Lecture 19: Mandatory Access Control

CS 181S

Fall 2020

Review: Access control

- Subject: principal to which execution can be attributed
- Object: data or resource
- Operation: performed by subject on object
- Right: entitlement to perform operation

Review: DAC

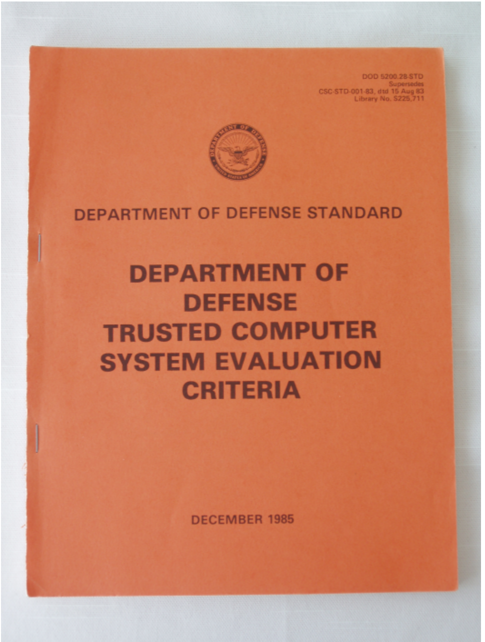
- Discretionary access control (DAC)
  - **Philosophy:** users have the *discretion* to specify policy themselves
  - Commonly, information belongs to the **owner** of object
  - Model: access control **relation**
    - Set of triples (subj,obj,rights)
    - Sometimes described as access control "matrix"
- Implementations:
  - Access control lists (ACLs): each object associated with list of (subject, rights)
  - Capability lists: each subject associated with list of (object, rights)
  - Capabilities: distributed ways of implementing privilege lists

MAC

- Mandatory access control (MAC)
  - **philosophy:** central authority *mandates* policy
  - information belongs to the authority, not to the individual users
  - not Message Authentication Code (applied crypto), nor Media Access Control (networking)

Multi-Level Security

- A mechanism for monitoring access control in a system where both principals and objects have security labels drawn from a hierarchy of labels
- Commonly associated with military systems
- Influenced "Orange Book" (DoD Trusted Computer System Evaluation Criteria)
  - A) Verified Protection
  - B) Mandatory Protection
  - C) Discretionary Protection
  - D) Minimal Protection



Sensitivity

- Concern is **confidentiality** of information
- Documents classified according to sensitivity: risk associated with release of information
- In US:
  - Top Secret
  - Secret
  - Confidential
  - Unclassified

Compartments

- Documents classified according to compartment(s): categories of information (in fact, aka category)
  - cryptography
  - nuclear
  - biological
  - reconnaissance
- **Need to Know Principle:** access should be granted only when necessary to perform assigned duties (instance of Least Privilege)
  - {crypto, nuclear}: must need to know about **both** to access
  - {}: no particular compartments

Labels

- Label: pair of sensitivity level and set of compartments, e.g.,
  - (Top Secret, {crypto, nuclear})
  - (Unclassified, {})
- Document is labeled aka classified
  - Perhaps each paragraph labeled
  - Label of document is most restrictive label for any paragraph
- Users are labeled according to their clearance
  - Users trustworthy by virtue of vetting process for security clearance
  - Out of scope (e.g.): user who views Top Secret information and calls the *Washington Post*
- Labels are imposed by organization
- **Notation:** let L(X) be the label of entity X

