Mandatory Access Control (MAC)

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Lattice-Based Access Control (LBAC)

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Denning's Axioms for Information Flow

Denning's Axioms

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

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

Denning's Axioms

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

1. SC is finite
2. $\rightarrow$ is a partial order on SC
   (i.e., reflexive, transitive, anti-symmetric)
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

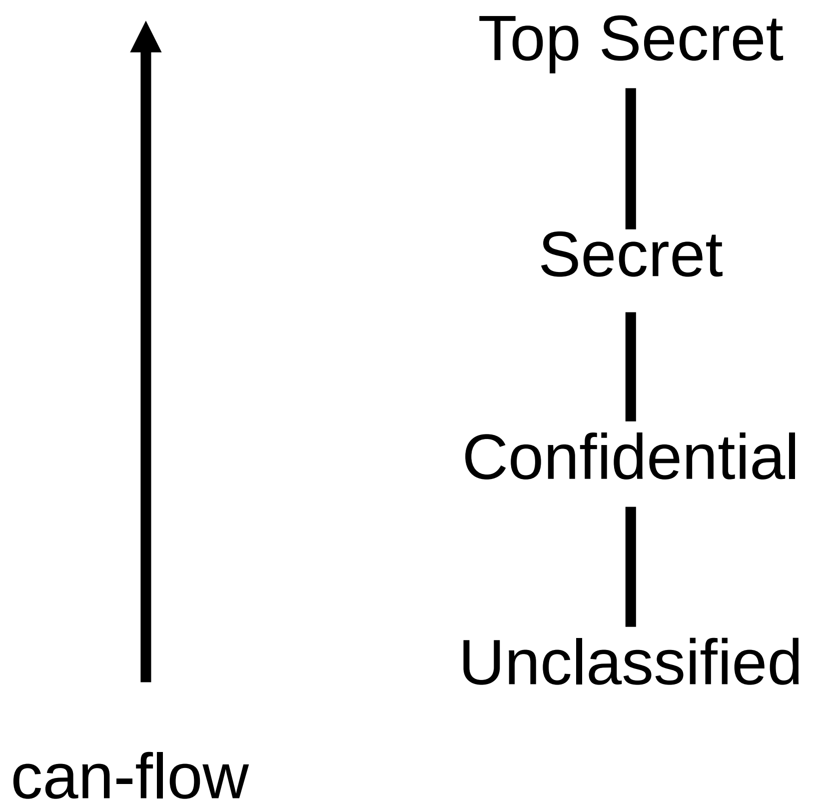
Justification for 1 and 2 is stronger than for 3 and 4.
In practice we may have a partially ordered set (poset).

Denning's Axioms Imply

- SC is a universally bounded lattice
- There exists a Greatest Lower Bound (glb) operator ⊗ (also called meet)
- There exists a highest security class H

