CSE 127: Computer Security

Multilevel Security

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Access Control

- **Access Control:** Restriction of access to information or function
  - **Access:** ability to see, use or modify
- Access control policy is part of security policy
  - In many settings access control is same as security
  - Not all security issues are naturally formulated as access
    - E.g.: availability

Access Control

- **Discretionary Access Control:**
  Access controlled by users
  - **New objects:** users (e.g. *owner*) decides who can access
  - Security *depends on users*
- **Mandatory Access Control:**
  Access not controlled by users
  - **New objects:** system determines who can access
  - Most systems conservative in assigning new object access

Examples

- **Discretionary Access Control:**
  Access controlled by users
  - Unix access control
  - SQL access control
- **Mandatory Access Control:**
  Access not controlled by users
  - Information flow tracking systems
  - AppArmor and SELinux

Non-Computer Examples

- Discretionary access control:
  - Physical keys (capabilities!)
  - Vampires (must be invite into home)
- Mandatory access control:
  - Child-proof medicine bottles
  - Infectious disease quarantine

Multilevel Security

- All objects have a security label
  - Labels form a lattice (partial order with supremum and infimum)
- Subjects limited to certain labels
  - Usually defined in terms of maximal accessible labels

Traditional Multilevel Security

- Labels
  - **Level:** *top secret* > *secret* > *confidential* > *unclassified*
  - **Category:** unordered set (e.g. ULTRA)
  - Other restrictions such as NOFORN (not foreign)
- Subjects cleared to certain level and category
- Subject must have all category clearance and same or higher level as object being accessed

Noninterference

- Want to stop information from leaking from higher levels
- How to formalize this? **Noninterference.**
- Information at higher levels can have *no effect* on information at lower levels
  - Prevent side-channels within system
  - Control classification of new information
    - Low-clearance information must not depend on higher-clearance information

Bell-LaPadula

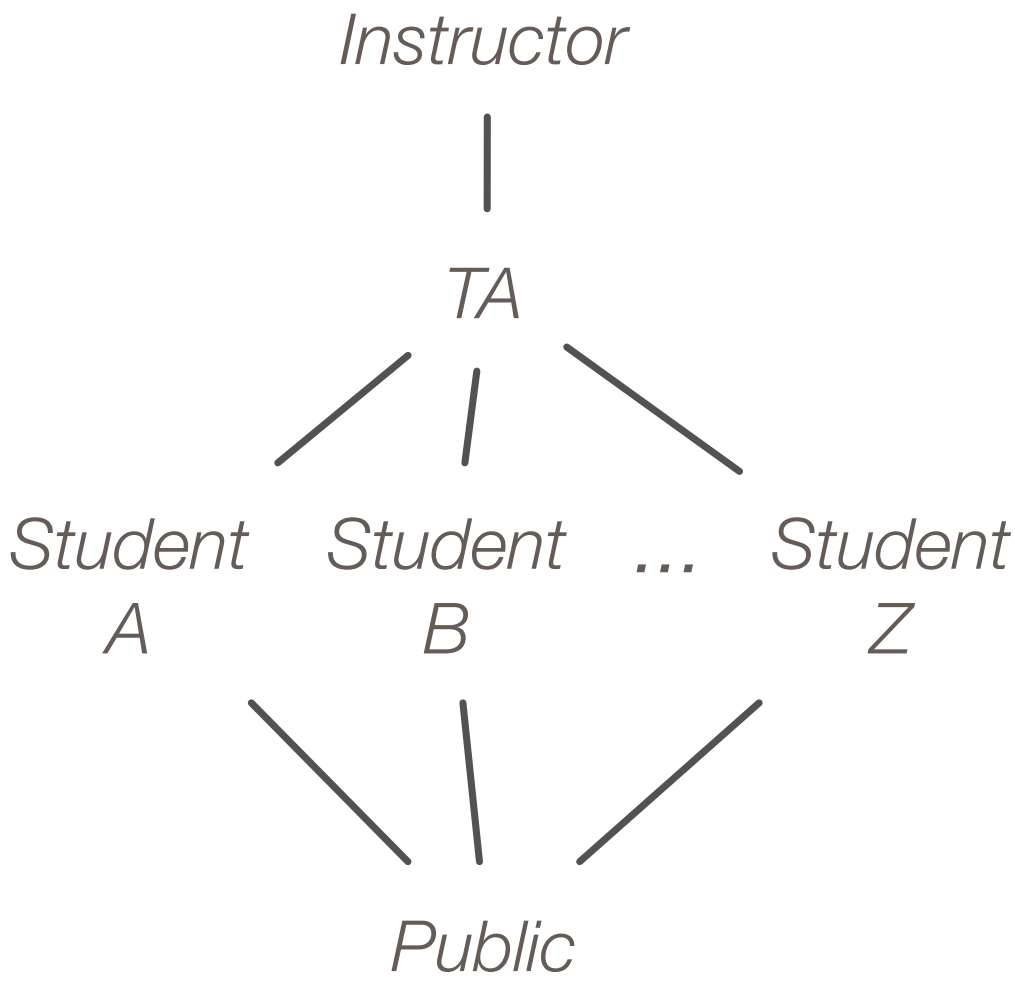
- Model for protecting *secrecy* of information
- Each process (running on behalf of user) **has a clearance**
- **No read up:** can't read data from higher level
- **No write down:** can't write data to lower level

