Chapter 8
Authorization

Authentication vs Authorization

- Authentication — Who goes there?
  - Restrictions on who (or what) can access system
- **Authorization** — Are you allowed to do that?
  - Restrictions on actions of authenticated users
- Authorization is a form of **access control**
- Authorization enforced by
  - Access Control Lists
  - Capabilities

Lampson's Access Control Matrix

- **Subjects** (users) index the rows
- **Objects** (resources) index the columns

	OS	Accounting program	Accounting data	Insurance data	Payroll data
Bob	rx	rx	r	---	---
Alice	rx	rx	r	rw	rw
Sam	rwx	rwx	r	rw	rw
Accounting program	rx	rx	rw	rw	rw

Are You Allowed to Do That?

- **Access control matrix** has all relevant info
- But how to manage a large access control (AC) matrix?
- Could be 1000's of users, 1000's of resources
- Then AC matrix with 1,000,000's of entries
- Need to check this matrix before access to any resource is allowed
- Hopelessly inefficient

Access Control Lists (ACLs)

- ACL: store access control matrix by **column**
- Example: ACL for **insurance data** is in **blue**

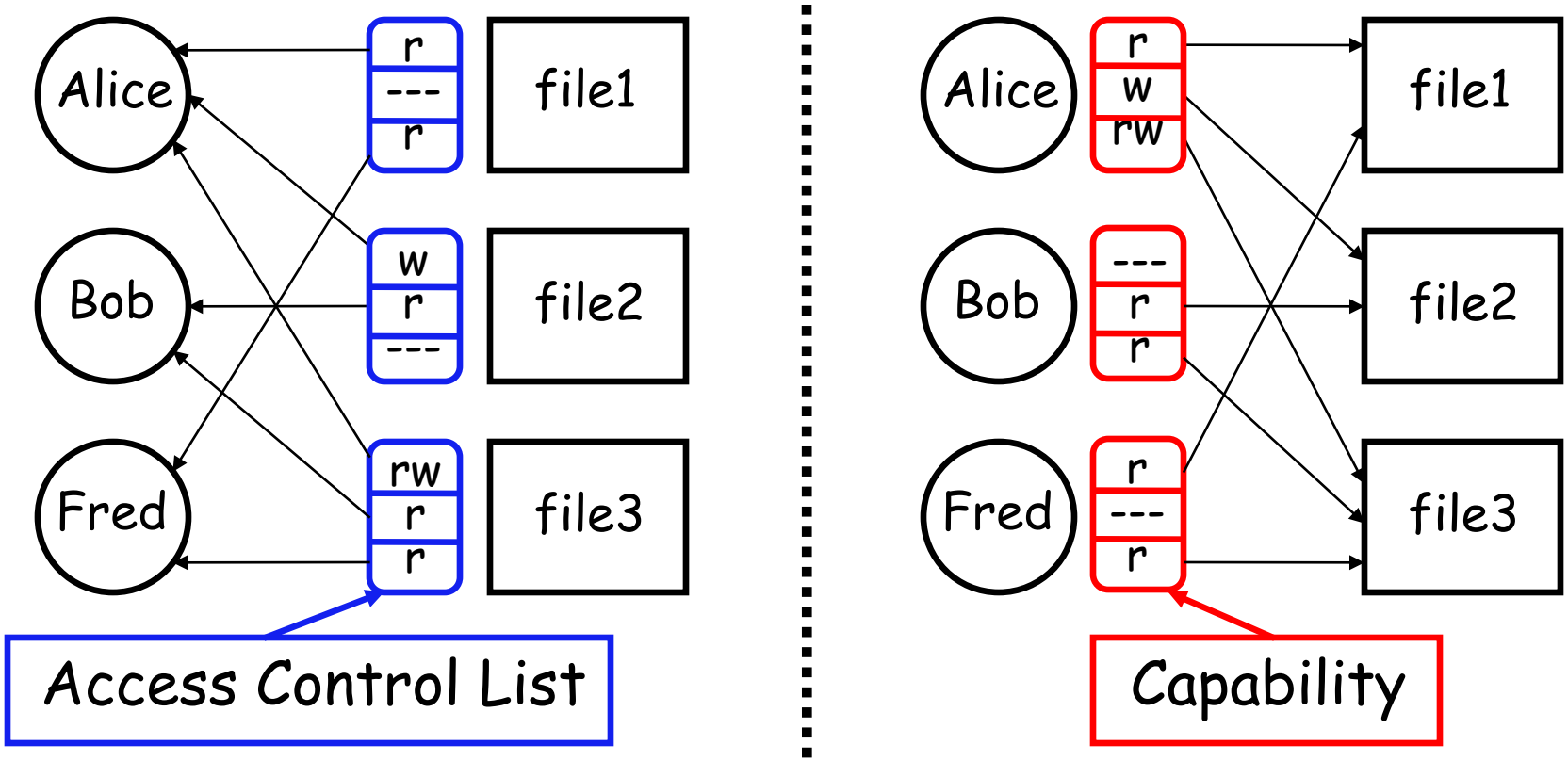
	OS	Accounting program	Accounting data	**Insurance data**	Payroll data
Bob	rx	rx	r	---	---
Alice	rx	rx	r	rw	rw
Sam	rwx	rwx	r	rw	rw
Accounting program	rx	rx	rw	rw	rw