Lattice Structures

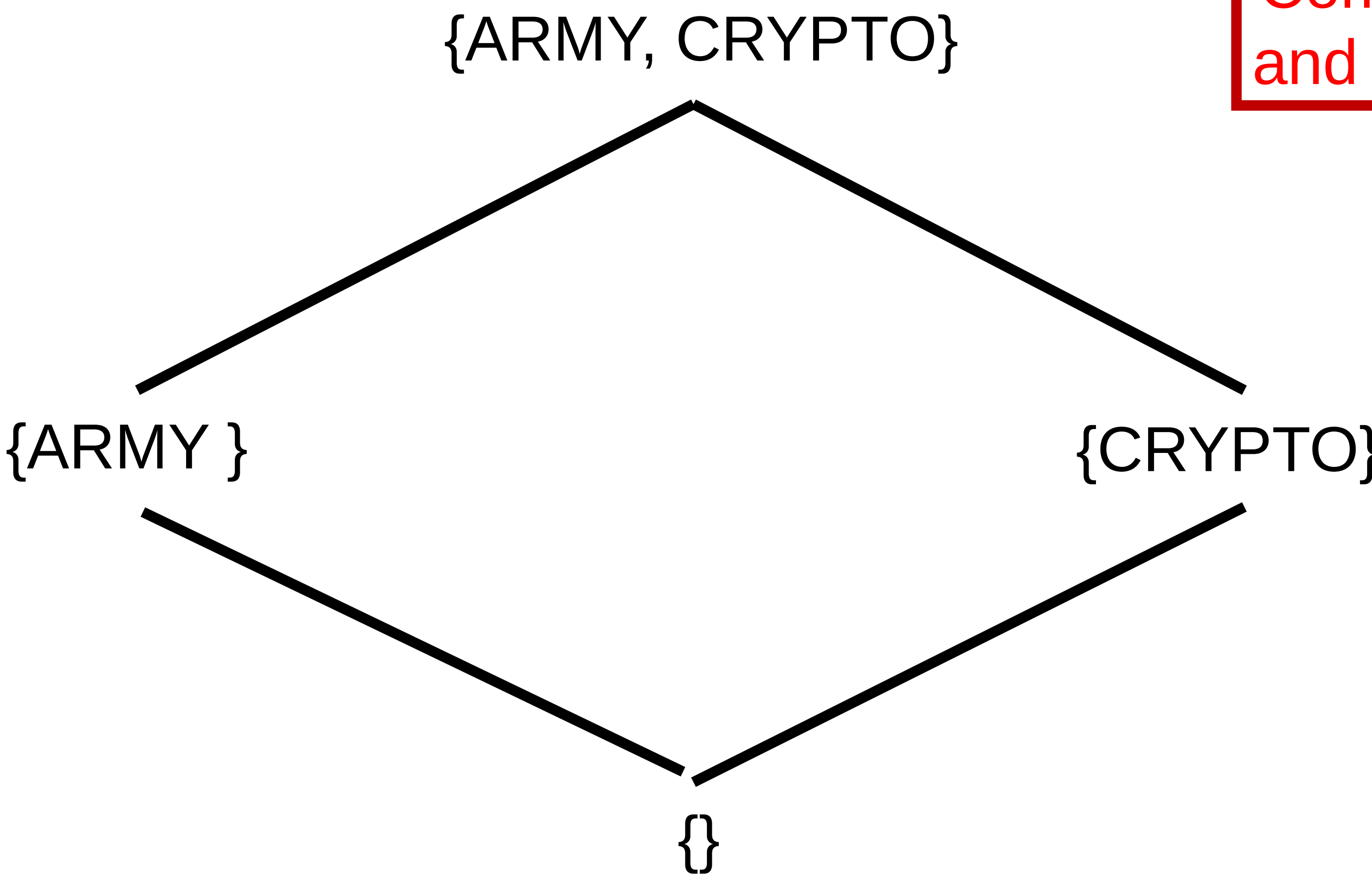
Hierarchical Classes



reflexive and transitive edges are implied but not shown

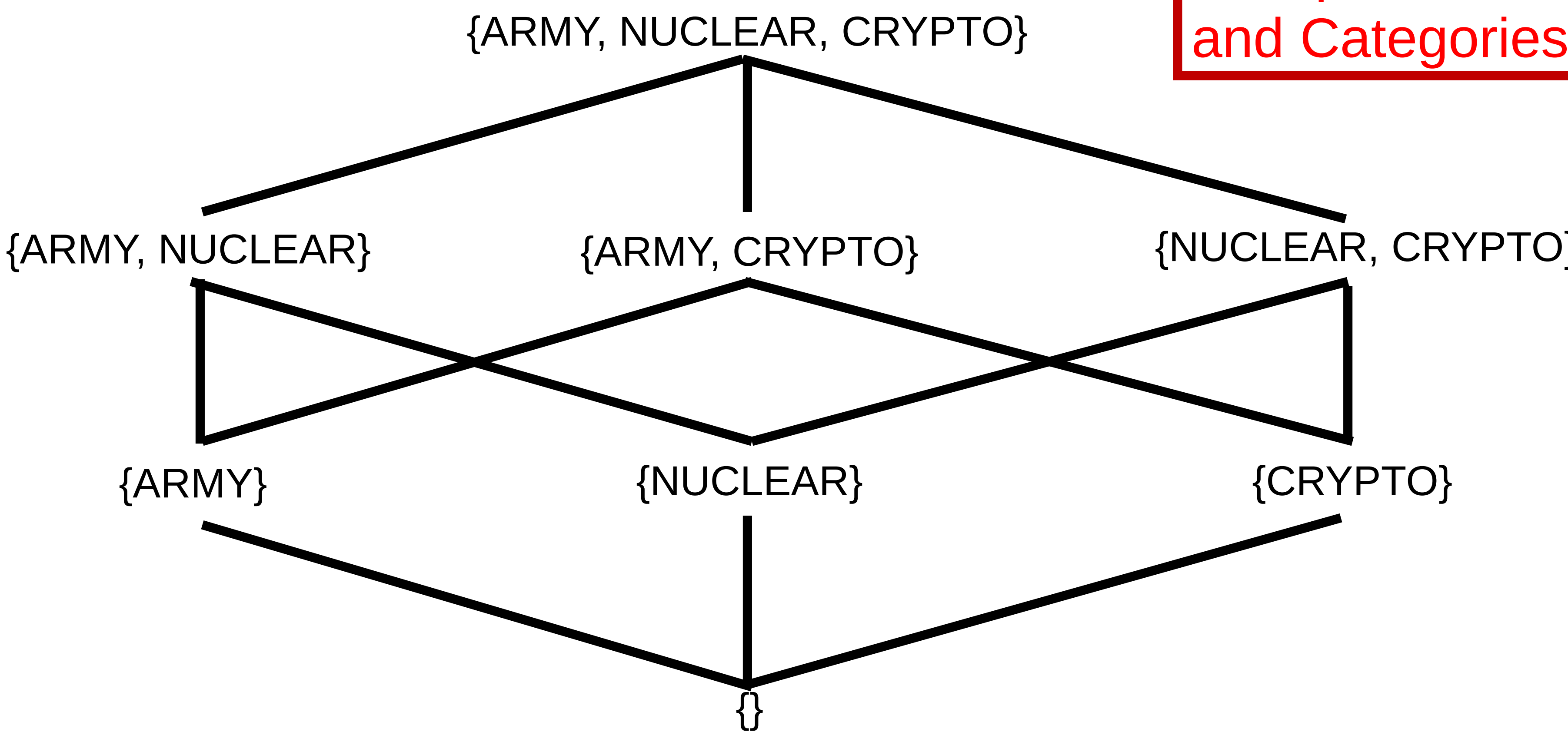
Lattice Structures

Compartments and Categories

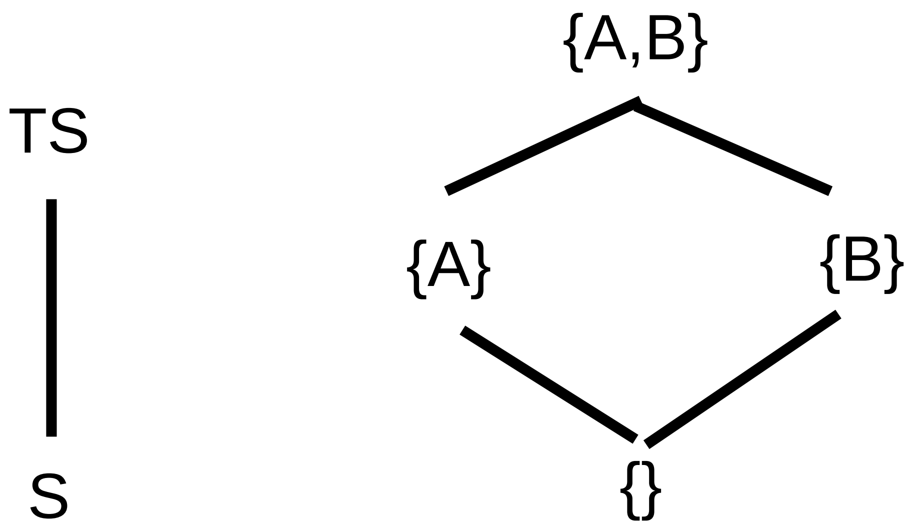


Lattice Structures

Compartments and Categories



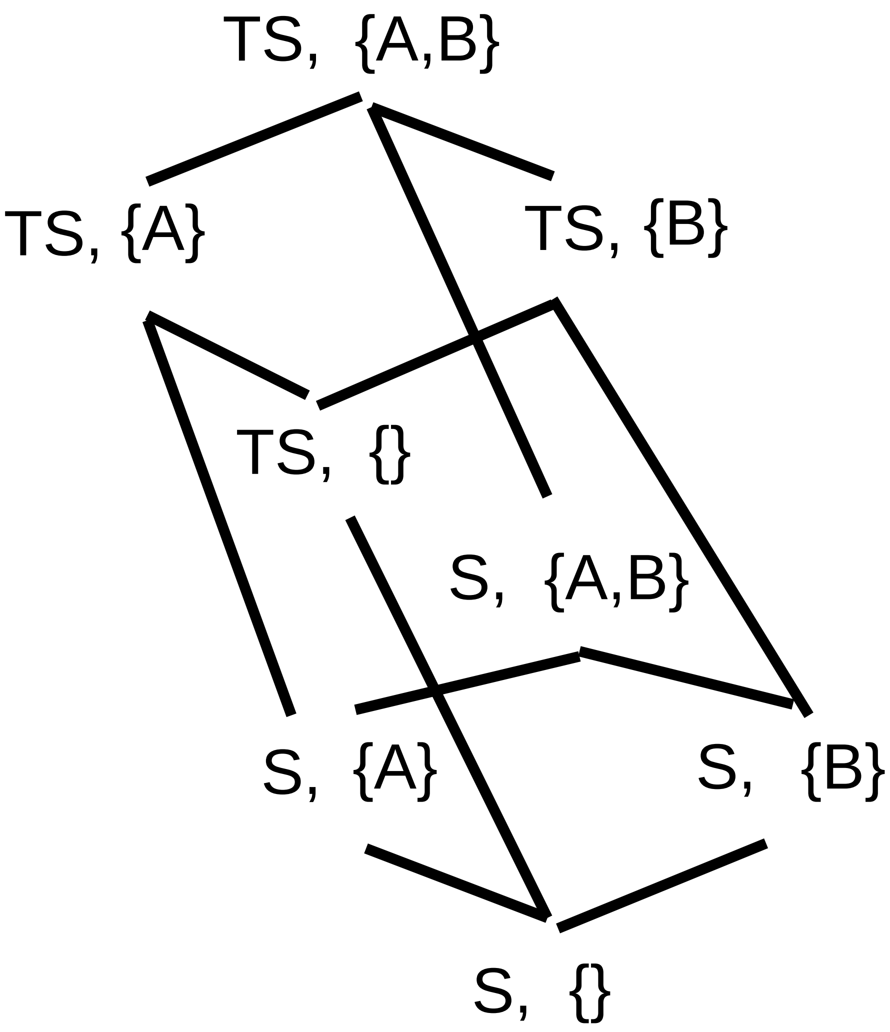
Lattice Structures



Hierarchical Classes with Compartments

product of 2 lattices is a lattice

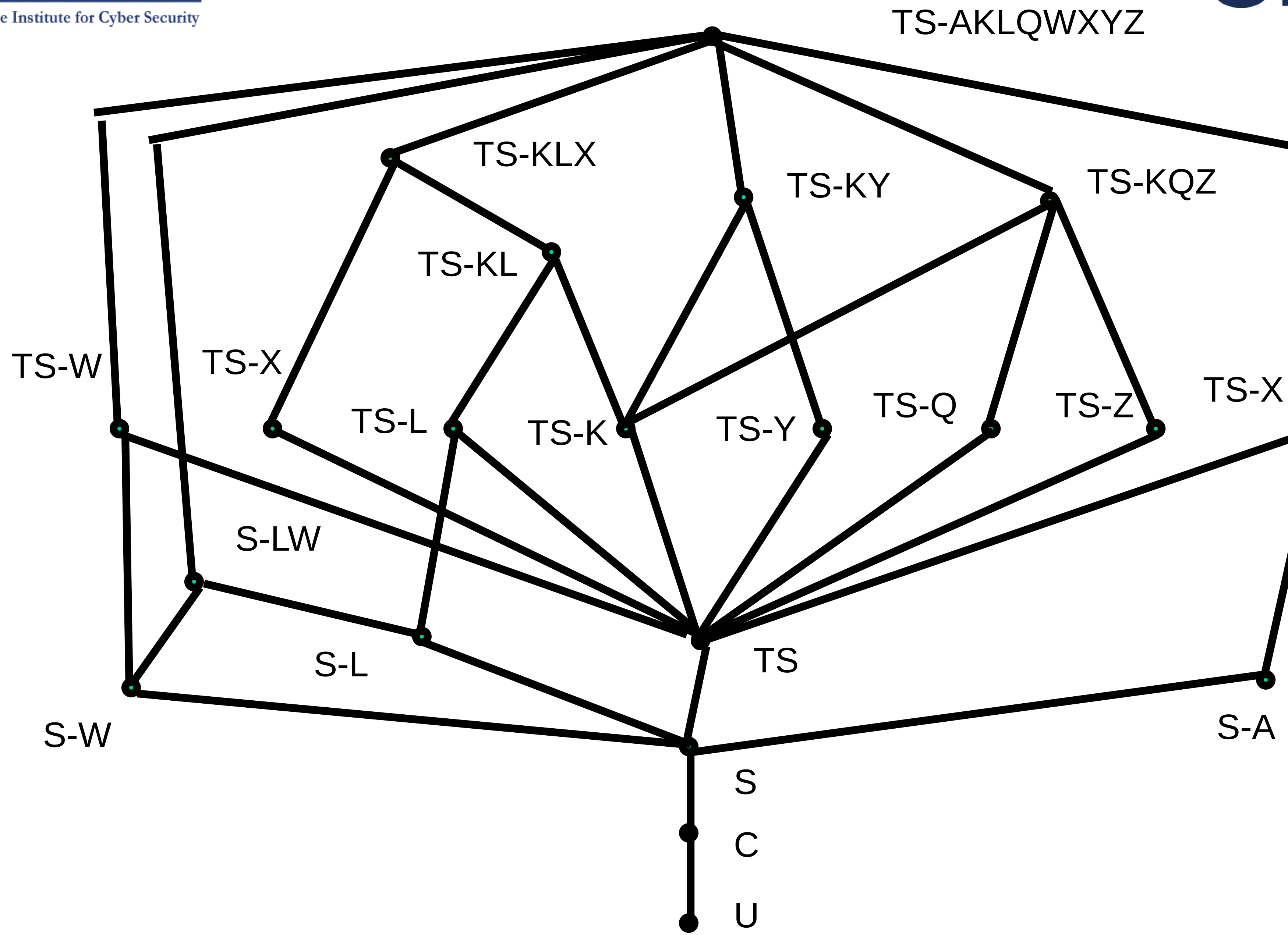
Lattice Structures



Hierarchical Classes with Compartments

product of 2 lattices is a lattice

Smith's Lattice



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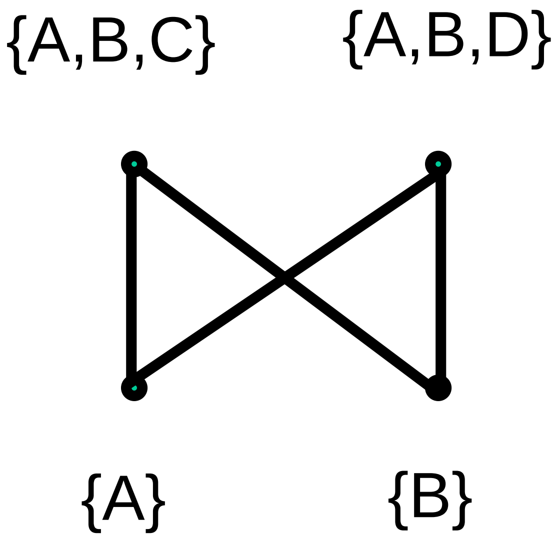
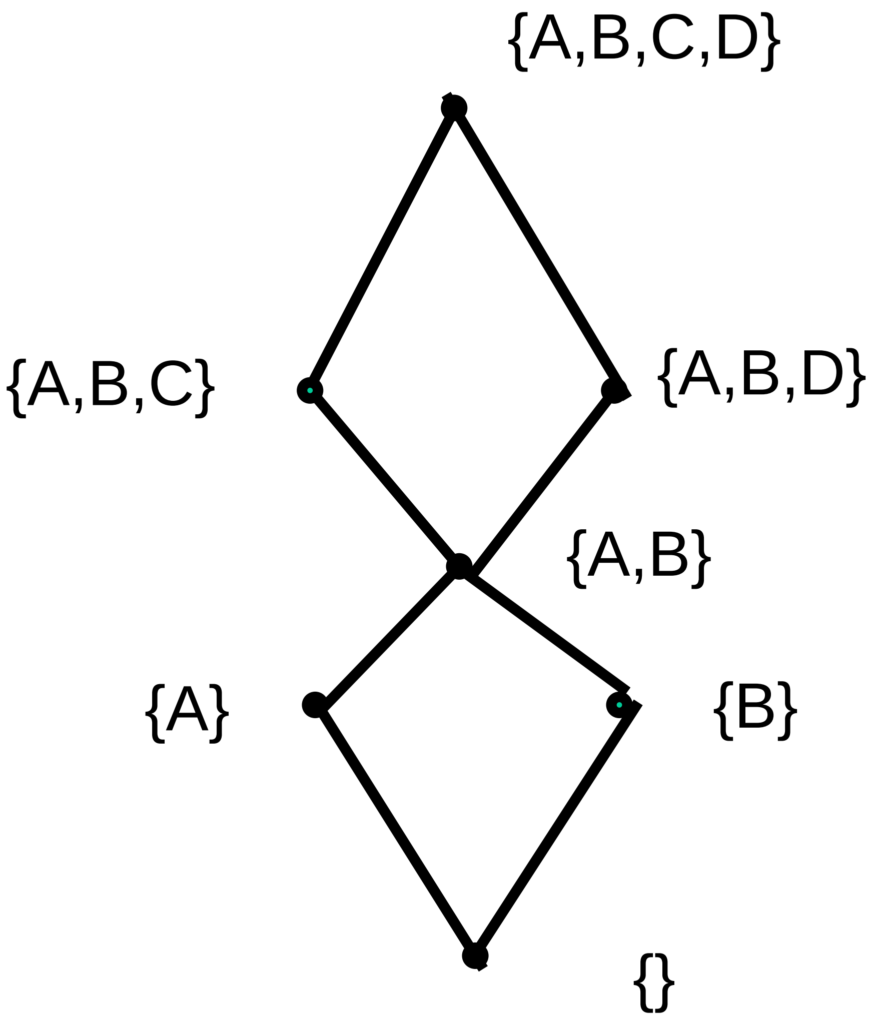
Smith's Lattice

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

Extending a POSET to a Lattice



$\Rightarrow$



such extension
is always possible

BLP Model for Confidentiality

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 $m \times n$ discretionary access matrix with $D[i,j] \subseteq R$
- M, an $m \times n$ current access matrix with $M[i,j] \subseteq R$

BLP Model (Liberal ★-Property)

- Lattice of confidentiality labels $\Lambda = \{\lambda 1, \lambda 2, ..., \lambda p\}$
- Static assignment of confidentiality labels λ: SUB $\cup$ OBJ $\rightarrow \Lambda$
- M, an m $\times$ n current access matrix with
  - $r \in M[i,j] \Rightarrow r \in D[i,j] \wedge \lambda(Si) \geq \lambda(Oj)$ simple security
  - $w \in M[i,j] \Rightarrow w \in D[i,j] \wedge \lambda(Si) \leq \lambda(Oj)$ liberal ★-property

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BLP Model (Strict ★-Property)

