

CSci 5271  
Introduction to Computer Security  
Day 11: OS security: access control

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## Outline

Multilevel and mandatory access control

Announcements intermission

Capability-based access control

## MAC vs. DAC

- Discretionary access control (DAC)
  - Users mostly decide permissions on their own files
  - If you have information, you can pass it on to anyone
  - E.g., traditional Unix file permissions
- Mandatory access control (MAC)
  - Restrictions enforced regardless of subject choices
  - Typically specified by an administrator

## Motivation: it's classified

- Government defense and intelligence agencies use *classification* to restrict access to information
- E.g.: Unclassified, Confidential, Secret, Top Secret
- Multilevel Secure (MLS) systems first developed to support mixing classification levels under timesharing

## Motivation: system integrity

- Limit damage if a network server application is compromised
  - Unix DAC is no help if server is root
- Limit damage from browser-downloaded malware
  - Windows DAC is no help if browser is "administrator" user

## Bell-LaPadula, linear case

- State-machine-like model developed for US DoD in 1970s
  - A subject at one level may not read a resource at a higher level
    - Simple security property, "no read up"
  - A subject at one level may not write a resource at a lower level
    - \* property, "no write down"

## High watermark property

- Dynamic implementation of BLP
- Process has security level equal to highest file read
- Written files inherit this level

## Biba and low watermark

- Inverting a confidentiality policy gives an integrity one
- Biba: no write up, no read down
- Low watermark policy
- BLP  $\wedge$  Biba  $\Rightarrow$  levels are isolated

## Information-flow perspective

- Confidentiality: secret data should not flow to public sinks
- Integrity: untrusted data should not flow to critical sinks
- Watermark policies are process-level conservative abstractions

## Covert channels

- Problem: conspiring parties can misuse other mechanisms to transmit information
- Storage channel: writable shared state
  - E.g., screen brightness on mobile phone
- Timing channel: speed or ordering of events
  - E.g., deliberately consume CPU time

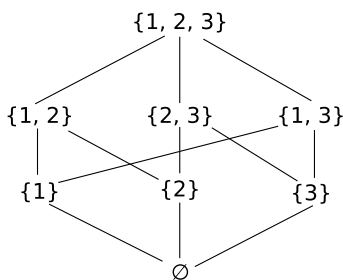
## Multilateral security / compartments

- In classification, want finer divisions based on need-to-know
- Also, selected wider sharing (e.g., with allied nations)
- Many other applications also have this character
  - Anderson's example: medical data
- How to adapt BLP-style MAC?

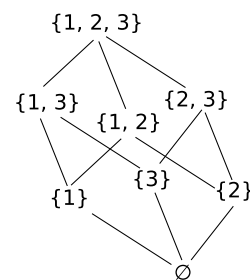
## Partial orders and lattices

- $\leq$  on integers is a *total order*
  - Reflexive, antisymmetric, transitive,  $a \leq b$  or  $b \leq a$
- Dropping last gives a *partial order*
- A *lattice* is a partial order plus operators for:
  - Least upper bound or join  $\sqcup$
  - Greatest lower bound or meet  $\sqcap$
- Example: subsets with  $\subseteq, \cup, \cap$

## Subset lattice example



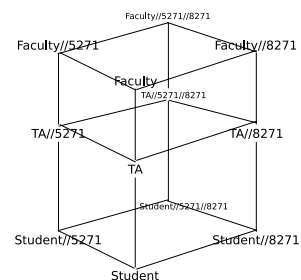
## Subset lattice example



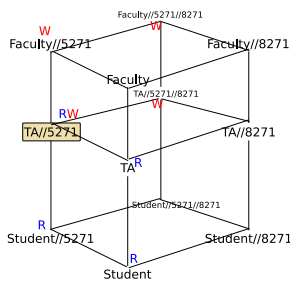
## Lattice model

- Generalize MLS levels to elements in a lattice
- BLP and Biba work analogously with lattice ordering
- No access to incomparable levels
- Potential problem: combinatorial explosion of compartments

