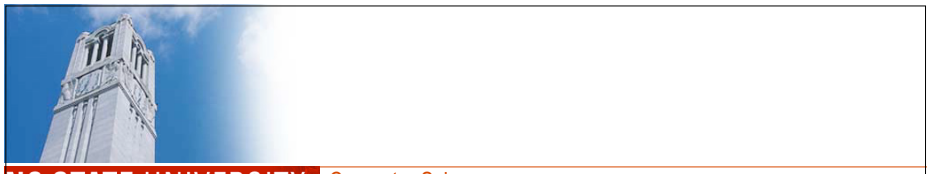


NC STATE UNIVERSITY Computer Science

CSC 474/574 Information Systems Security

Topic 4.2: Lattice Based Access Control Models

LATTICE-BASED MODELS

- Information flow policies
  - Denning's axioms
- Bell-LaPadula model (BLP)
- Biba model and its duality (or equivalence) to BLP

Information Flow Policies

- Concerned with the flow of information from one *security class* to another.
  - Not between objects
  - Does such a policy care about
    - Information from *top secret class* to *secret class*?
    - Information from *file A* to *file B*?
- Approach
  - Assign each object a security class (also called a security label).
  - Control information flow between objects based on their labels.
- Information flows from security class A to security class B
  - Information flows from an object labeled A to an object labeled B.

Denning's Definition of Information Flow Policy

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

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

Intuitions:

A$\rightarrow$B: Information can flow from security class A to security class B.

A$\oplus$B$\rightarrow$C: Information combined from A and B can flow to C.

Example 1

- High-low policy
  - Information can only flow between each class and from low class to high class, but not from high class to low class
- In Denning's formalism:
  - SC={H, L}
  - →={_____, _____, _____}
  - ⊕={H ⊕ H=___, H⊕ L=___, L ⊕ H=___, L ⊕ L=___}

Example 2

- Policy
  - Two departments A and B.
  - Four security classes
    - {}: Public information
    - {A}: Only people working in A can access
    - {B}: Only people working in B can access.
    - {A, B}: Only people working in both A and B can access.
  - Never disclose any secret information.
- In Denning's formalism:
  - SC = {____, ____, ____, ____}
  - →={_____, _____, _____, _____, _____, _____, _____, _____, _____}
  - ⊕={_____, _____, _____, _____, _____, _____}

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 totally defined least upper bound operator on SC

DENNING'S AXIOMS (Cont'd)

- Axiom 2: $\rightarrow$ is a partial order on SC
  - $\rightarrow$ is reflexive:
    - For all A in SC, A→A.
    - Intuition: Information can flow within each class.
  - $\rightarrow$ is transitive:
    - If A→B and B→C, then A→C.
    - Intuition: If indirect flow is possible from A to C via B, then we should allow directly information flow from A to C.
    - Not always desirable.
  - $\rightarrow$ is anti-symmetric:
    - If A→B and B→A, then A=B.
    - Intuition: We don't need redundant classes.
    - Equivalently, if A→B and A!=B, then B !→ A.

Example 3

- Which of the following are partial orders?
  - {A, B, C}, A→B, B→C, A→C
  - {A, B, C}, A→A, B→B, C→C
  - {A, B, C}, A→A, B→B, C→C, A→B

DENNING'S AXIOMS (Cont'd)

- Axiom 3: SC has a lower bound L such that L→A for all A in SC.
  - Existence of public information in the system.

DENNING'S AXIOMS (Cont'd)

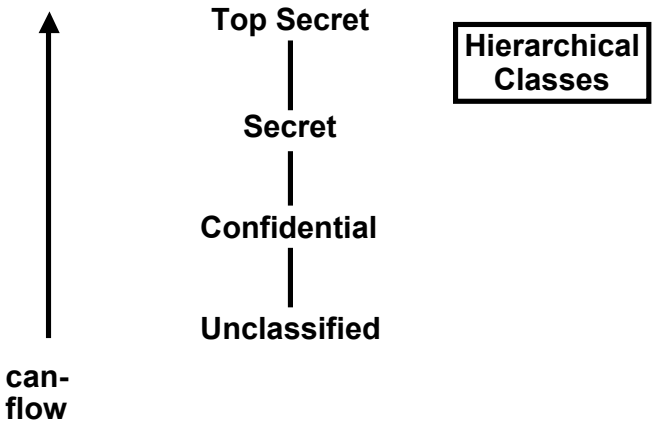
- Axiom 4: $\oplus$ is a totally defined least upper bound (lub) operator on SC
  - A $\oplus$ B is defined for each pair of A and B in SC.
    - Intuition: It is possible to combine information from any two classes.
  - The $\oplus$ operator is a least upper bound
    - A$\rightarrow$A $\oplus$ B and B$\rightarrow$A $\oplus$ B for all A, B in SC
    - If A$\rightarrow$C and B$\rightarrow$C, then A $\oplus$ B$\rightarrow$C.
      - A $\oplus$ B is the least one among all the upper bounds of A and B.
  - The $\oplus$ operator can be applied to any number of security classes.

