ c implies a ≤ c

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Poset examples

- Natural numbers with less than (total order)
- Sets under the subset relation (not a total order)
- Natural numbers ordered by divisibility

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Lattice

- Partially ordered set (S, ≤) and two operations:
  - greatest lower bound (glb X)
    - Greatest element less than all elements of set X
  - least upper bound (lub X)
    - Least element greater than all elements of set X
- Every lattice has
  - bottom (glb L) a least element
  - top (lub L) a greatest element

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Lattice examples

- Natural numbers in an interval (0 .. n) with less than
  - Also the linear order of clearances (U ≤ FOUO ≤ S ≤ TS)
- The powerset of a set of generators under inclusion
  - E.g. Powerset of security categories {NUC, Crypto, ASI, EUR}
- The divisors of a natural number under divisibility

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New lattices from old

- The opposite of a lattice is a lattice
- The product of two lattices is a lattice
- The lattice of security classifications used by Bishop is the product of the lattice of clearances and the lattice of sets generated from the categories (compartments)

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Mandatory Access Control

- In a MAC system all documents are assigned labels by a set of rules
- Documents can only be relabeled under defined special circumstances
- Violations of the policy are considered very serious offenses (criminal or treasonous acts)

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Bell LaPadula Context

- Pre-Anderson report policy was not to mix data of different classifications on a single system
- Still a good idea if it meets your needs
- Anderson report identified “on-line multi-level secure operation” as a goal of computer security

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From Paper to Computers

- How to apply MAC to computers?
- Documents are analogous to objects in Lampson's Access Control model
  - Every object can be labeled with a classification
- Cleared personnel are analogous to subjects
  - Every subject can be labeled with a clearance
- What about processes?

Note on subject labels

- A person is generally cleared "up to" a level
- Cross level communication requires that a person be able to interact below their level of clearance
- Subjects are given two labels:
  - The maximum level
  - The current level
- Current never exceeds maximum
- We will focus on static labelings
  - A subject will not dynamically change their current level

Bell LaPadula

- Task was to propose a theory of multi-level security
  - supported by a mechanism implemented in an Anderson-style reference monitor
  - prevents unwanted information flow

BLP model

- Adapt Lampson ACM
- Characterize system as state machine
- Characterize key actions, such as file system interaction, as transitions
  - Classify actions as
    - observation (reads)
    - alteration (writes)
    - [Aside: How to classify execute?]
- Show that only “safe states” are reachable

Simple Security

- The simple security property
  - The current level of a subject dominates the level of every object that it observes
- This property strongly analogous to paper systems
- It is referred to by the slogan “no read up”

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Problem

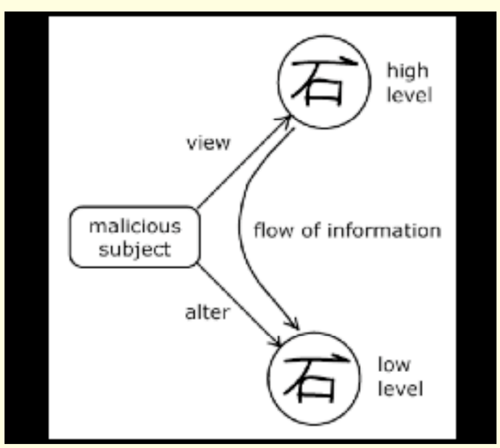

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Figure from Bell 2005

Problem

- Simple Security does not account for alterations (writes)
- Another property is needed to characterize alterations

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* - Property

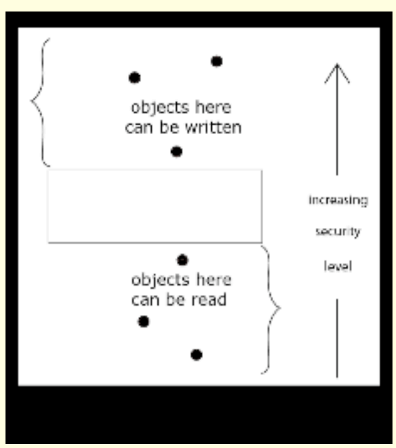

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Figure from Bell 2005

*- Property

- In any state, if a subject has simultaneous "observe" access to object-1 and "alter" access to object-2, then level (object-1) is dominated by level (object-2).
  - From BLP 1976, Unified Exposition
- Slogan: "No write down"