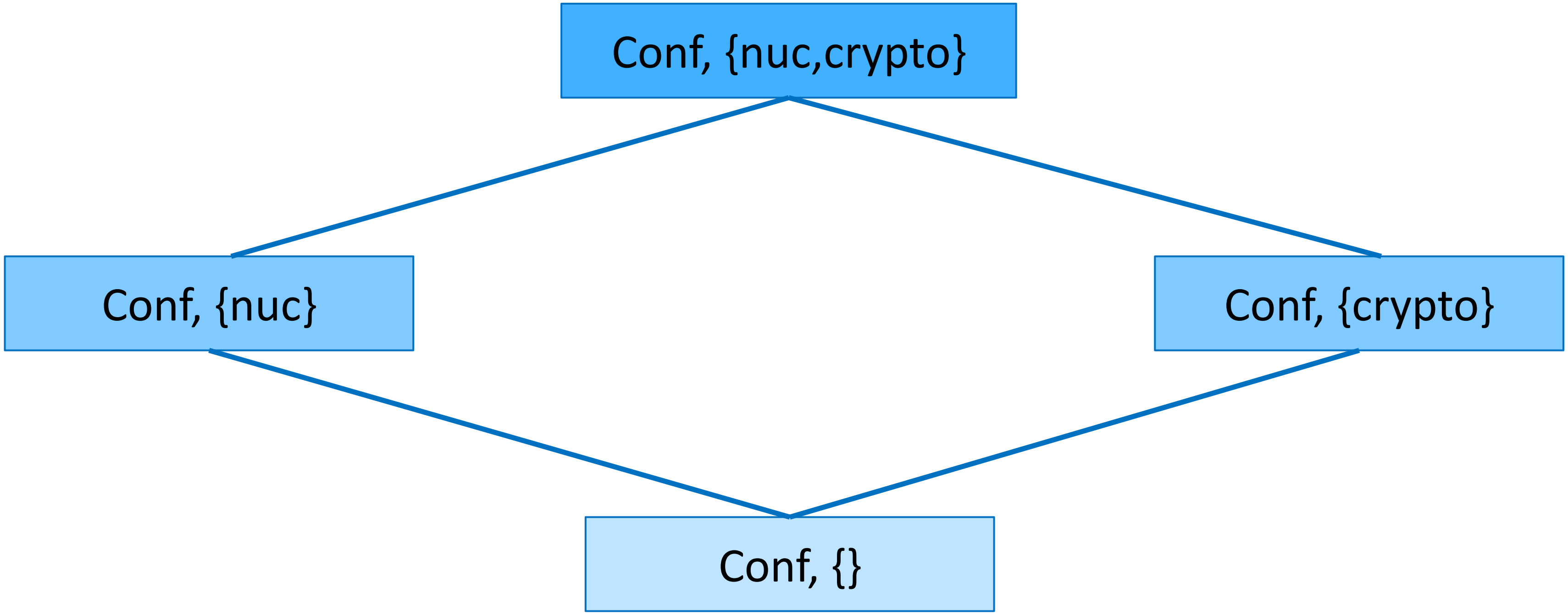
Restrictiveness of labels

Notation: $L1 \sqsubseteq L2$

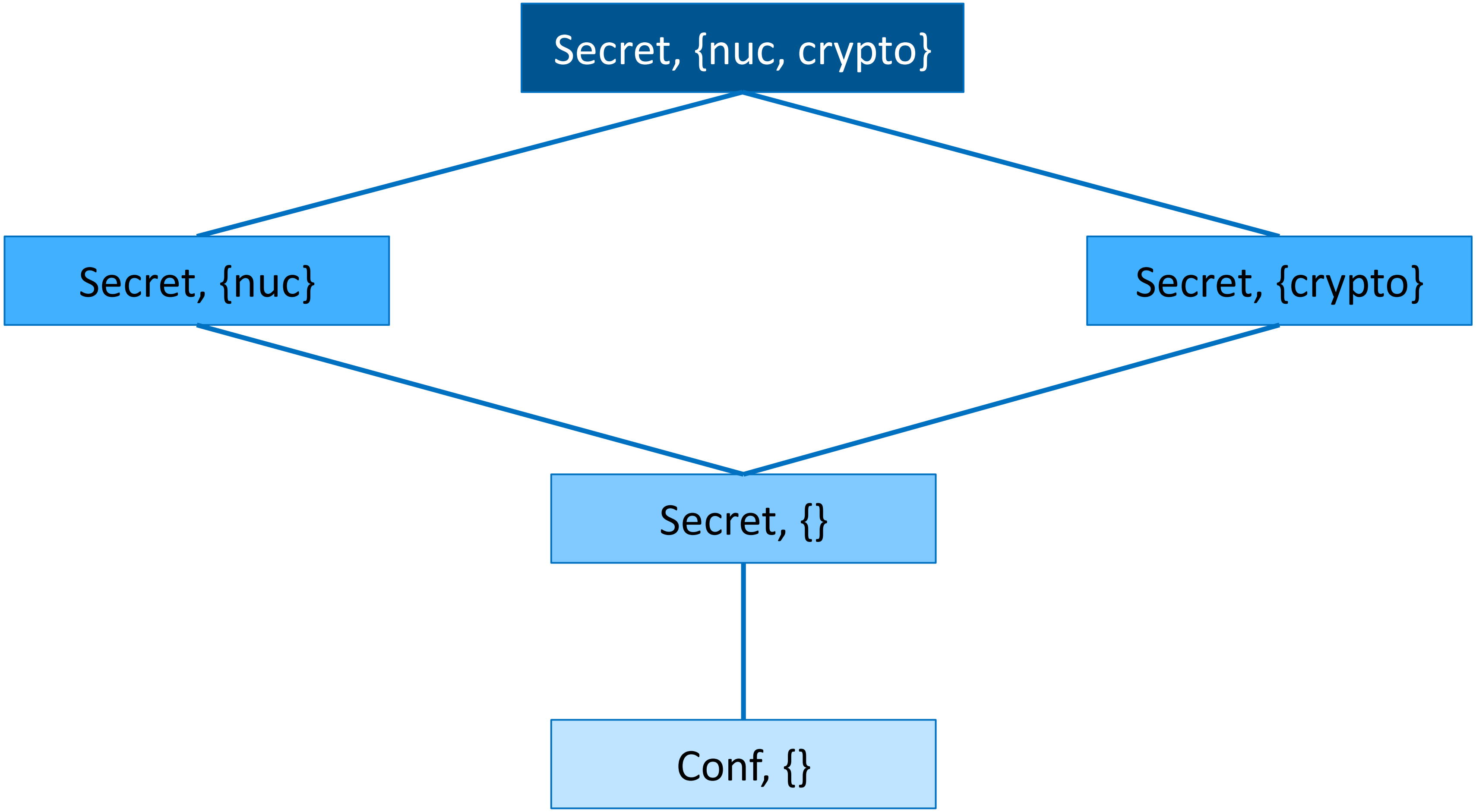
- means L1 is less (or equally) restrictive than L2

- **Definition:**
  - Let L1 = (S1, C1) and L2 = (S2, C2)
  - $L1 \sqsubseteq L2$ iff $S1 \leq S2$ and $C1 \subseteq C2$
  - Where ≤ is order on sensitivity:
    Unclassified ≤ Confidential ≤ Secret ≤ Top Secret
- e.g.
  - (Unclassified,{}) ⊑ (Top Secret, {})
  - (Top Secret, {crypto}) ⊑ (Top Secret, {crypto,nuclear})