DENNING'S AXIOMS IMPLY

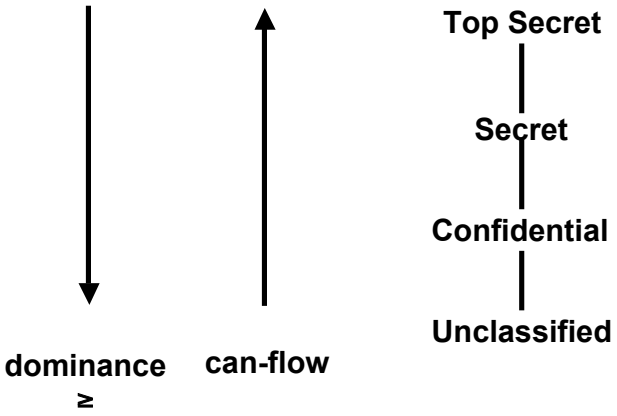
- SC is a universally bounded lattice
- there exists a Greatest Lower Bound (glb) operator $\otimes$ (also called meet)
- there exists a highest security class H

LATTICE STRUCTURES

- reflexive and transitive edges are implied but not shown



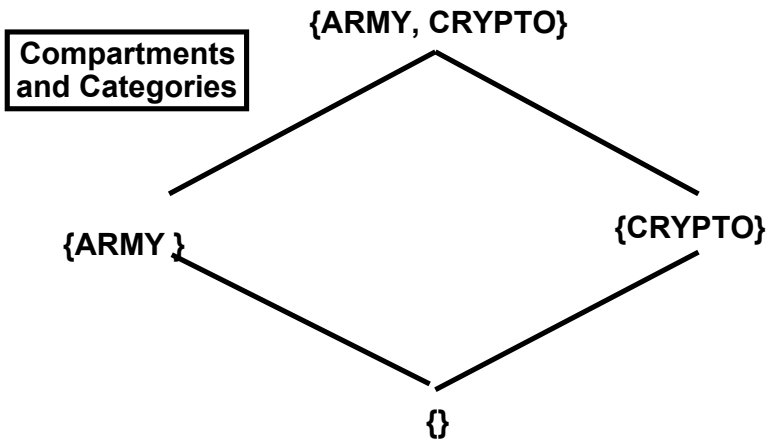
LATTICE STRUCTURES



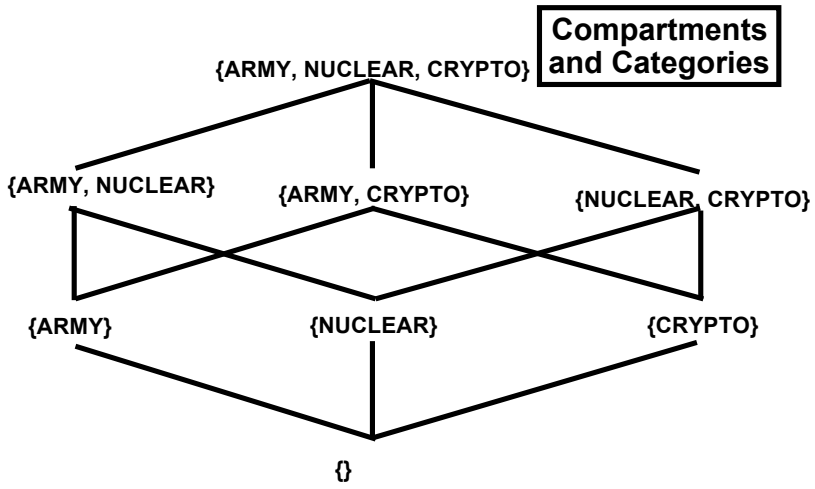
Categories and Compartments

- Categories: individual elements
- Compartments: set of categories.
  - The set of compartments is the power set of the set of categories.
  - Compartments form a subset lattice over the set of categories.
- Example:
  - The set of categories: {A, B}
  - The set of Compartments:
    - {_____, _____, _____, _____}