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Discretionary

- In addition to the MAC mechanisms of the simple security and *-properties, the BLP model also has a discretionary component
  - All accesses must be allowed by both the MAC and discretionary rules

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BLP Basic Security Theorem

- If all transitions (consdiered individually) satisfy
  - simple security property
  - * - property
  - discretionary security property
- Then system security is preserved inductively (that is, all states reached from a “secure” state are “secure”)

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Bell Retrospective

- Note: This presentation and Bishop largely follow “unified exposition”
- How did the *-property evolve?
- Where did current security level come from?

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Bell Discussion

- What was the motivating example of a "trusted subject"
  - Explain the concept
  - How must the BLP model be adapted?
- Bell's paper changes mode in Section 5
  - transitions from description of BLP to reflections on impact
  - Will return to these topics periodically

Systems Built on BLP

- BLP was a simple model
- Intent was that it could be enforced by simple mechanisms
- File system access control was the obvious choice
- Multics implemented BLP
- Unix inherited its discretionary AC from Multics

BLP in action

- Bishop describes Data General B2 UNIX system in detail
  - Treatment addresses:
    - Explicit and implicit labeling (applied to removable media)
    - Multilevel directory management
      - Consider challenges of a multilevel /tmp with traditional UNIX compilation tools
    - MAC Regions (intervals of levels)

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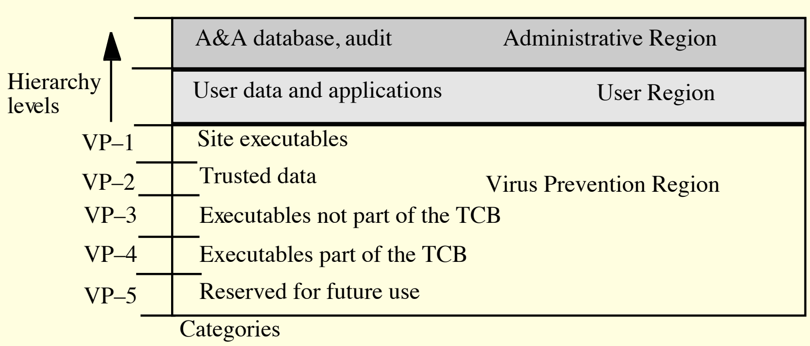
MAC Regions



IMPL_HI is "maximum" (least upper bound) of all levels
IMPL_LO is "minimum" (greatest lower bound) of all levels

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Slide from Bishop "05.ppt"

Discussion

- When would you choose to apply a model this restrictive?

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Further Reading

- Ross Anderson's *Security Engineering*, Chapter 7: Multilevel security
  - Standard Criticisms
  - Alternative formulations
  - Several more examples

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Criticisms of Bell LaPadula

- BLP is straightforward, supports formal analysis
- Is it enough?
- McLean wrote a critical paper asserting BLP rules were insufficient

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McLean's System Z

- Proposed System Z = BLP + (request for downgrade)
- User L gets file H by first requesting that H be downgraded to L and then doing a legal BLP read
- Proposed fix: tranquility
  - Strong: Labels never change during operation
  - Weak: Labels never change in a manner that would violate a defined policy

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Alternatives

- Goguen & Meseguer, 1982: Noninterference
  - Model computation as event systems
  - Interleaved or concurrent computation can produce interleaved traces
  - High actions have no effect on low actions
    - The trace of a "low trace" of a system is the same for all "high processes" that are added to the mix
  - Problem: Needs deterministic traces; does not scale to distributed systems

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Nondeducibility

- Sutherland, 1986.
  - Low can not deduce anything about high with 100% certainty
  - Historically important, hopelessly weak
  - Addressed issue of nondeterminism in distributed systems

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Intranstitive non-interference

- Rushby, 1992
  - Updates Goguen & Meseguer to deal with the reality that some communication may be authorized (e.g. High can interefere with low if it is mediated by crypto)

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Looking forward

- Chapter 6: Integrity Policies

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