UTSA

- Lattice of confidentiality labels $\Lambda = \{\lambda 1, \lambda 2, ..., \lambda p\}$
- Static assignment of confidentiality labels λ: SUB $\cup$ OBJ $\rightarrow \Lambda$
- M, an m $\times$ n current access matrix with
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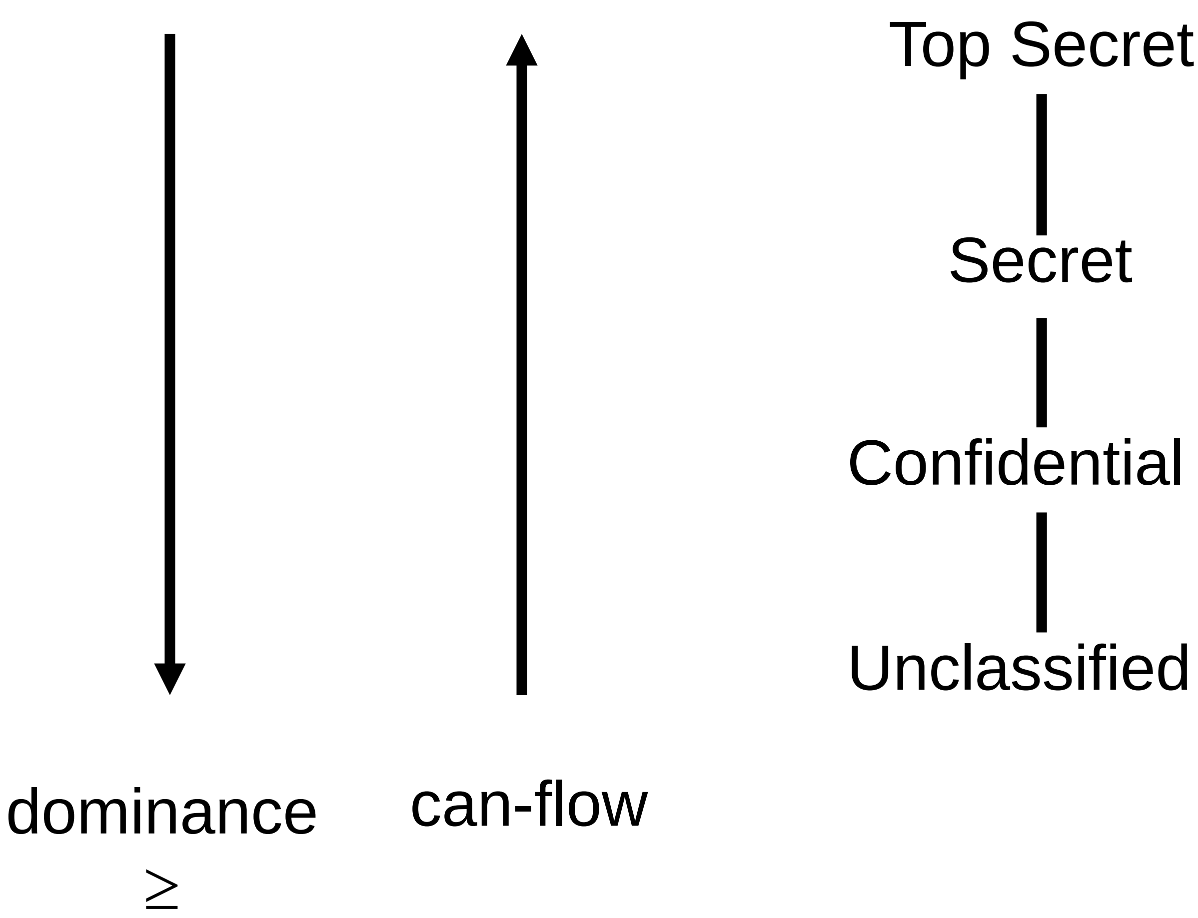
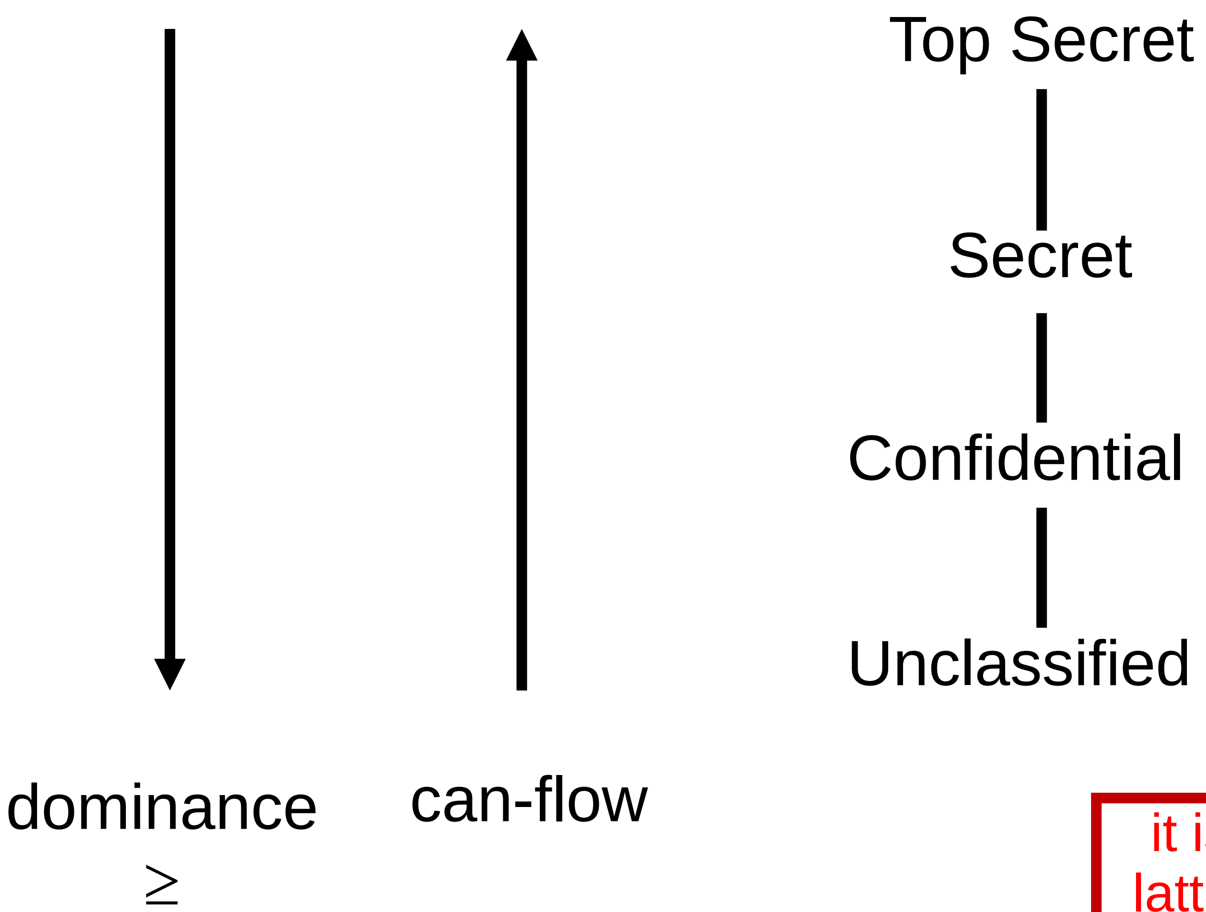
  - $w \in M[i,j] \Rightarrow w \in D[i,j] \wedge \lambda(Si) = \lambda(Oj)$ strict ★-property

BLP vis a vis Lattices



BLP vis a vis Lattices



it is risky to visualize lattices as total orders but it is ok sometimes

BLP vis a vis Lattices

H (High)

L (Low)

dominance

≥

can-flow

often 2 levels suffice to make the main point

★-Property

- Applies to subjects not to users
  - Users are trusted (must be trusted) not to disclose secret information outside of the computer system
  - A user can login (create a subject) with any label dominated by the user's clearance
  - Subjects are not trusted because they may have Trojan Horses embedded in the code they execute
- ★-property prevents deliberate leakage and does not address
  - inference
  - covert channels
- Simple-security and ★-Property do not account for
  - encryption

Dynamic Labels in BLP

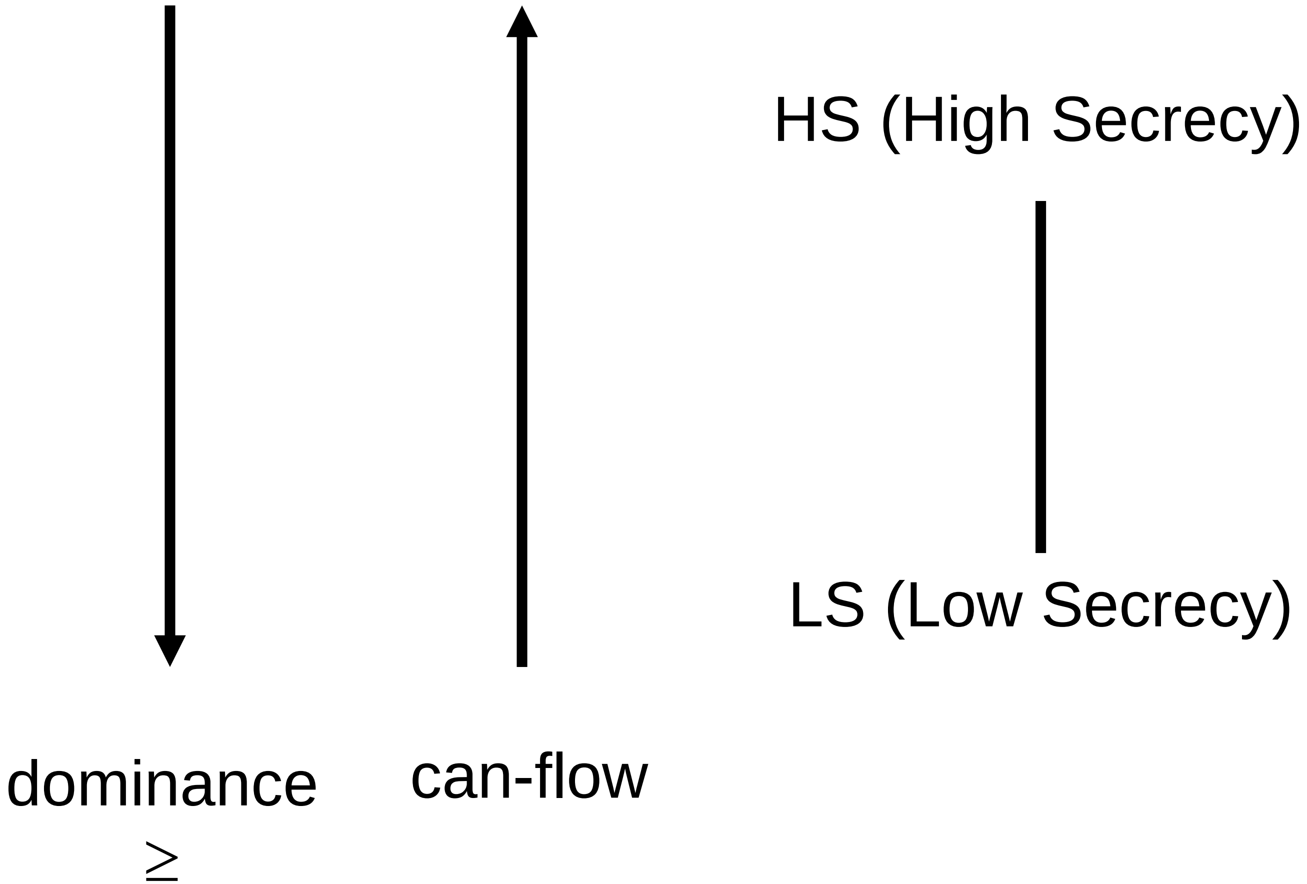
- Tranquility: λ is static for subjects and objects
- BLP without tranquility may be secure or insecure depending upon the specific dynamics of labeling
  - High water mark on subjects: secure
    λ is static for objects
    λ may increase but not decrease for subjects
    [increase caused by subject trying to read up]
  - High water mark on objects: insecure
    λ may increase but not decrease for objects
    [increase caused by subject trying to write down]
    λ is static for subjects