Bell-LaPadula with HWM

- Model for protecting *secrecy* of information
- Each process (running on behalf of user) has a *maximum* clearance and a *current* clearance
- **No read up:** can't read data from higher level
- **No write down:** can't write data to lower level
- **High water mark principle:** Process starts at lowest level and raises current clearance (up to maximum) to read data with label above current clearance

CSE 127 Lattice

- **Instructor:** can be viewed by instructor only
- **TA:** Can be viewed by TAs and instructor only
- **Student *X*:** Can be viewed by Student *X*, TAs, and instructor only



CSE 127 Bell-LaPadula

- Grade of student A classified *Student A*
  - Can be read by student A, TAs, instructor, administrator
- Homework answer key classified *TA*
  - Can be read by TAs and instructor, administrator

CSE 127 Bell-LaPadula

- **No write down implies:**
  - Student can write email for instructor's eyes only
  - I can only write to *Instructor* level, which you can't read!
- Need high water mark principle

CSE 127 Bell-LaPadula

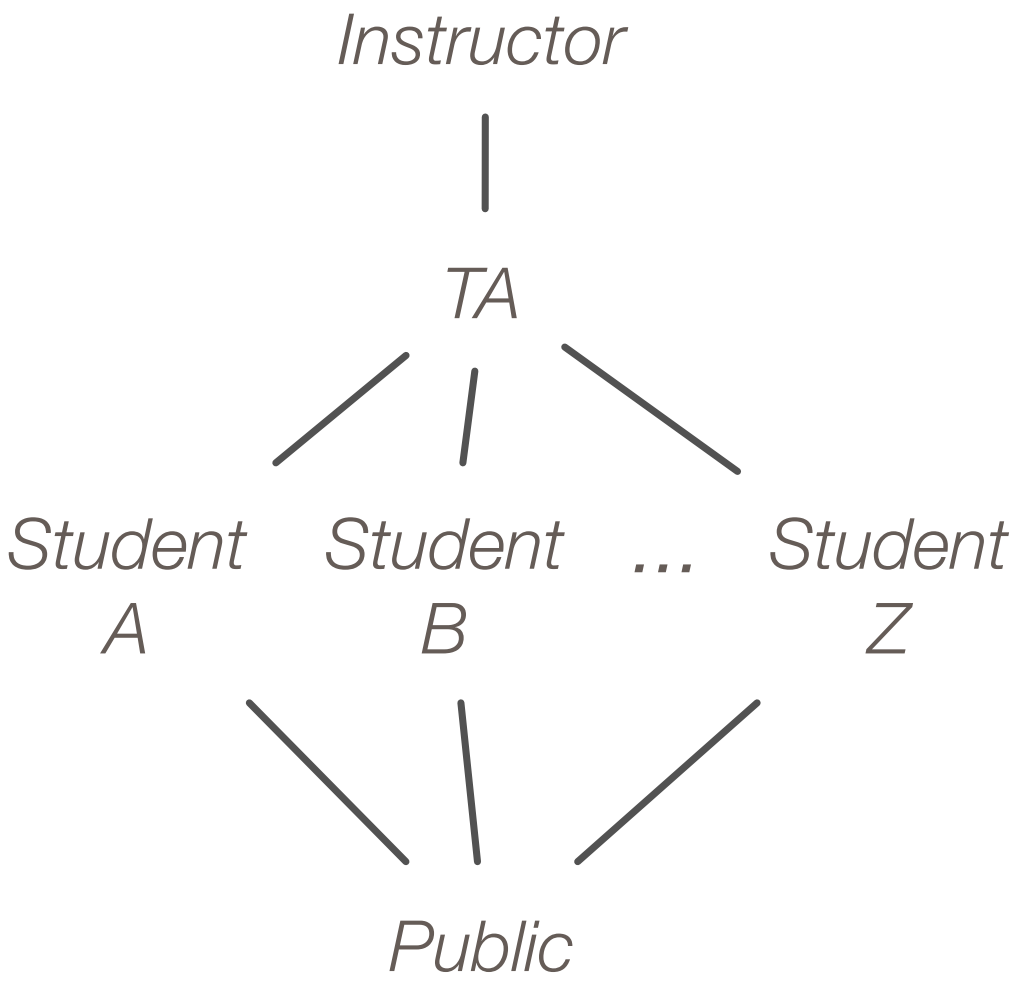
- ***Let's say:* New process when I sit down at a desk**
  - Short-term *Memento*-style amnesia
- I start at *Public* clearance
  - Can write up to any level
  - Can only read *Public* at current level
- I read student *X*'s homework labeled *Student A*
  - Read raises up my current process clearance to *Student A*
  - Can write up to *Student A*, *TA*, *Instructor*, but **not** *Public*