LATTICE STRUCTURES



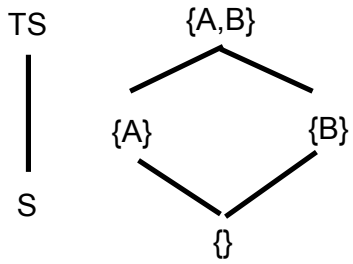
LATTICE STRUCTURES



Combining Different Lattices

- Two lattices L1= (SC1, →, ⊗) and L2 = (SC2, →, ⊗) can be combined into L = (SC, →, ⊗) as follows:
  - SC = SC1 × SC2
    - Intuition: The result security classes are all combinations of those in L1 and L2.
  - For (c1, c2) and (c1', c2') in SC, (c1, c2) → (c1', c2') if and only if c1→c1' and c2→c2'.
    - Intuition: Information can flow from (c1, c2) to (c1', c2') if and only if L1 permits information flow from c1 to c1' and L2 permits information flow from c2 to c2'
  - (c1, c2) ⊗ (c1', c2') = (c1 ⊗ c1', c2 ⊗ c2').
    - Intuition: Combining security classes in L is equivalent to combining security classes in L1 and L2 separately.

LATTICE STRUCTURES

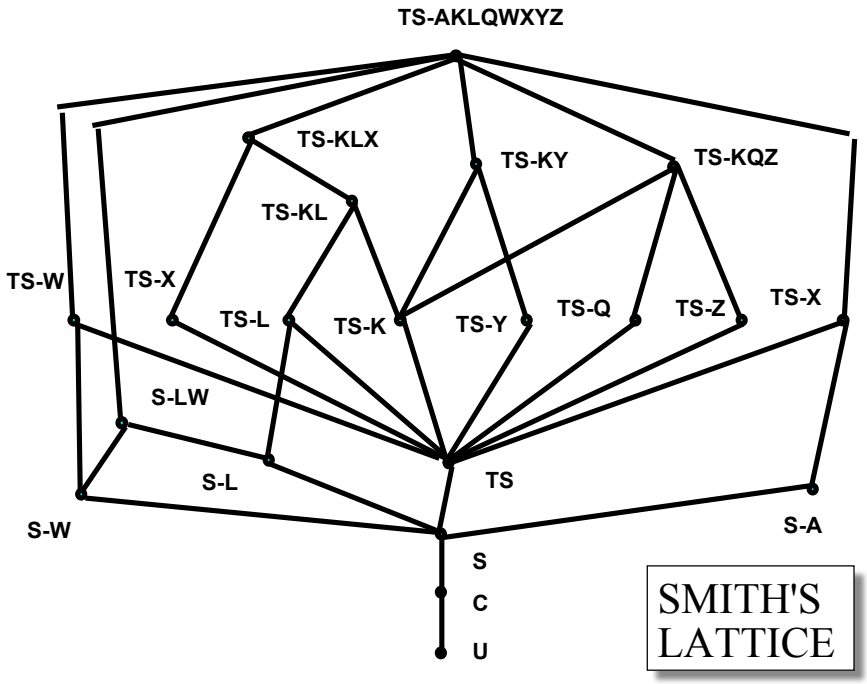


Combined Lattice:

The product of the two lattices.