Label partial order



Label partial order



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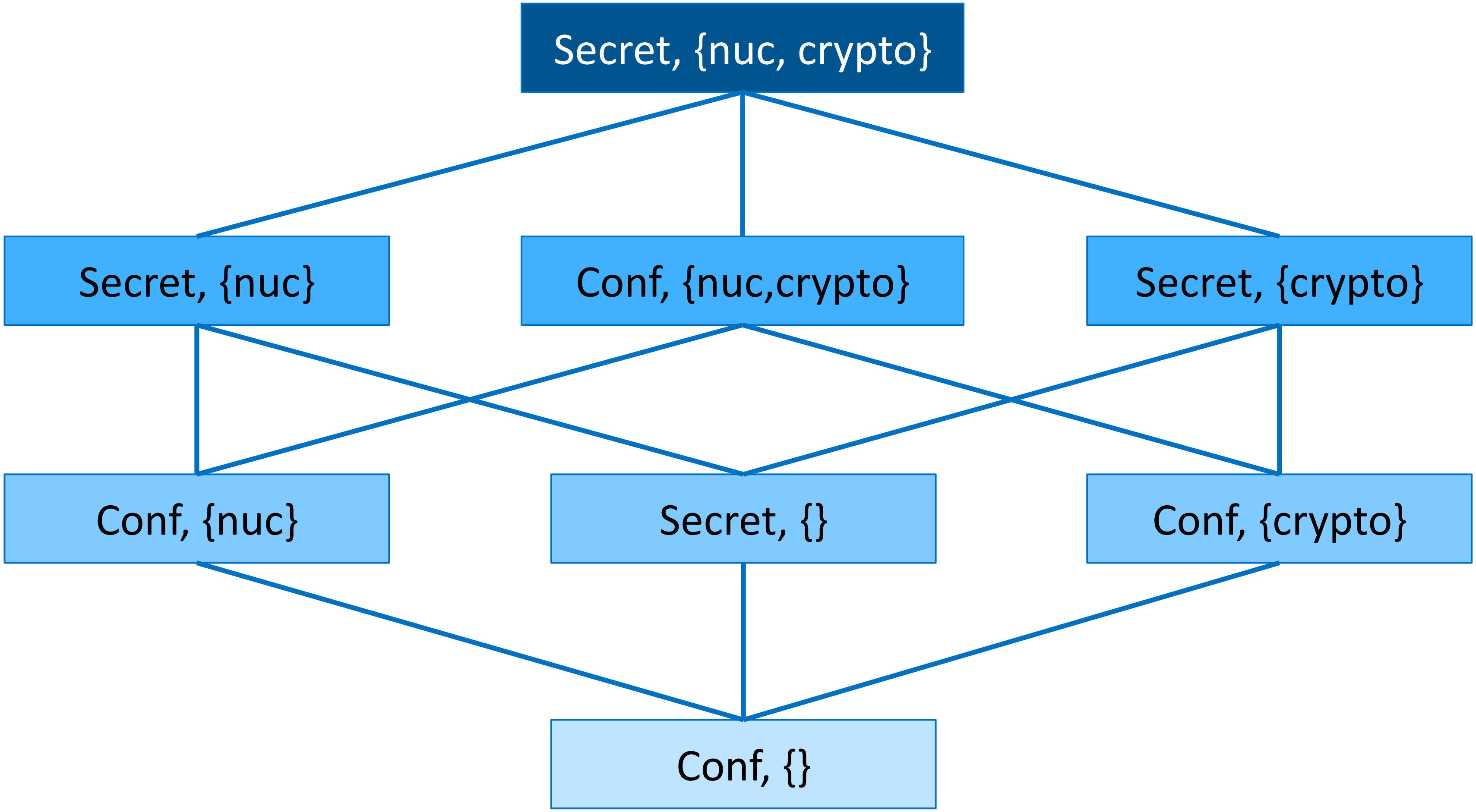