BLP in HRU

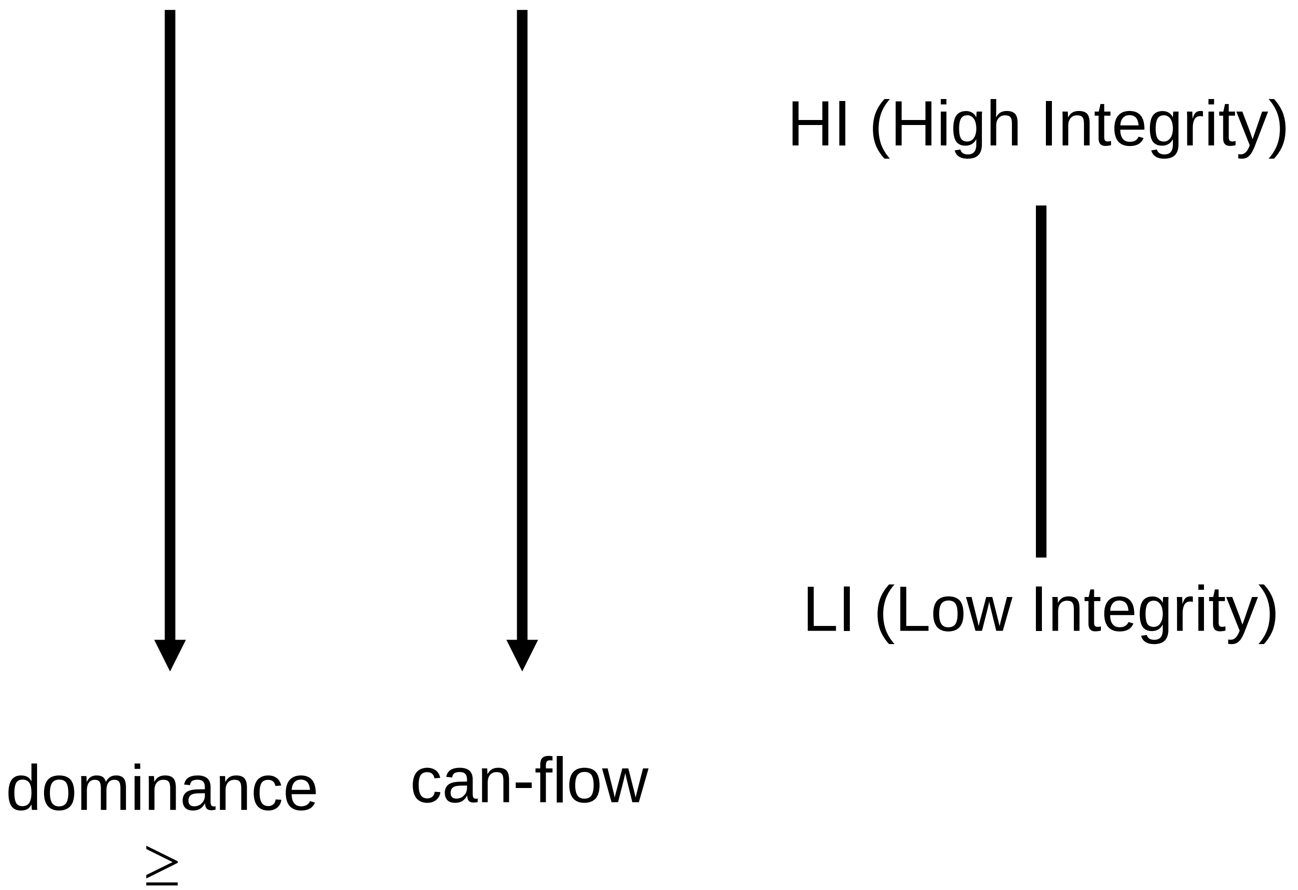
Pittelli, P. A. (1987). The Bell-La Padula Computer Security Model Represented as a Special Case of the Harrison-Ruzzo-Ullman Model. National Computer Sec. Conf. (pp. 118-121).

Biba Model
for
Integrity

BLP Revisited



Biba Inverted Flow



Biba and BLP Aligned: BLP Style

HS (High Secrecy)

LS (Low Secrecy)

LI (Low Integrity)

HI (High Integrity)

dominance
≥

can-flow

One-directional flow is the key point
No need for opposite directions for confidentiality and integrity

Biba and BLP Aligned: Biba Style

LS (Low Secrecy) HI (High Integrity)

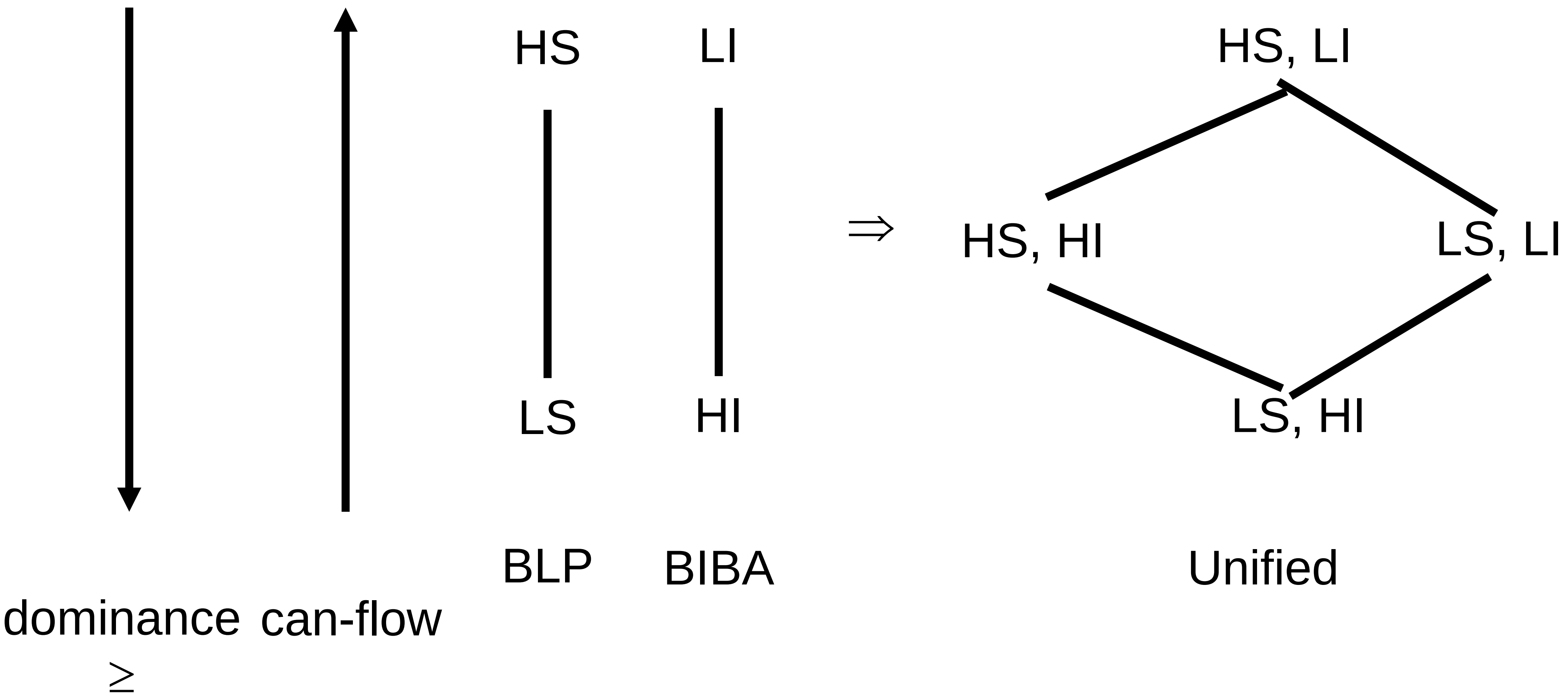
HS (High Secrecy) LI (Low Integrity)

dominance
≥

can-flow

One-directional flow is the key point
No need for opposite directions for confidentiality and integrity