CSE 127 Bell-LaPadula

- I read student *A*'s homework labeled *Student A*
- I am now **tainted** by the knowledge of *Student A* info
- Anything I write may be derived from knowledge of *Student A* level material
- I can't write anything to level *Public* because it might leak *Student A* level information to *Public*

CSE 127 Bell-LaPadula

- Still sitting down, I read homework of student B
- What is my new current process clearance?
  - Must be at least as high as *Student A* and *Student B*
  - Process clearance now *TA*
  - Can only write to level *TA* and *Instructor*



CSE 127 Bell-LaPadula

- What happens when TA grades homework?
  - **Input:** student A's homework at level *Student A*
  - **Input:** Answer key at level *TA*
  - **Output:** Grade at level … ?
- Reading answer key increased TA's current process clearance to level *TA*
- Need way to *declassify* information

CSE 127 Bell-LaPadula

- Special user or process can declassify information
- *Strain the analogy further:* I can declassify information when I am wearing Hammer pants
  - Grade: *TA* to *Student A*

Bell-LaPadula Summary

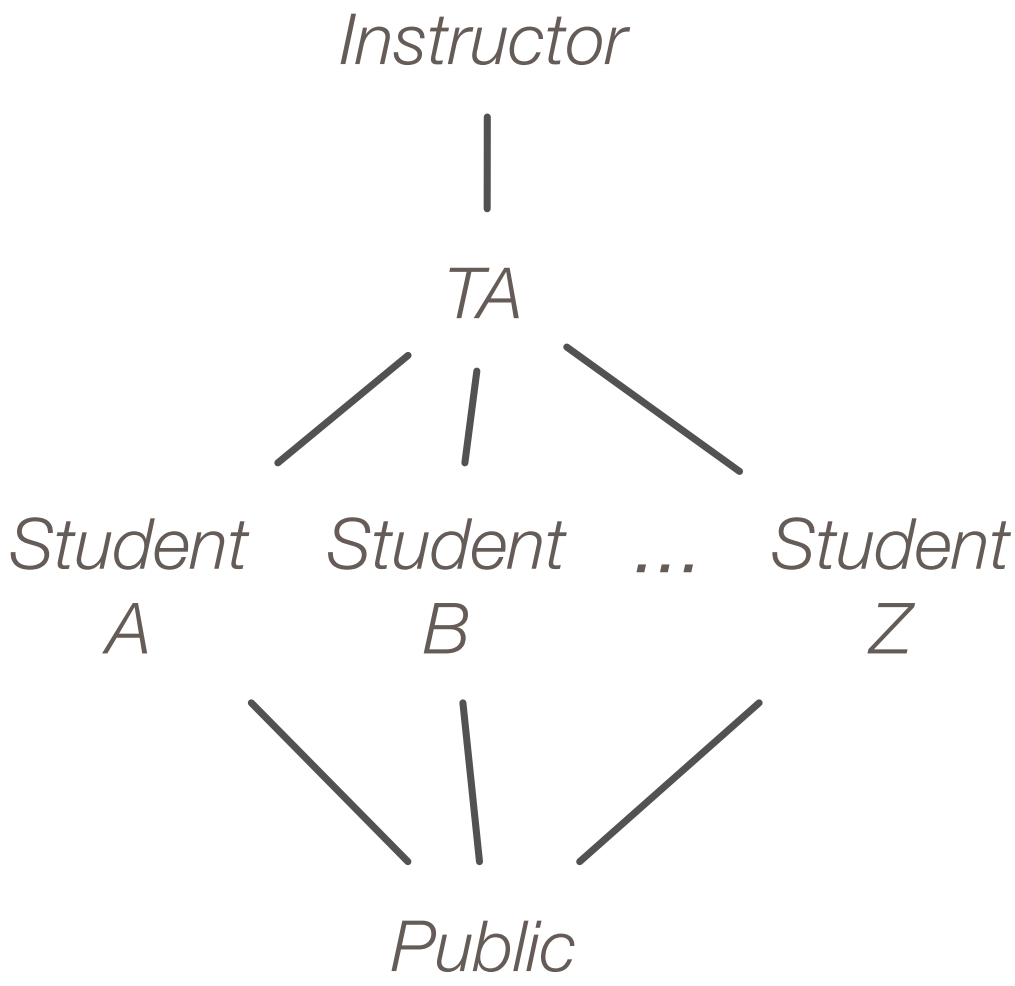
- BLP only protects *secrecy* of information
  - Integrity must be handled some other way
- System must label every piece of information
  - Recall *Complete Mediation* design principle
  - Requires a closed system
- What happens when data leaves system?