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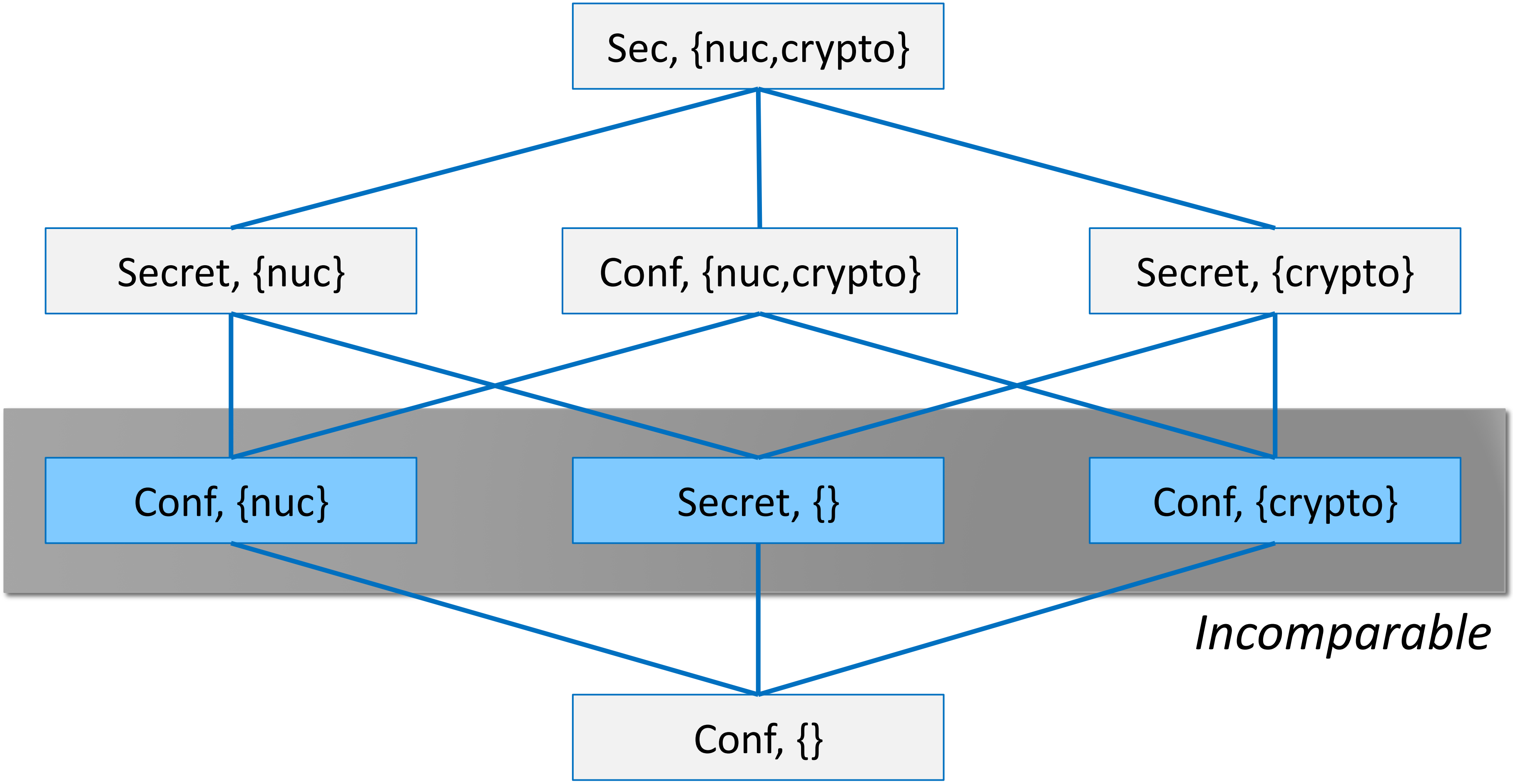
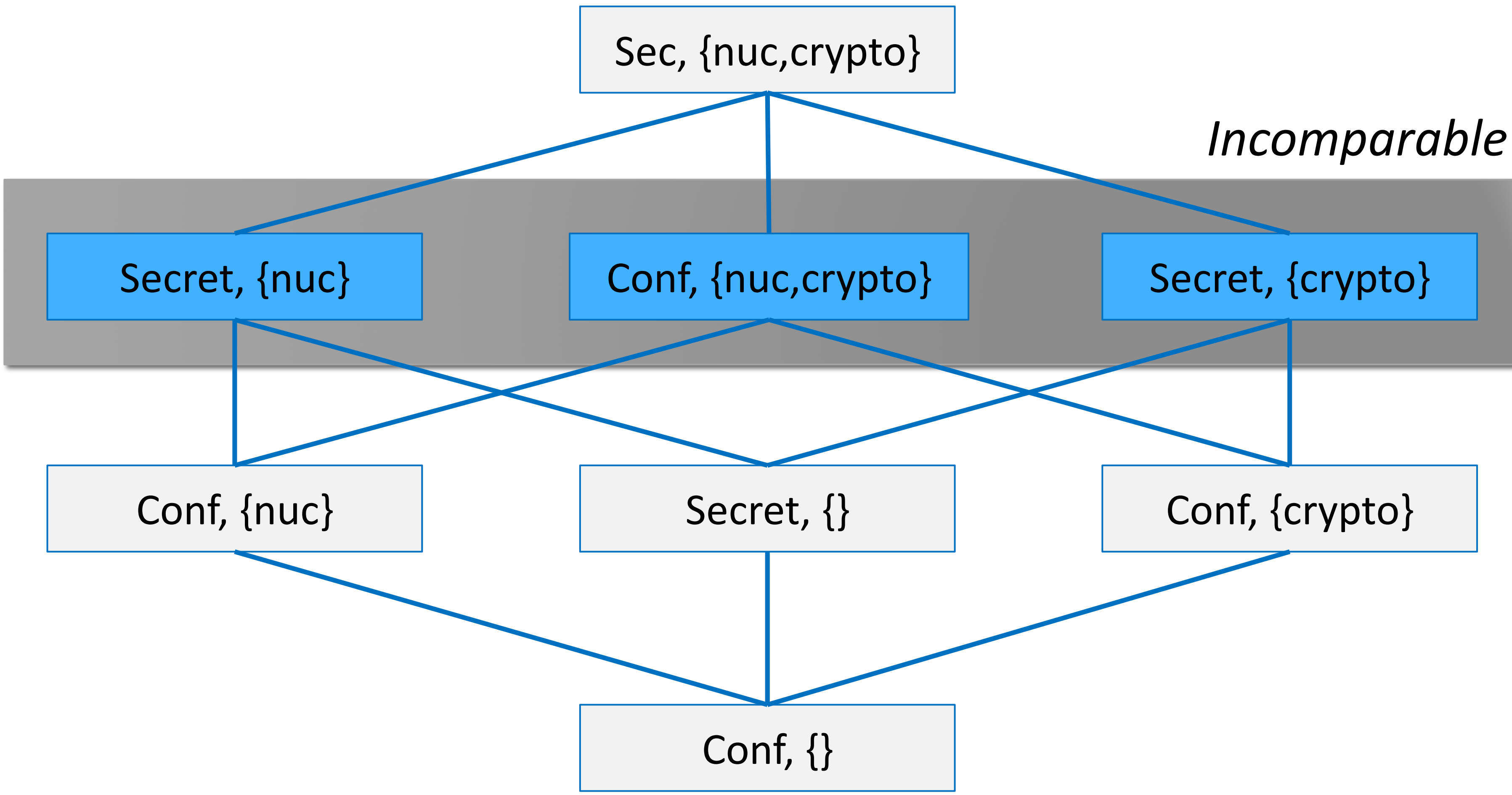