Capabilities (or C-Lists)

- Store access control matrix by **row**
- Example: Capability for **Alice** is in **red**

	OS	Accounting program	Accounting data	Insurance data	Payroll data
Bob	rx	rx	r	---	---
Alice	**rx**	**rx**	**r**	**rw**	**rw**
Sam	rwx	rwx	r	rw	rw
Accounting program	rx	rx	rw	rw	rw

ACLs vs Capabilities



- Note that arrows point in opposite directions!
- With ACLs, still need to associate users to filess

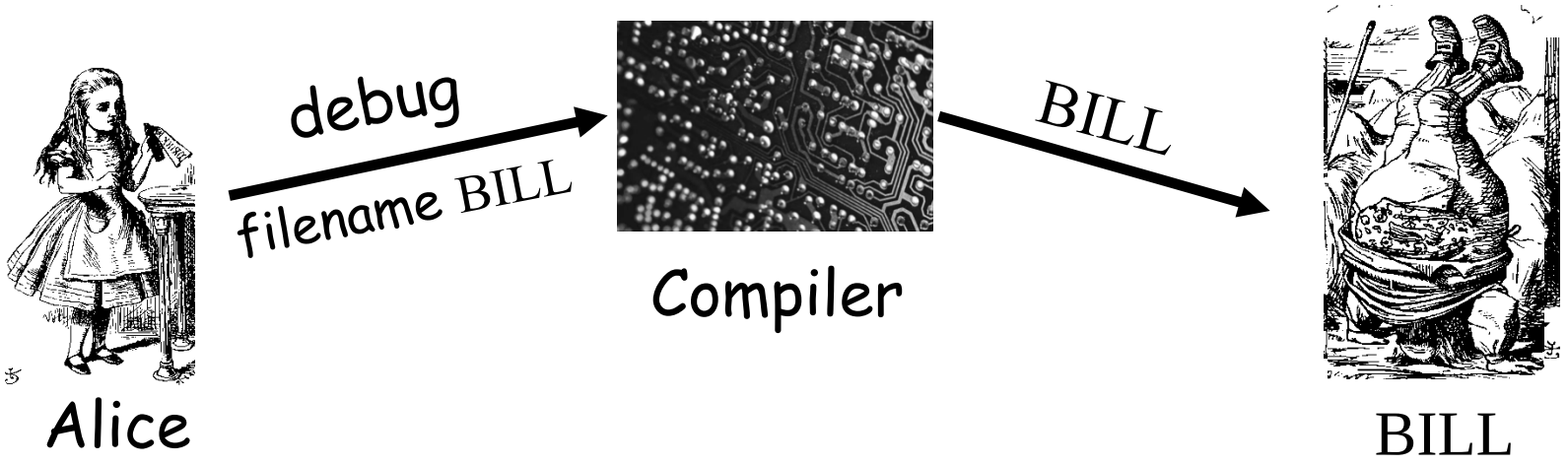
Confused Deputy

- Two resources
  - Compiler and BILL file (billing info)
- Compiler can write file BILL
- Alice can invoke compiler with a debug filename
- Alice not allowed to write to BILL