Biba Model

- Model for protecting *integrity* of information
- Each process (running on behalf of user) **has a level**
- **No read down:** can't read data from lower level
- **No write up:** can't write data to higher level
- **Low water mark:** start at highest level, decrease as necessary on read operation

CSE 127 Lattice

- Lattice now describes integrity (accuracy) of information
- **Instructor:** highest
- **Public:** lowest



CSE 127 Biba: without LWM

- I will only believe what I wrote myself
- TAs will only believe what they wrote or I wrote
- Each student only believe his/her own documents, as well as documents of TAs and instructor
- So when is low water mark policy useful?

Don't Talk About It

- **Two levels:** *Not Seen Fight Club* > *Seen Fight Club*
- Everyone starts at *Not Seen Fight Club*
- After seeing *Fight Club* level becomes *Seen Fight Club*
- Everything you write or say is labeled with your level
- If you have not seen Fight Club and read something written by someone who has, you're **tainted**
  - I will not talk to you because what you know might spoil movie

BLP vs Biba

- Which is better?
- When should you use BLP?
- When should you use Biba?

Multilevel Security

- BLP and Biba operate on processes and files
  - This is too coarse: processes get tainted easily
- What if we label *every byte of data on the system?*
- "Process" is now a single instruction
  - BLP: result of operation the higher of each operand's labels
  - Biba: result of operation the lower of each operand's labels

Multilevel Security

- **Information Flow Tracking** (IFT)**:**
  Fine-grained label tracking
- Labeled *sources* and *sinks* of data
- *Static:* Label variables in a program
  - Compiler verifies all statements comply with policy
  - Labels could be inferred automatically (like type inference)
- *Dynamic:* Track byte labels at run time
  - Tracks label of each byte of data

MLS vs IFT

Multilevel Security	**Information Flow Tracking**
Process	Operation (add, sub, xor, *etc.*)
Label	Taint tag
File or input device	File or input device
High/low water marking	Bitwise OR of taint tag

IFT for Secrecy

```
int x, y, z;

fscanf(secretfile, "%d", &x);
fscanf(publicfile, "%d", &y);

z = x + y; // z now contains secret info

fprintf(publicfile, "%d", x); // Leaks secret to public
fprintf(publicfile, "%d", y); // Allowed: same level
fprintf(publicfile, "%d", z); // Leaks secret to public

fprintf(secretfile, "%d", x); // Allowed :same level
fprintf(secretfile, "%d", y); // Allowed: write down
fprintf(secretfile, "%d", z); // Allowed: write down
```

TaintDroid

- Track data labels at variable granularity by modifying Android's Dalvik virtual machine
- Labels are 32 bits
- The label of result of every operation is bitwise-OR of labels of operands
- What do the labels represent in TaintDroid?

