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TOPIC

LATTICE-BASED
ACCESS-CONTROL MODELS

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LATTICE-BASED MODELS

- **Denning's axioms**
- **Bell-LaPadula model (BLP)**
- **Biba model and its duality (or equivalence) to BLP**
- **Dynamic labels in BLP**

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DENNING'S AXIOMS

< SC, $\rightarrow$, $\oplus$ >

SC	**set of security classes**
$\rightarrow \subseteq$ SC X SC	**flow relation (i.e., can-flow)**
$\oplus$: SC X SC -> SC	**class-combining operator**

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DENNING'S AXIOMS

< SC, $\rightarrow$, $\oplus$ >

1 **SC is finite**

2 **$\rightarrow$ is a partial order on SC**

3 **SC has a lower bound L such that L $\rightarrow$ A for all A $\in$ SC**

4 **$\oplus$ is a least upper bound (lub) operator on SC**

Justification for 1 and 2 is stronger than for 3 and 4. In practice we may therefore end up with a partially ordered set (poset) rather than a lattice.

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DENNING'S AXIOMS IMPLY

- **SC is a universally bounded lattice**
- **there exists a Greatest Lower Bound (glb) operator $\otimes$ (also called meet)**
- **there exists a highest security class H**

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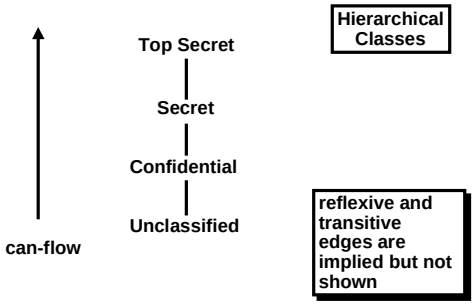
LATTICE STRUCTURES



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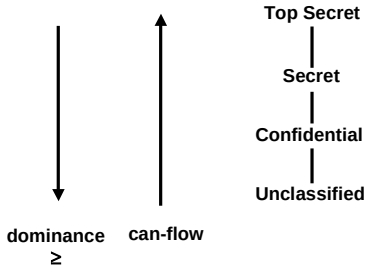
LATTICE STRUCTURES



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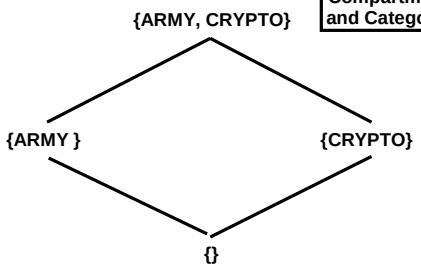
LATTICE STRUCTURES

Compartments and Categories



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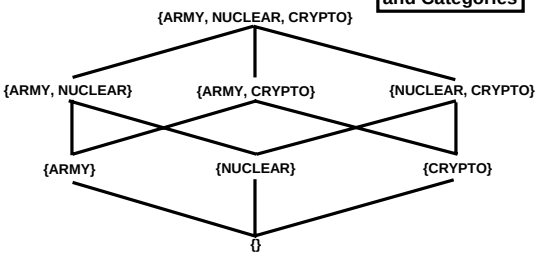
LATTICE STRUCTURES

Compartments and Categories



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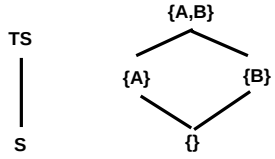
LATTICE STRUCTURES

Hierarchical Classes with Compartments



product of 2 lattices is a lattice

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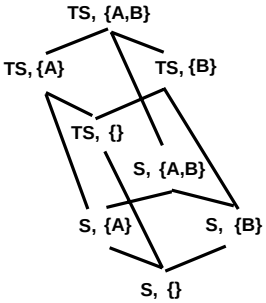
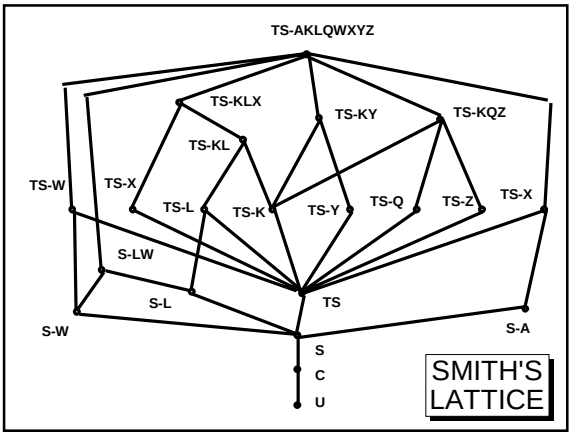
LATTICE STRUCTURES