- Access control matrix

	Compiler	BILL
Alice	x	---
Compiler	rx	rw

ACL's and Confused Deputy



- Compiler is **deputy** acting on behalf of Alice
- Compiler is **confused**
  - Alice is not allowed to write BILL
- Compiler has confused its rights with Alice's

Confused Deputy

- Compiler acting for Alice is confused
- There has been a separation of **authority** from the **purpose** for which it is used
- With ACLs, difficult to avoid this problem
- With Capabilities, easier to prevent problem
  - Must maintain association between authority and intended purpose
  - Capabilities make it easy to **delegate** authority

ACLs vs Capabilities

- ACLs
  - Good when users manage their own files
  - Protection is data-oriented
  - Easy to change rights to a resource
- Capabilities
  - Easy to delegate
  - Easy to add/delete users
  - Easier to avoid the confused deputy
  - More difficult to implement
  - The "Zen of information security"
- Capabilities loved by academics
  - Capability Myths Demolished

Multilevel Security (MLS) Models

Classifications and Clearances

- **Classifications** apply to **objects**
- **Clearances** apply to **subjects**
- US Department of Defense uses 4 levels of classifications/clearances

  TOP SECRET

  SECRET

  CONFIDENTIAL

  UNCLASSIFIED

Clearances and Classification

- To obtain a **SECRET** clearance requires a routine background check
- A **TOP SECRET** clearance requires extensive background check
- Practical classification problems
  - Proper classification not always clear
  - Level of granularity to apply classifications
  - Aggregation — flipside of granularity

Subjects and Objects

- Let O be an **object**, S a **subject**
  - O has a classification
  - S has a clearance
  - Security **level** denoted L(O) and L(S)
- For DoD levels, we have

  TOP SECRET > SECRET > CONFIDENTIAL > UNCLASSIFIED

Multilevel Security (MLS)

- MLS needed when subjects/objects at different levels use same system
- MLS is a form of **Access Control**
- Military/government interest in MLS for many decades
  - Lots of funded research into MLS
  - Strengths and weaknesses of MLS relatively well understood (theoretical and practical)
  - Many possible uses of MLS outside military

MLS Applications

- Classified government/military information
- **Business example:** info restricted to
  - Senior management only
  - All management
  - Everyone in company
  - General public
- Network firewall
  - Keep intruders at low level to limit damage
- Confidential medical info, databases, etc.

MLS Security Models

- MLS models explain **what** needs to be done
- Models do **not** tell you **how** to implement
- Models are descriptive, not prescriptive
  - High level description, not an algorithm
- There are many MLS models
- We'll discuss simplest MLS model
  - Other models are more realistic
  - Other models also more complex, more difficult to enforce, harder to verify, etc.

Bell-LaPadula

- BLP security model designed to express essential requirements for MLS
- BLP deals with **confidentiality**
  - To prevent unauthorized reading
- Recall that O is an object, S a subject
  - Object O has a classification
  - Subject S has a clearance
  - Security level denoted $L(O)$ and $L(S)$

Bell-LaPadula

- BLP consists of
  - **Simple Security Condition**: S can read O if and only if $L(O) \leq L(S)$
  - ***-Property** (**Star Property**): S can write O if and only if $L(S) \leq L(O)$
- **No read up, no write down**

McLean's Criticisms of BLP

- McLean: BLP is "so trivial that it is hard to imagine a realistic security model for which it does not hold"
- McLean's "system Z" allowed administrator to reclassify object, then "write down"
- Is this fair?
- Violates spirit of BLP, but **not** expressly forbidden in statement of BLP
- Raises fundamental questions about the nature of (and limits of) modeling