SMITH'S LATTICE

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

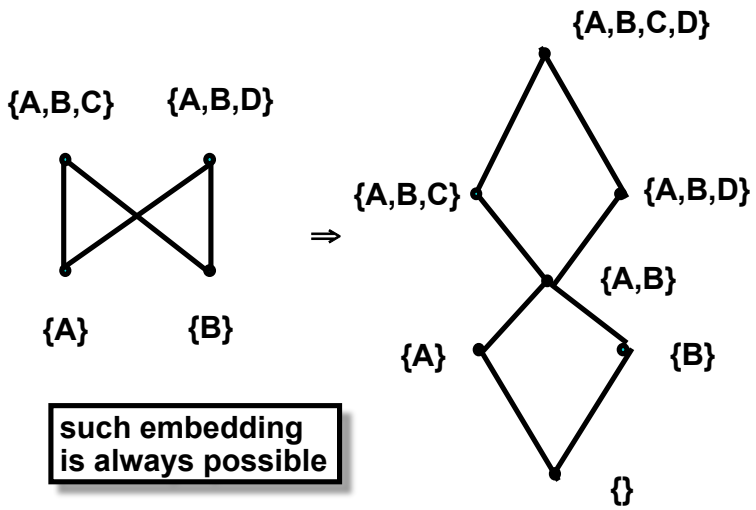


SMITH'S LATTICE

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

EMBEDDING A POSET IN A LATTICE



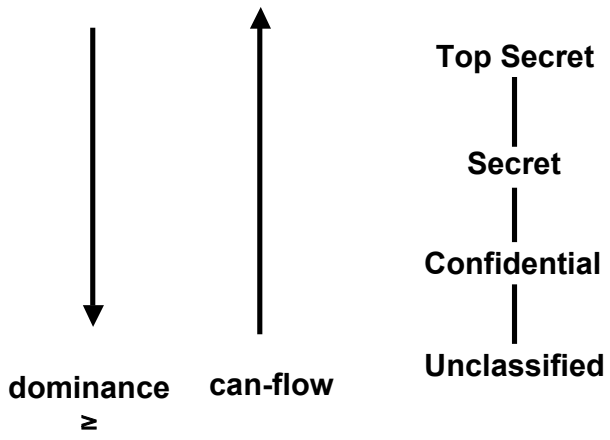
BELL LAPADULA (BLP) MODEL

- SIMPLE-SECURITY — Subject S can read object O only if
  - label(S) dominates label(O)
  - information can flow from label(O) to label(S)
- STAR-PROPERTY — Subject S can write object O only if
  - label(O) dominates label(S)
  - information can flow from label(S) to label(O)

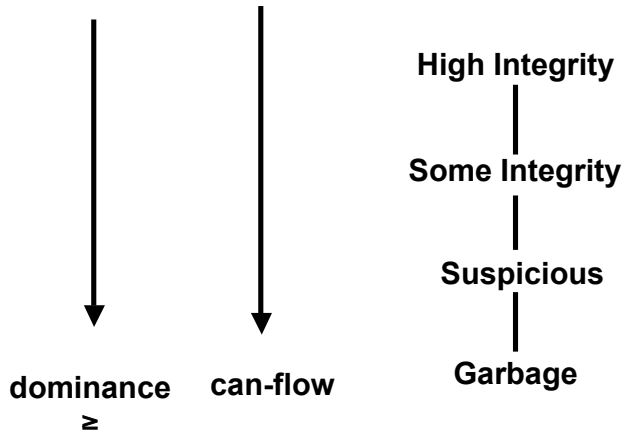
STAR-PROPERTY

- applies to subjects (principals) 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

BLP MODEL



BIBA MODEL



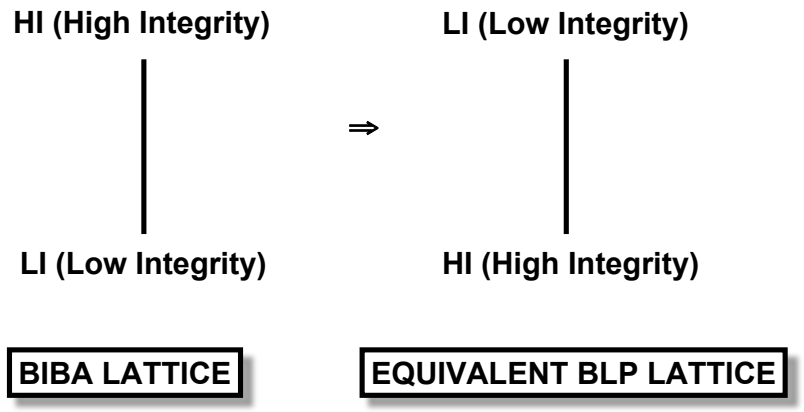
BIBA MODEL

- SIMPLE-INTEGRITY — Subject S can read object O only if
  - label(O) dominates label(S)
  - information can flow from label(O) to label(S)
- STAR-PROPERTY — Subject S can write object O only if
  - label(S) dominates label(O)
  - information can flow from label(S) to label(O)