Label partial order



Exercise 1: Label Partial Order

- For each pair of labels, determine whether L1 $\sqsubseteq$ L2, L2 $\sqsubseteq$ L1, or neither

1. L1= (Conf, {}), L2 = (Secret, {crypto})

2. L1 = (Conf, {nuc}), L2 = (Secret, {crypto})

3. L1 = (Secret, {nuc,crypto}), L2= (Conf, {crypto}

Access control with MLS

- When may a subject read an object?
  - **Threat:** subject attempts to read information for which it is not cleared
  - e.g., subject with clearance Unclassified attempts to read Top Secret information

- When may a subject write an object?

Access control with MLS

- When may a subject read an object?
  - **S may read O iff $L(O) \sqsubseteq L(S)$**
  - object's classification must be below (or equal to) subject's clearance
  - "no read up"
- When may a subject write an object?

Exercise 2: Reading with MLS

- Scenario:
  - Colonel with clearance (Secret, {nuclear, Europe})
  - DocA with classification (Confidential, {nuclear})
  - DocB with classification (Secret, {Europe, US})
  - DocC with classification (Top Secret, {nuclear, Europe})
- Which documents may Colonel **read**?
  - Recall: S may read O iff $L(O) \sqsubseteq L(S)$
  - DocA: (Confidential, {nuclear}) $\sqsubseteq$ (Secret, {nuclear, Europe})
  - DocB: (Secret, {Europe, US}) $\not\sqsubseteq$ (Secret, {nuclear, Europe})
  - DocC: (Top Secret, {nuclear, Europe}) $\not\sqsubseteq$ (Secret, {nuclear, Europe})

Access control with MLS

- When may a subject read an object?
  - **S may read O iff L(O) ⊑ L(S)**
  - object's classification must be below (or equal to) subject's clearance
  - "no read up"
- When may a subject write an object?
  - **Threat:** subject attempts to *leak* information by writing into a lower-security object
  - e.g., subject with clearance Top Secret reads Top Secret information then writes it into an Unclassified file

Access control with MLS

- When may a subject read an object?
  - **S may read O iff $L(O) \sqsubseteq L(S)$**
  - object's classification must be below (or equal to) subject's clearance
  - "no read up"
- When may a subject write an object?
  - **S may write O iff $L(S) \sqsubseteq L(O)$**
  - object's classification must be above (or equal to) subject's clearance
  - "no write down"