B and LP's Response

- BLP enhanced with **tranquility property**
  - Strong tranquility property: security labels never change
  - Weak tranquility property: security label can only change if it does not violate "established security policy"
- Strong tranquility impractical in real world
  - Often want to enforce "least privilege"
  - Give users lowest privilege needed for current work
  - Then upgrade privilege as needed (and allowed by policy)
  - This is known as the **high water mark** principle
- Weak tranquility allows for **least privilege** (high water mark), but the property is vague

BLP: The Bottom Line

- BLP is simple, but probably too simple
- BLP is one of the few security models that can be used to prove things about systems
- BLP has inspired other security models
  - Most other models try to be more realistic
  - Other security models are more complex
  - Other models difficult to analyze and/or apply in practice

Biba's Model

- BLP for confidentiality, Biba for **integrity**
  - Biba is to prevent unauthorized writing
- Biba is (in a sense) the dual of BLP
- Integrity model
  - Spse you trust the integrity of O but not O
  - If object O includes O and O then you cannot trust the integrity of O
- Integrity level of O is minimum of the integrity of any object in O
- **Low water mark** principle for integrity

Biba

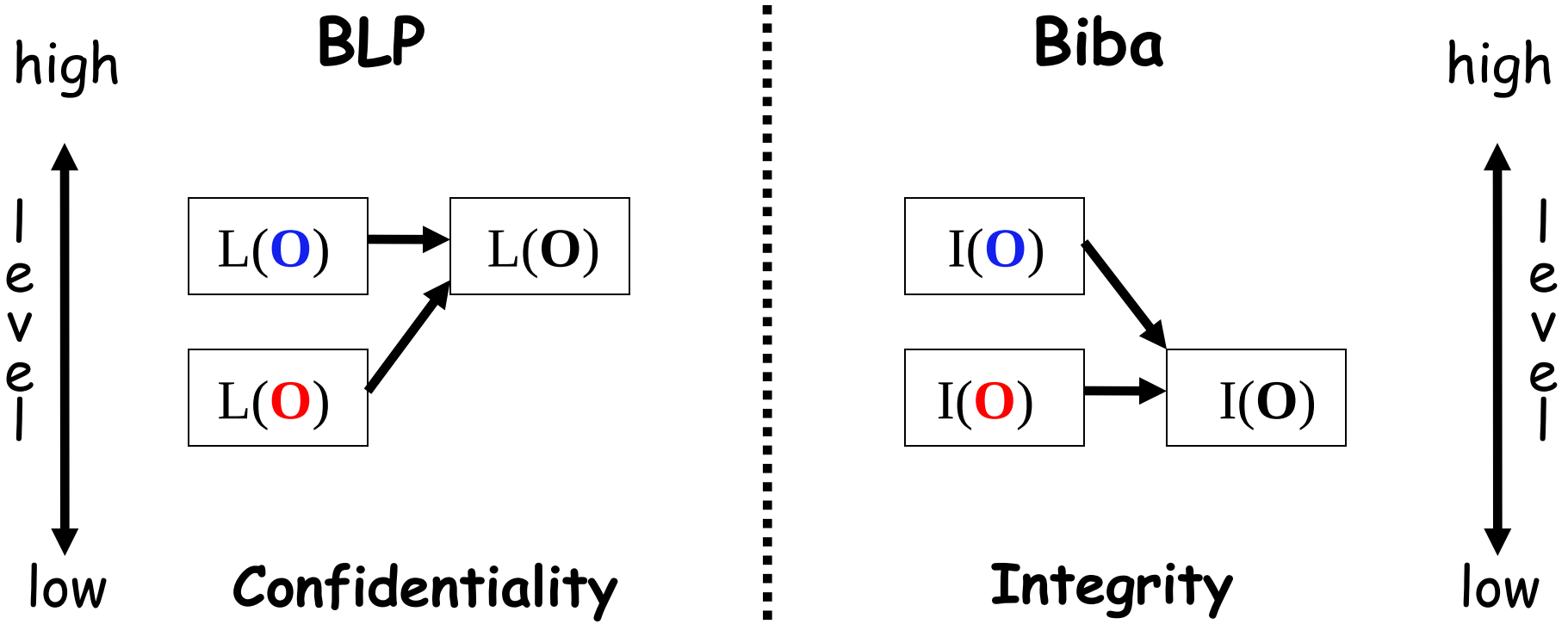
- Let I(O) denote the integrity of object O and I(S) denote the integrity of subject S
- Biba can be stated as