Hierarchical Classes with Compartments





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SMITH'S LATTICE

- With large lattices a vanishingly small fraction of the labels will actually be used
  - Smith's lattice: 4 hierarchical levels, 8 compartments, therefore

    number of possible labels = 4*2^8 = 1024

    Only 21 labels are actually used (2%)
  - Consider 16 hierarchical levels, 64 compartments which gives 10^20 labels

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EMBEDDING A POSET IN A LATTICE

- Smith's subset of 21 labels do form a lattice. In general, however, selecting a subset of labels from a given lattice
  - may not yield a lattice, but
  - is guaranteed to yield a partial ordering
- Given a partial ordering we can always add extra labels to make it a lattice

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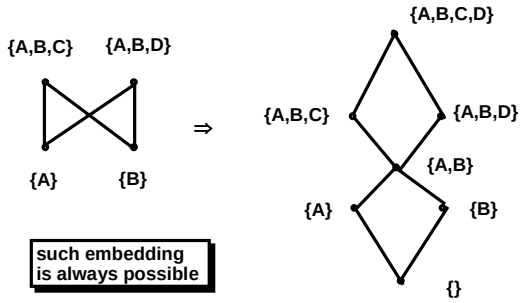
EMBEDDING A POSET IN A LATTICE



such embedding is always possible

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BLP BASIC ASSUMPTIONS

- SUB = {S1, S2, ..., Sm}, a fixed set of subjects
- OBJ = {O1, O2, ..., On}, a fixed set of objects
- R ⊇ {r, w}, a fixed set of rights
- D, an m × n discretionary access matrix with D[i,j] ⊆ R
- M, an m × n current access matrix with M[i,j] ⊆ {r, w}

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BLP MODEL

- Lattice of confidentiality labels

  $\Lambda = \{\lambda 1, \lambda 2, ..., \lambda p\}$
- Static assignment of confidentiality labels

  λ: SUB ∪ OBJ → Λ
- M, an m × n current access matrix with
  - $r \in M[i,j] \Rightarrow r \in D[i,j] \wedge \lambda(Si) \geq \lambda(Oj)$ simple security
  - $w \in M[i,j] \Rightarrow w \in D[i,j] \wedge \lambda(Si) \leq \lambda(Oj)$ star-property

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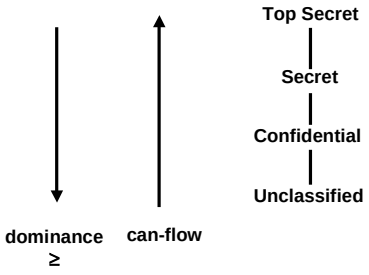
BLP MODEL



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STAR-PROPERTY

- applies to subjects not to users
- users are trusted (must be trusted) not to disclose secret information outside of the computer system
- subjects are not trusted because they may have Trojan Horses embedded in the code they execute
- star-property prevents overt leakage of information and does not address the covert channel problem

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BIBA MODEL

- Lattice of integrity labels

  $\Omega = \{\omega 1, \omega 2, ..., \omega q\}$
- Assignment of integrity labels

  ω: SUB $\cup$ OBJ $\rightarrow \Omega$
- M, an m $\times$ n current access matrix with
  - $r \in M[i,j] \Rightarrow r \in D[i,j] \wedge \omega(Si) \leq \omega(Oj)$ simple integrity
  - $w \in M[i,j] \Rightarrow w \in D[i,j] \wedge \omega(Si) \geq \omega(Oj)$ integrity confinement