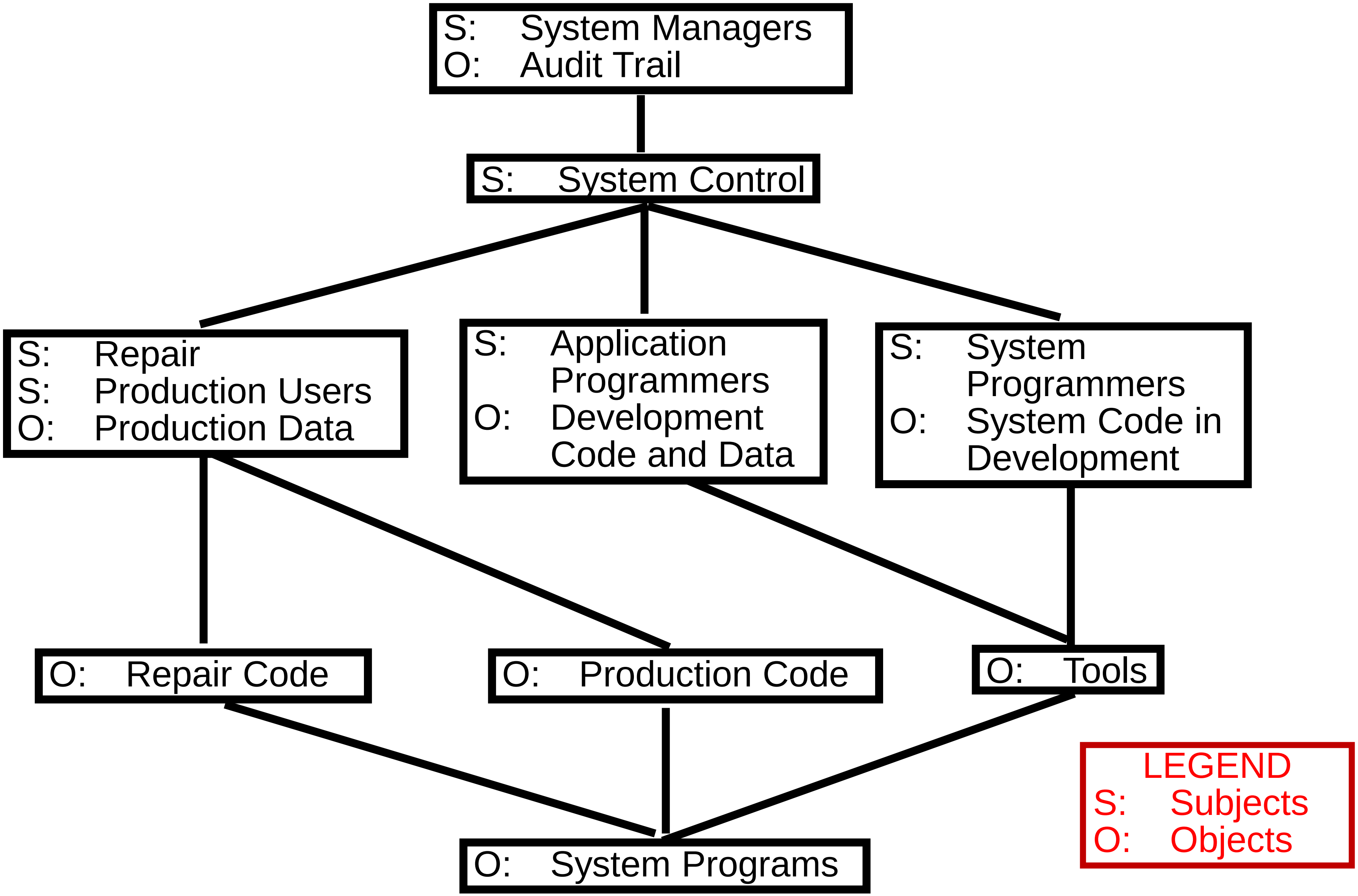
BLP-Biba Unified Lattice: BLP Style



BLP versus 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:
  - high confidentiality, low integrity at the top
  - low confidentiality, high integrity at the bottom

Lipner's Lattice in BLP Style



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
- 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 ★-property and allowed to
  - write down (with respect to confidentiality)

  or equivalently

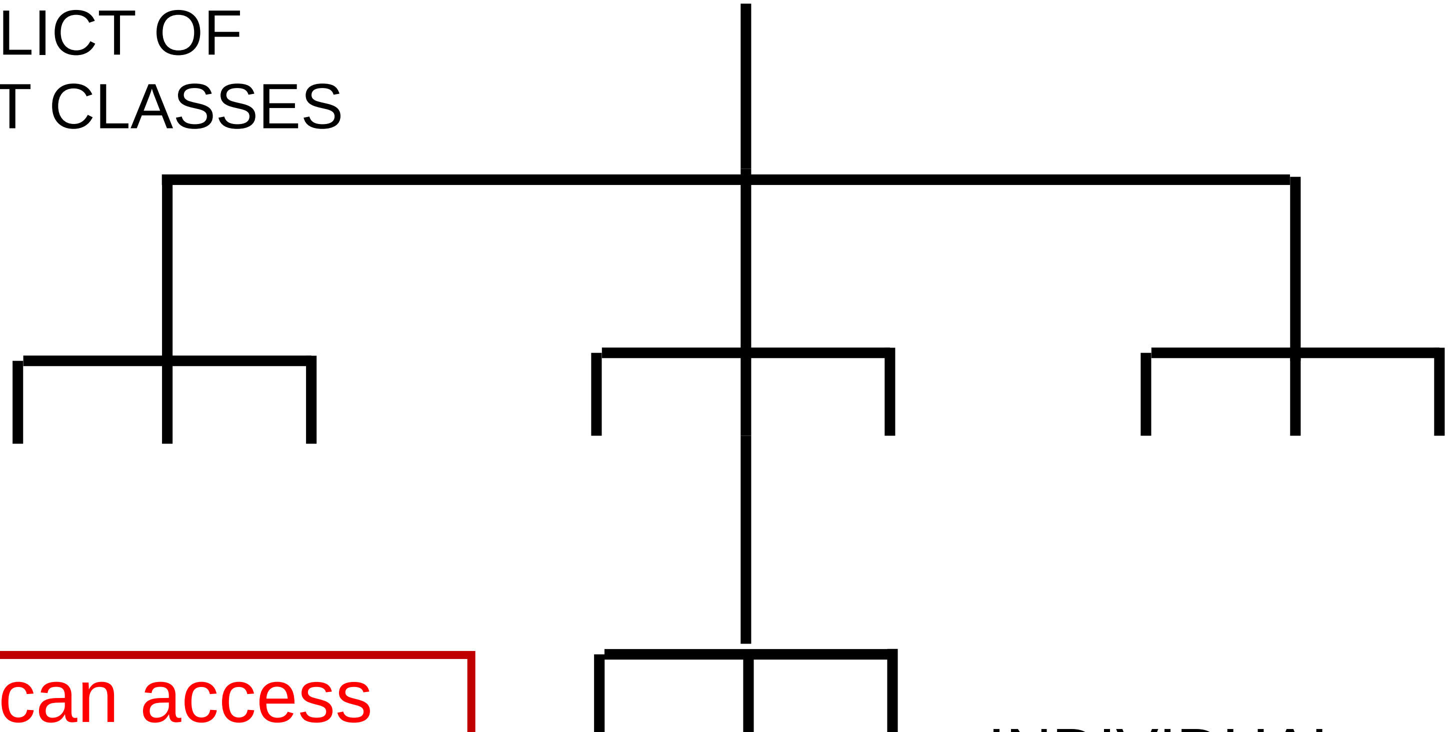
  - write up (with respect to integrity)

The Chinese Wall Lattice for Separation of Duty

Chinese Wall Policy

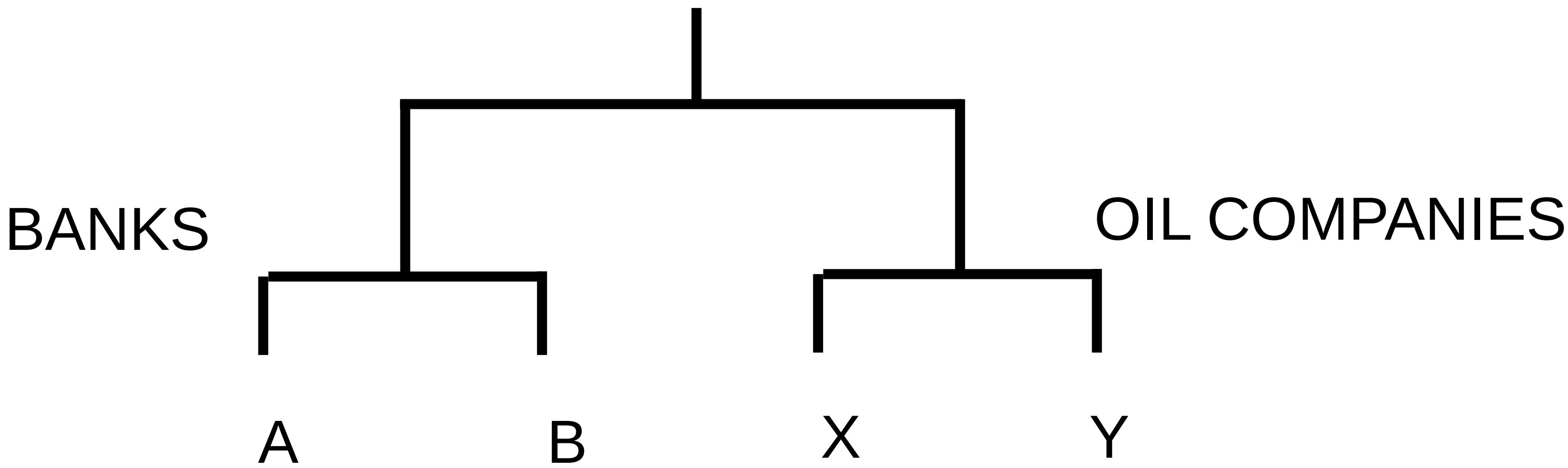
- A commercial security policy for separation of duty driven confidentiality
- Mixture of free choice (discretionary) and mandatory controls
- Requires some kind of dynamic labelling