  Write Access Rule: S can write O if and only if
  $I(O) \leq I(S)$
  (if S writes O, the integrity of O ≤ that of S)

  Biba's Model: S can read O if and only if
  $I(S) \leq I(O)$
  (if S reads O, the integrity of S ≤ that of O)
- Often, replace Biba's Model with

  Low Water Mark Policy: If S reads O, then
  $I(S) = \min(I(S), I(O))$

BLP vs Biba


BLP
high
level
low
L(O)
L(O)
L(O)
Confidentiality
Biba
high
level
low
I(O)
I(O)
I(O)
Integrity

Multilateral Security (Compartments)

Multilateral Security

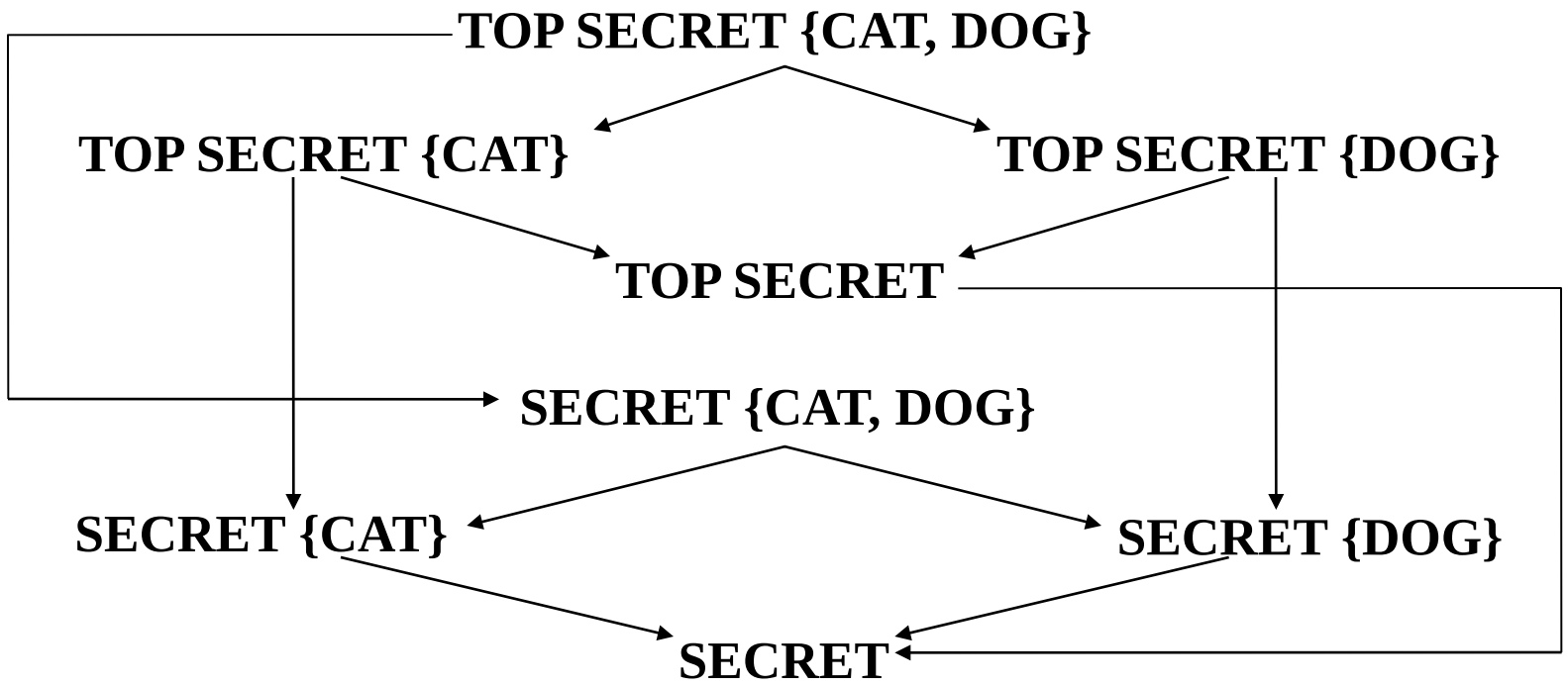
- Multilevel Security (MLS) enforces access control **up and down**
- Simple hierarchy of security labels may not be flexible enough
- Multilateral security enforces access control **across** by creating compartments
- Suppose **TOP SECRET** divided into **TOP SECRET {CAT}** and **TOP SECRET {DOG}**
- Both are **TOP SECRET** but information flow restricted across the **TOP SECRET** level