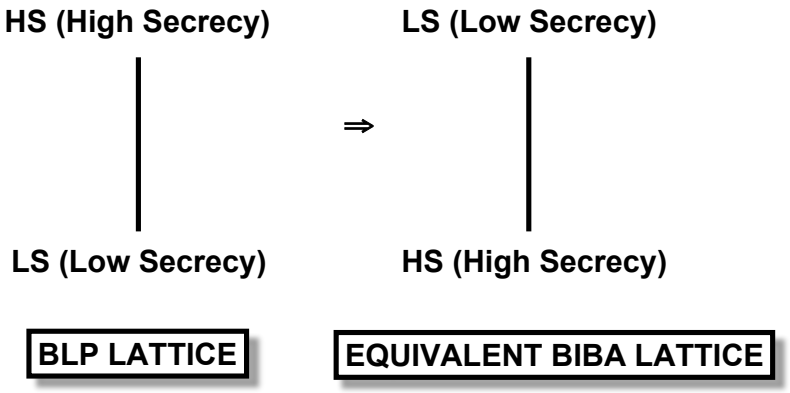
EQUIVALENCE OF BLP AND BIBA

- 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

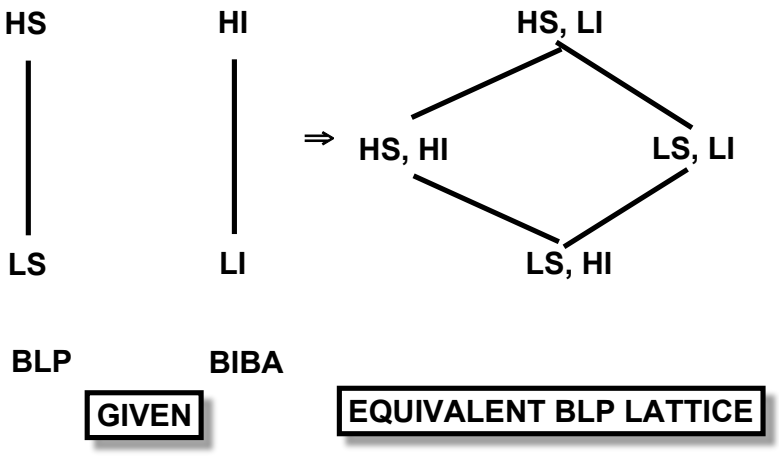
EQUIVALENCE OF BLP AND BIBA

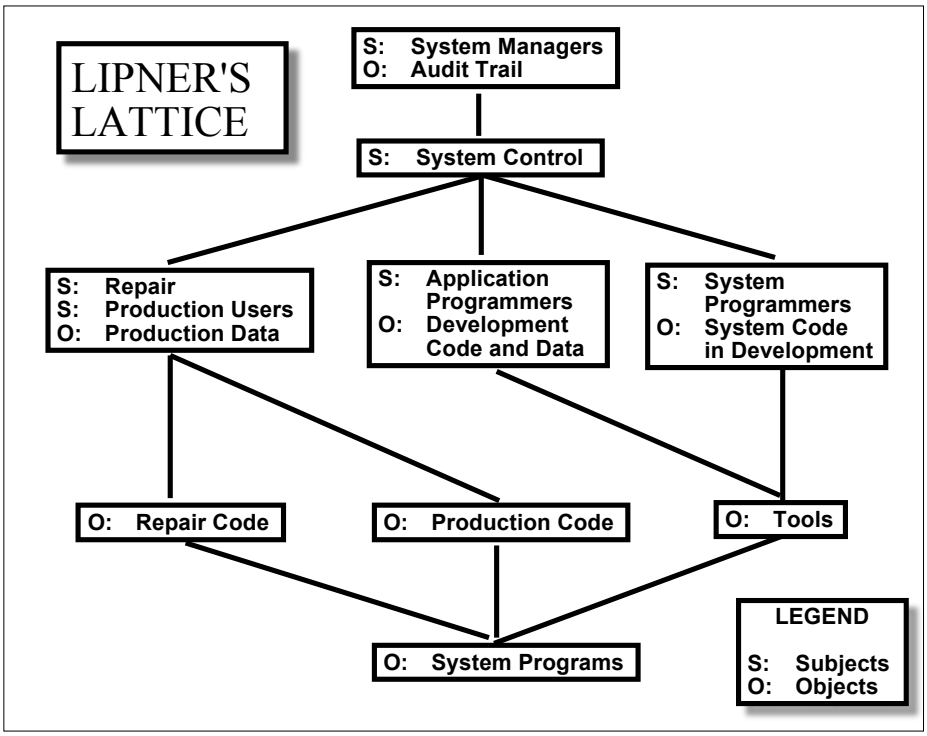


EQUIVALENCE OF BLP AND BIBA



COMBINATION OF DISTINCT LATTICES





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

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)