Chinese Wall Policy

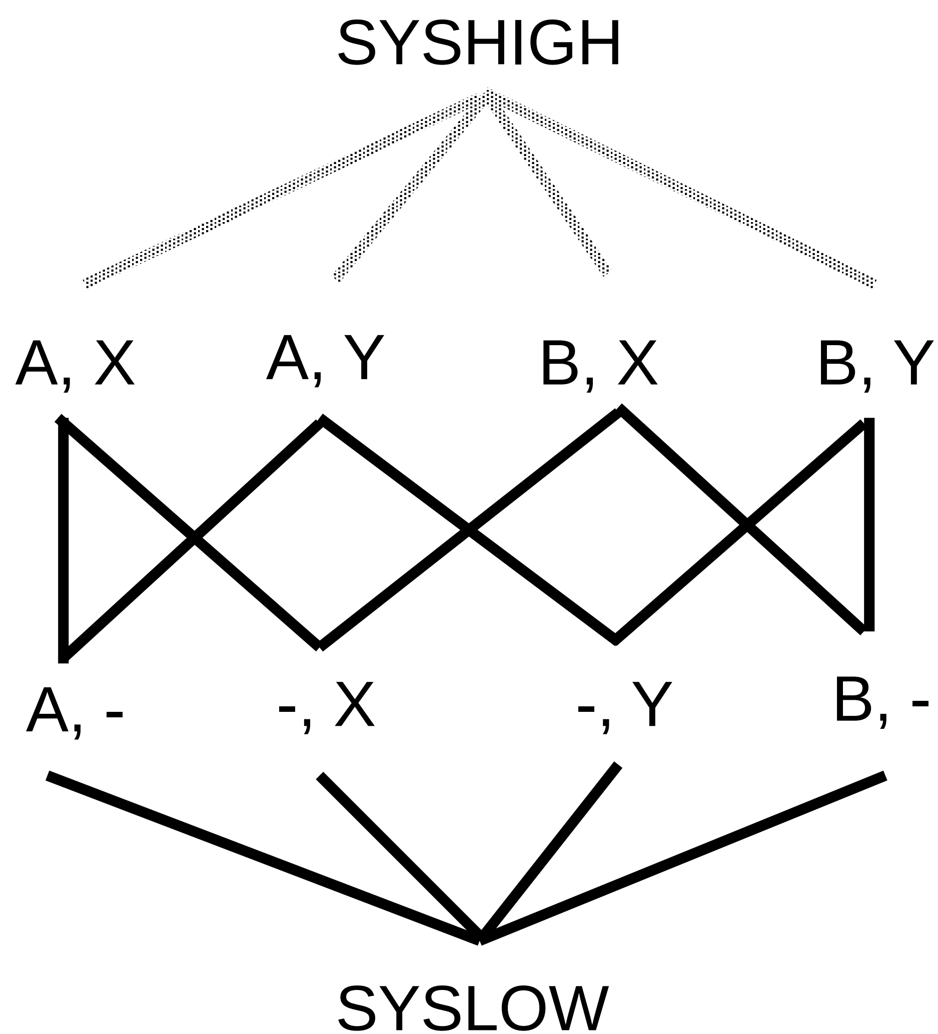


A consultant can access information about at most one company in each conflict of interest class

Chinese Wall Example



Chinese Wall Lattice



Conclusion

MAC or LBAC or BLP (or Biba)

- BLP enforces one-directional information flow in a lattice of security labels
- BLP can enforce one-directional information flow policies for
  - Confidentiality
  - Integrity
  - Separation of duty
  - Combinations thereof

MAC or LBAC or BLP (or Biba)

- BLP enforces one-directional information flow in a lattice of security labels

Enforcement

- BLP can enforce one-directional information flow policies for
  - Confidentiality
  - Integrity
  - Separation of duty
  - Combinations thereof