Multilateral Security

- Why compartments?
  - Why not create a new classification level?
- May not want either of
  - **TOP SECRET {CAT} ≥ TOP SECRET {DOG}**
  - **TOP SECRET {DOG} ≥ TOP SECRET {CAT}**
- Compartments allow us to enforce the **need to know** principle
  - Regardless of your clearance, you only have access to info that you need to know

Multilateral Security

- Arrows indicate "≥" relationship



- Not all classifications are comparable, e.g.,

TOP SECRET {CAT} vs **SECRET {CAT, DOG}**

Lattice ...

MLS vs Multilateral Security

- MLS can be used without multilateral security or vice-versa
- But, MLS almost always includes multilateral
- Example
  - MLS mandated for protecting medical records of British Medical Association (BMA)
  - AIDS was **TOP SECRET**, prescriptions **SECRET**
  - What is the classification of an AIDS drug?
  - Everything tends toward **TOP SECRET**
  - Defeats the purpose of the system!
- Multilateral security was used instead

Covert Channel

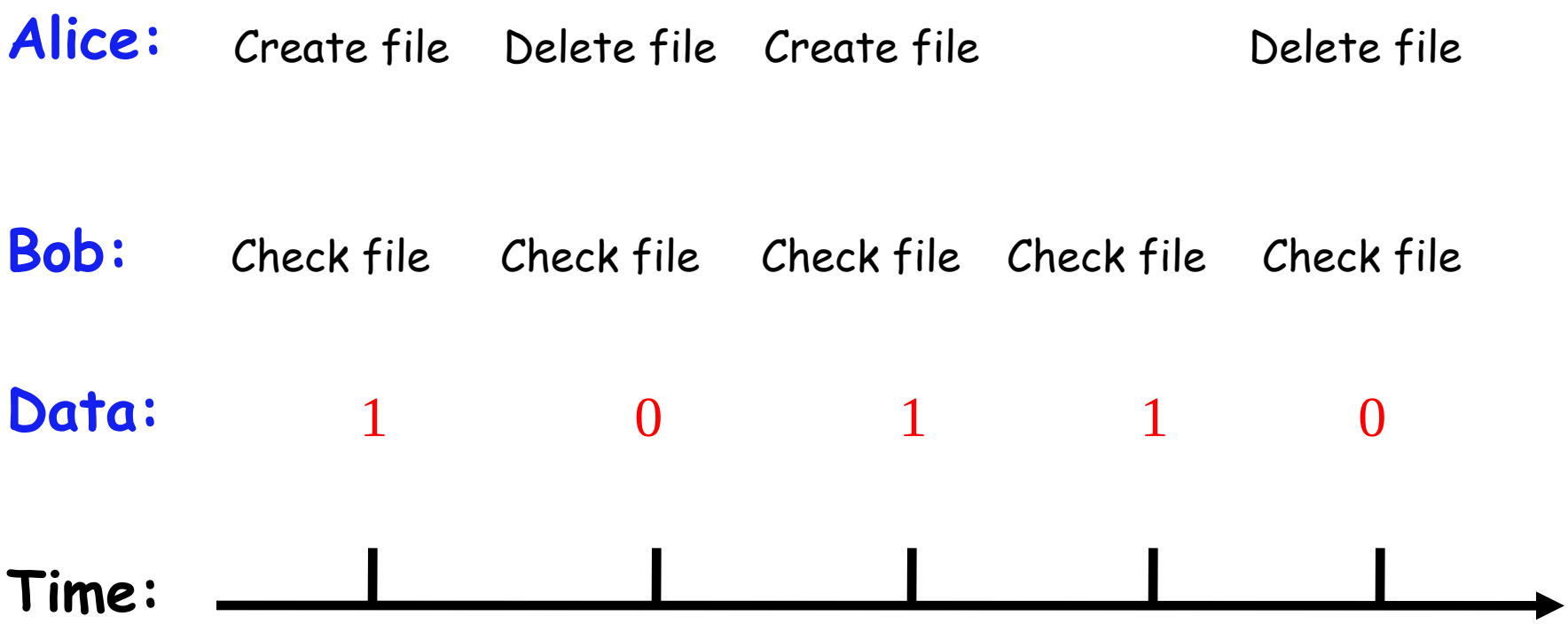
Covert Channel

- MLS designed to restrict legitimate channels of communication
- May be other ways for information to flow
- For example, resources shared at different levels may signal information
- **Covert channel**: "communication path not intended as such by system's designers"

Covert Channel Example

- Alice has **TOP SECRET** clearance, Bob has **CONFIDENTIAL** clearance
- Suppose the file space shared by all users