TaintDroid

- Track data labels at variable granularity by modifying Android's Dalvik virtual machine
- Labels are 32 bits
- The label of result of every operation is bitwise-OR of labels of operands
- What do the labels represent in TaintDroid?
  - Source of sensitive data (e.g. GPS or microphone)
  - Data the user may not want to leave the device

TaintDroid

- Is TaintDroid trying to protect *secrecy* or *integrity?*
  - *Secrecy*, although mechanism can be used for both
- TaintDroid records when an app sends tainted data out
  - Can be used to prevent such data from leaving phone

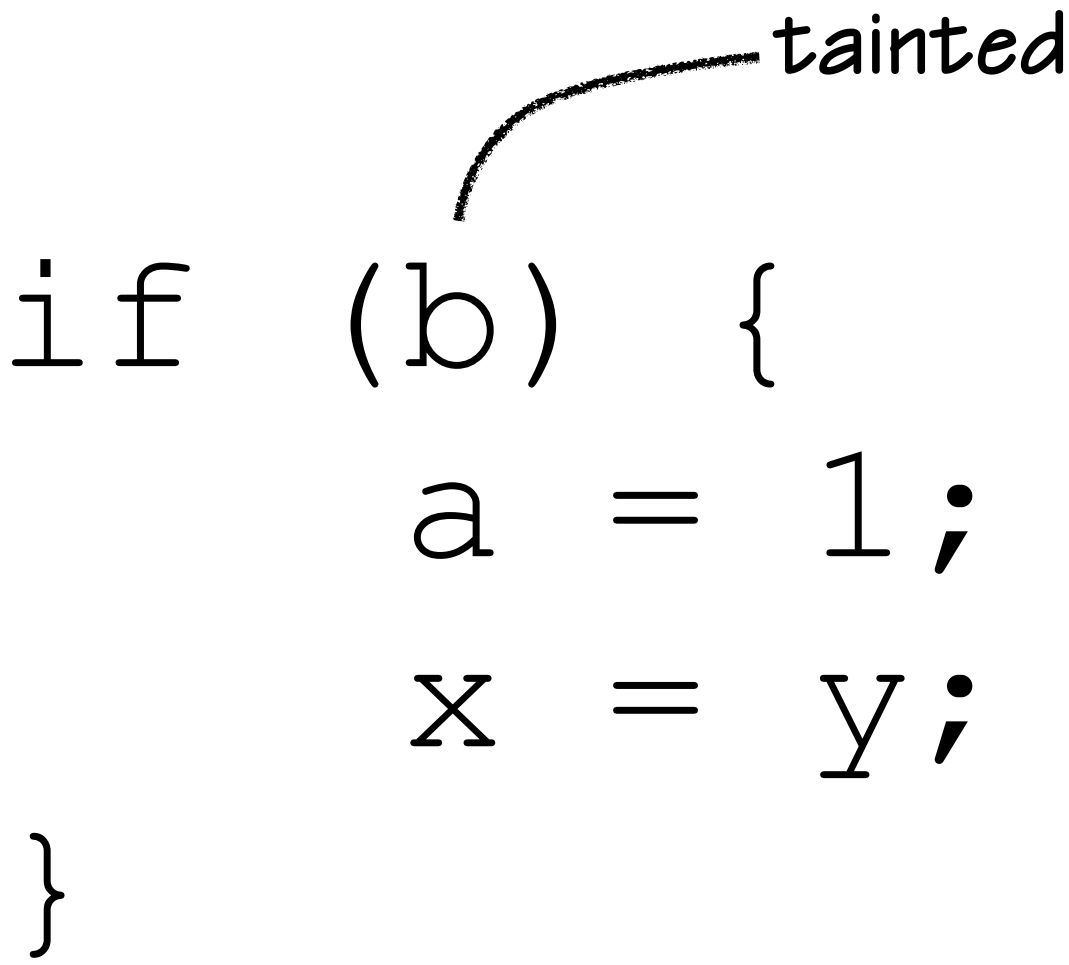
IFT for Integrity

- How can you use IFT to protect integrity?
  - *High:* trusted data, *Low:* untrusted data
  - Do not execute *Low* code or use *Low* address in jump
- Protect files, directories, processes from *Low* data
- What are the limits?

IFT Achille's Heel

What do you do when tainted data used as condition of jump?

IFT Achille's Heel



IFT Achille's Heel

- Option 1: Ignore control dependencies
  - Only taint arithmetic and memory access operations
- Option 2: Taint all variables *inside* then and *else* clauses
- Neither one is ideal:
  - Option 1 leads to incomplete taint
  - Option 2 leads to over-tainting

Summary

- Multilayer security guarantees information protection
- Implementation must be correct
- Declassification must be correct
- Side-channels may still exist