Exercise 3: Writing with MLS

- Scenario:
  - Colonel with clearance (Secret, {nuclear, Europe})
  - DocA with classification (Confidential, {nuclear})
  - DocB with classification (Secret, {Europe, US})
  - DocC with classification (Top Secret, {nuclear, Europe})
- Which documents may Colonel **write**?
  - Recall: S may write O iff $L(S) \sqsubseteq L(O)$
  - DocA: (Secret, {nuclear, Europe}) $\not\sqsubseteq$ (Confidential, {nuclear})
  - DocB: (Secret, {nuclear, Europe}) $\not\sqsubseteq$ (Secret, {Europe, US})
  - DocC: (Secret, {nuclear, Europe}) $\sqsubseteq$ (Top Secret, {nuclear, Europe})

Reading and writing with MLS

- Scenario:
  - Colonel with clearance (Secret, {nuclear, Europe})
  - DocA with classification (Confidential, {nuclear})
  - DocB with classification (Secret, {Europe, US})
  - DocC with classification (Top Secret, {nuclear, Europe})
- Summary:
  - DocA: Colonel may read but not write
  - DocB: Colonel may neither read nor write
  - DocC: Colonel may write but not read

Perplexities of writing with MLS

1. Blind write: subject may not read higher-security object yet may write it
   - Useful for logging
   - Some implementations prohibit writing up as well as writing down
2. **User** who wants to write lower-security object may not
   - **Attenuation of privilege:** login at a lower security level than clearance
   - Motivated by Trojan Horse
   - Nice (annoying?) application of Least Privilege
3. Declassification violates "no write down"
   - Encryption or billing procedure produces (e.g.) Unclassified output from Secret information
   - Traditional solution is trusted subjects who are not constrained by access control rules

Formalizing MLS

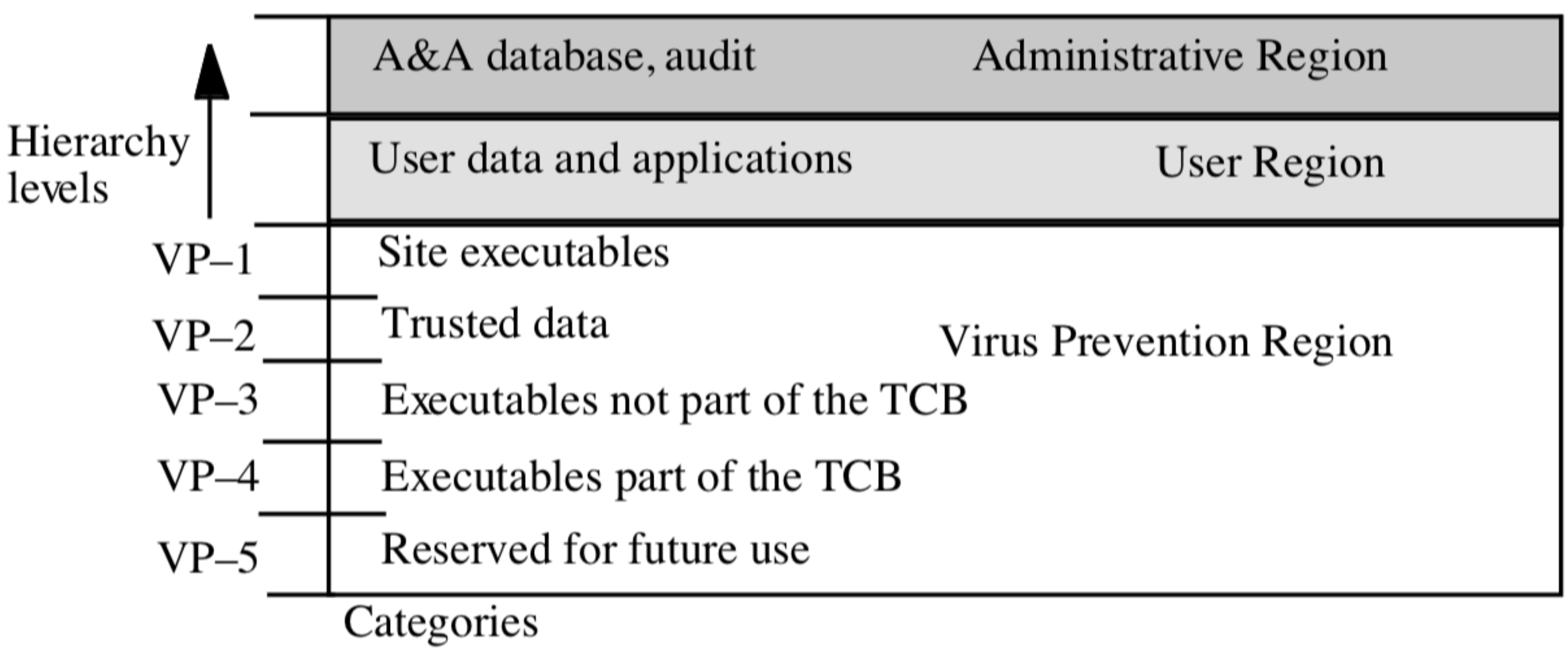
[Bell and LaPadula 1973]