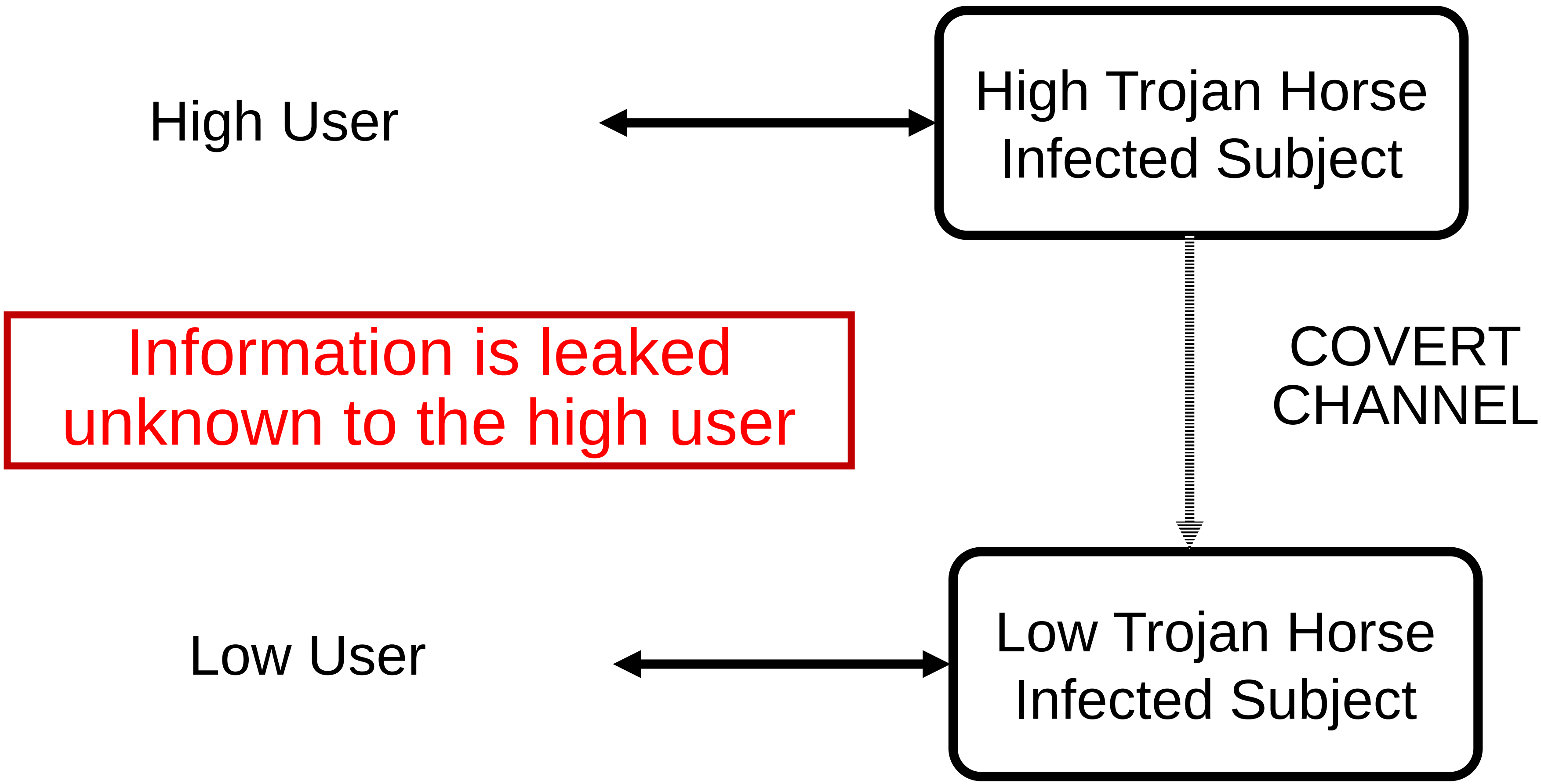
Policy

Covert Channels

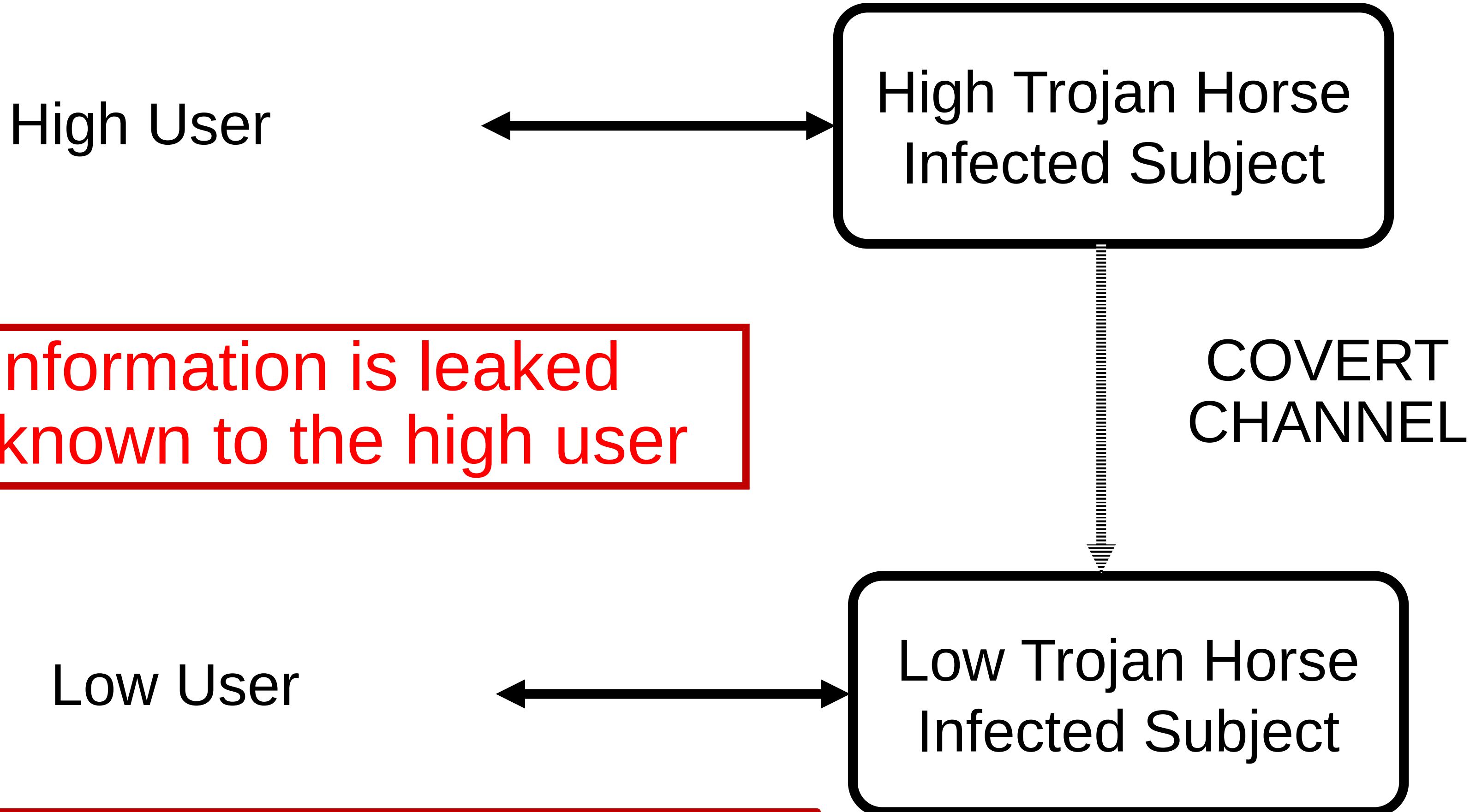
Covert Channels

- A covert channel is a communication channel based on the use of system resources not normally intended for communication between subjects (processes)

Covert Channels



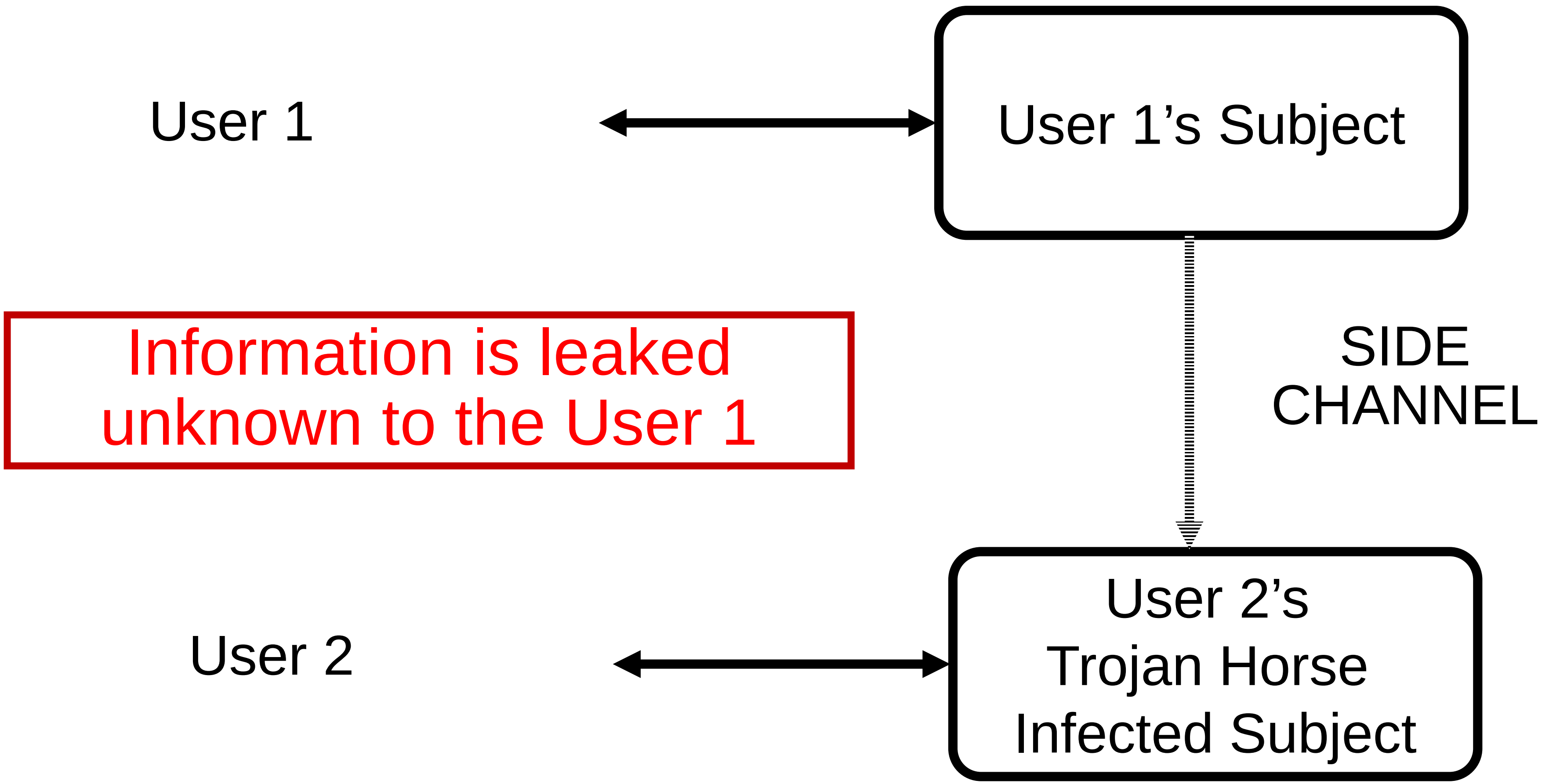
Covert Channels



Information is leaked unknown to the high user

★-property prevents overt leakage of information and does not address covert channels

Side Channels



Covert Channels versus Side Channels

- Covert channels require a cooperating sender and receiver
- Side channels do not require a sender but nevertheless information is leaked to a receiver

- Identify the channel
  - close the channel or slow it down
  - detect attempts to use the channel
  - tolerate its existence

Storage Channels

- Also known as Resource Exhaustion Channels
- Given 5GB pool of dynamically allocated memory
  - HIGH PROCESS (sender)
    bit = 1 $\Rightarrow$ request 5GB of memory
    bit = 0 $\Rightarrow$ request 0GB of memory
  - LOW PROCESS (receiver)
    request 5GB of memory
    if allocated then bit = 0 otherwise bit = 1

Timing Channels

- Also known as Load Sensing Channels
- Given 5GB pool of dynamically allocated memory
  - HIGH PROCESS (sender)
    bit = 1 $\Rightarrow$ enter computation intensive loop
    bit = 0 $\Rightarrow$ go to sleep
  - LOW PROCESS (receiver)
    perform a task with known computational requirement
    if completed promptly then bit = 0 otherwise bit = 1