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EQUIVALENCE OF BLP AND BIBA

- Information flow in the Biba model is from top to bottom
- Information flow in the BLP model is from bottom to top
- Since top and bottom are relative terms, the two models are fundamentally equivalent

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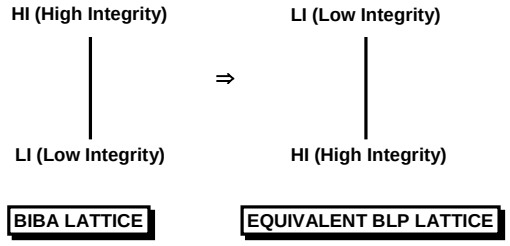
EQUIVALENCE OF BLP AND BIBA



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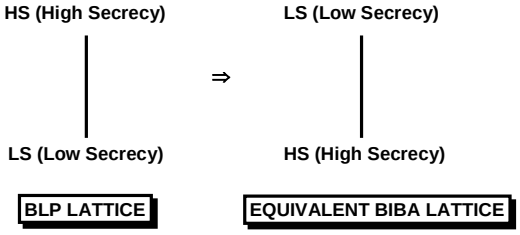
EQUIVALENCE OF BLP AND BIBA



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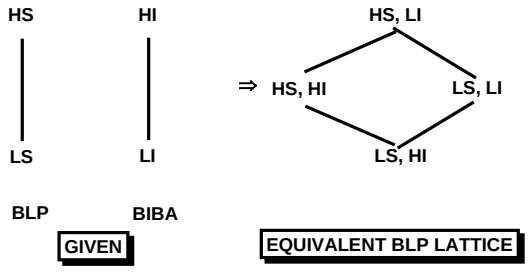
COMBINATION OF DISTINCT LATTICES



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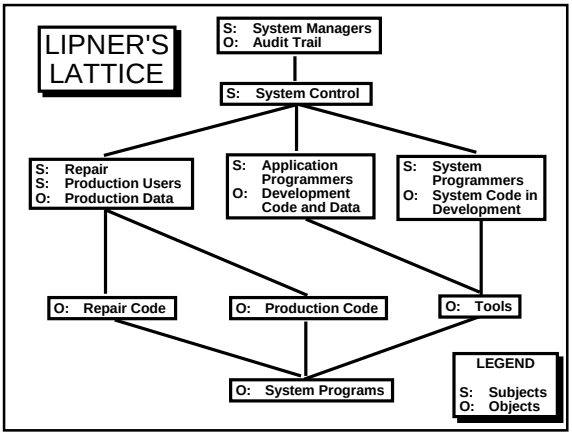
BLP AND BIBA

- **BLP and Biba are fundamentally equivalent and interchangeable**
- **Lattice-based access control is a mechanism for enforcing one-way information flow, which can be applied to confidentiality or integrity goals**
- **We will use the BLP formulation with high confidentiality at the top of the lattice, and high integrity at the bottom**



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LIPNER'S LATTICE

- **Lipner's lattice uses 9 labels from a possible space of 192 labels (3 integrity levels, 2 integrity compartments, 2 confidentiality levels, and 3 confidentiality compartments)**
- **The single lattice shown here can be constructed directly from first principles**

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LIPNER'S LATTICE

- **The position of the audit trail at lowest integrity demonstrates the limitation of an information flow approach to integrity**
- **System control subjects are exempted from the star-property and allowed to**
  - **write down (with respect to confidentiality)**

  or equivalently
  - **write up (with respect to integrity)**

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DYNAMIC LABELS IN BLP

- **Tranquility (most common):**
  λ is static for subjects and objects
- **BLP without tranquility may be secure or insecure depending upon the specific dynamics of labelling**
- **Noninterference can be used to prove the security of BLP with dynamic labels**

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DYNAMIC LABELS IN BLP

- **High water mark on subjects:**
  λ is static for objects
  λ may increase but not decrease for subjects

  Is secure and is useful
- **High water mark on objects:**
  λ is static for subjects
  λ may increase but not decrease for subjects

  Is insecure due to disappearing object signaling channel

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REFERENCES

- **Ravi Sandhu, "Lattice-Based Access Control Models." Manuscript handed out in class**

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