## Classification lattice example



## Lattice BLP example



## Another notation

Faculty  
→ (Faculty,  $\emptyset$ )  
Faculty//5271  
→ (Faculty, {5271})  
Faculty//5271//8271  
→ (Faculty, {5271, 8271})

## MLS operating systems

- 1970s timesharing, including Multics
- "Trusted" versions of commercial Unix (e.g. Solaris)
- SELinux (called "type enforcement")
- Integrity protections in Windows Vista and later

## Multi-VM systems

- One (e.g., Windows) VM for each security level
- More trustworthy OS underneath provides limited interaction
- E.g., NSA NetTop: VMWare on SELinux
- Downside: administrative overhead

## Air gaps, pumps, and diodes

- The lack of a connection between networks of different levels is called an *air gap*
- A *pump* transfers data securely from one network to another
- A *data diode* allows information flow in only one direction

## Chelsea Manning cables leak

- Manning (née Bradley) was an intelligence analyst deployed to Iraq
- PC in a T-SCIF connected to SIPRNet (Secret), air gapped
- CD-RWs used for backup and software transfer
- Contrary to policy: taking such a CD-RW home in your pocket <http://www.fas.org/sgp/jud/manning/022813-statement.pdf>

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## Project progress reports due tonight

- Due tonight, 11:59pm
- Note that these should be written and submitted individually
- On Canvas (no Gradescope for project-related submissions)

## Exercise Set 1 results up

- See Gradescope for per-question comments
- Grades in Canvas gradebook include late penalties if any
  - This semester using, e.g.,  $\min(75, x)$  instead of  $0.75 \cdot x$

## Exercise Set 2 coming soon

- Will be due next Wednesday the 20th if we are able to release it soon
  - This schedule lets you discuss solutions on Piazza before the midterm
- Hands-on assignment will also be available as soon as it is ready, schedule announced then

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## ACLs: no fine-grained subjects

- Subjects are a list of usernames maintained by a sysadmin
- Unusual to have a separate subject for an application
- Cannot easily subset access (sandbox)

## ACLs: ambient authority

- All authority exists by virtue of identity
- Kernel automatically applies all available authority
- Authority applied incorrectly leads to attacks

## Confused deputy problem

- Compiler writes to billing database
- Compiler can produce debug output to user-specified file
- Specify debug output to billing file, disrupt billing

## (Object) capabilities

- A *capability* both designates a resource and provides authority to access it
- Similar to an object reference
  - Unforgeable, but can copy and distribute
- Typically still managed by the kernel

## Capability slogans (Miller et al.)

- No designation without authority
- Dynamic subject creation
- Subject-aggregated authority mgmt.
- No ambient authority
- Composability of authorities
- Access-controlled delegation
- Dynamic resource creation

### Partial example: Unix FDs

- Authority to access a specific file
- Managed by kernel on behalf of process
- Can be passed between processes
  - Though rare other than parent to child
- Unix not designed to use pervasively

### Distinguish: password capabilities

- Bit pattern itself is the capability
  - No centralized management
- Modern example: authorization using cryptographic certificates

### Revocation with capabilities

- Use indirection: give real capability via a pair of middlemen
- $A \rightarrow B$  via  $A \rightarrow F \rightarrow R \rightarrow B$
- Retain capability to tell R to drop capability to B
- Depends on composability

### Confinement with capabilities

- A cannot pass a capability to B if it cannot communicate with A at all
- Disconnected parts of the capability graph cannot be reconnected
- Depends on controlled delegation and data/capability distinction

### OKL4 and seL4

- Commercial and research microkernels
- Recent versions of OKL4 use capability design from seL4
- Used as a hypervisor, e.g. underneath paravirtualized Linux
- Shipped on over 1 billion cell phones

### Joe-E and Caja

- Dialects of Java and JavaScript (resp.) using capabilities for confined execution
- E.g., of JavaScript in an advertisement
- Note reliance on Java and JavaScript type safety