- Formal mathematical model of MLS plus access control matrix
- Proof that information cannot leak to subjects not cleared for it
- "No read up": simple security property
- "No write down": *-property
- *"The influence of [BLP] permeates all policy modeling in computer security"* –Matt Bishop
  - Influenced Orange Book
  - Led to research field "foundations of computer security”

MLS in OSs

DG/UX

- Discontinued Unix OS, release 1985
- Three regions:
  Virus Protection $\sqsubseteq$ User Region $\sqsubseteq$ Administrative Region



MLS in OSs

DG/UX

- Discontinued Unix OS, release 1985
- Three regions:
  Virus Protection $\sqsubseteq$ User Region $\sqsubseteq$ Administrative Region
- MLS confidentiality: read down, no read up
- Extra integrity: no write down, no write up
  - for shared directories (e.g., /tmp), introduced mulit-level directories with one hidden subdirectory for each level

MLS in OSs

SELinux

- Kernel security module, dates back to NSA c. 2000, merged with Linux kernel mainline in 2.6
- Goal: separate security policy from security decisions
- Supports mandatory access controls in reference policy. When MLS is enabled:
  - Each principal (user or process) is assigned a context
    (username, role, domain, (sensitivity))
  - Each object (file, port, hardware) is assigned a context
  - SELinux enforces MLS

MLS in OSs

TrustedBSD [2000]

- Similar goals to SELinux: separate policy from security mechanism, implements MLS
- ported parts of SELinux to FreeBSD
- Many components eventually folded into FreeBSD
- Most interfaces supported on Macs since OSX 10.5

BLP, for integrity

- BLP is about confidentiality
- Adapted to integrity by Biba [1977]: same rules, different lattice
  - Instead of Unclassified and Secret, labels could be Untrusted and Trusted
- L1 ⊑ L2 means "L1 may flow to L2 without breaking confidentiality"
  - BLP: low secrecy sources may flow to high secrecy sinks
    - Hence Unclassified ⊑ Secret, but not v.v.
  - Biba: low integrity sources may not flow to high integrity sinks
    - Hence Trusted ⊑ Untrusted, but not v.v.
  - High vs. low is "flipped" (lattices are *duals*)

Biba model

- **S may read O iff $L(O) \sqsubseteq L(S)$**
  - E.g., Trusted subject cannot read Untrusted object
  - But Untrusted subject may read Trusted object
- **S may write O iff $L(S) \sqsubseteq L(O)$**
  - E.g., Trusted subject may write Untrusted object
  - But Untrusted subject may not write Trusted object

Beyond Multi-level Security…

Mandatory access control comes in many different forms (not just MLS):

1. Multi-level security (confidentiality, military)
2. Biba model (integrity, military)
3. Role-based access control (hybrid, organization)
4. Clark-Wilson (integrity, business)
5. Brewer-Nash (hybrid, consulting firm)

Exercise 4: Feedback

1. Rate how well you think this recorded lecture worked
    1. Better than an in-person class
    2. About as well as an in-person class
    3. Less well than an in-person class, but you still learned something
    4. Total waste of time, you didn't learn anything

2. How much time did you spend on this video lecture (including time spent on exercises)?

3. Do you have particular questions you would like me to address class?

4. Do you have any other comments or feedback?