- Alice creates file FileXYzW to signal "1" to Bob, and removes file to signal "0"
- Once each minute Bob lists the files
  - If file FileXYzW does not exist, Alice sent 0
  - If file FileXYzW exists, Alice sent 1
- Alice can leak **TOP SECRET** info to Bob!

Covert Channel Example



Covert Channel

- Other examples of covert channels
  - Print queue
  - ACK messages
  - Network traffic, etc., etc., etc.
- When does a covert channel exist?
  1. Sender and receiver have a shared resource
  2. Sender able to vary property of resource that receiver can observe
  3. Communication between sender and receiver can be synchronized

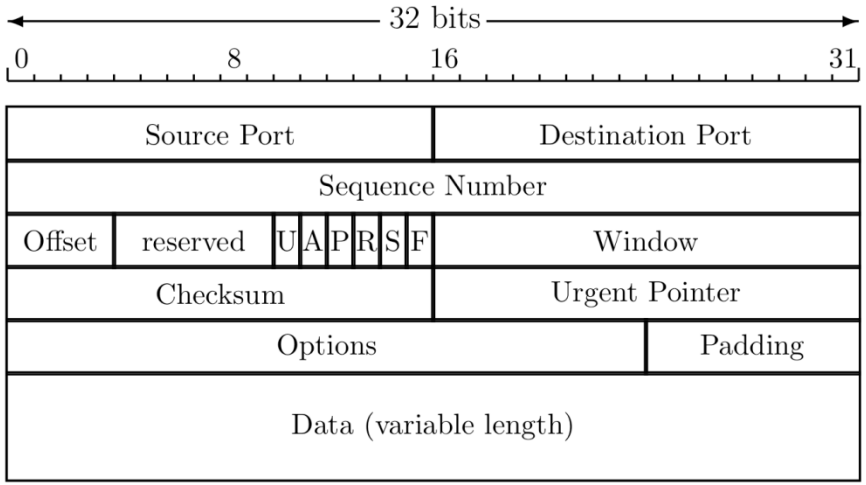
Covert Channel

- Covert channels exist almost everywhere
- Easy to eliminate covert channels…
  - Provided you eliminate all shared resources and all communication
- Virtually impossible to eliminate all covert channels in any useful system
  - DoD guidelines: goal is to **reduce covert channel capacity** to no more than 1 bit/second
  - Implication is that DoD has given up trying to eliminate covert channels!

Covert Channel

- Consider 100MB **TOP SECRET** file
  - Plaintext version stored in **TOP SECRET** place
  - Encrypted with AES using 256-bit key, ciphertext stored in **UNCLASSIFIED** location
- Suppose we reduce covert channel capacity to 1 bit per second
- It would take more than 25 years to leak entire document thru a covert channel
- But it would take less than 5 minutes to leak 256-bit AES key thru covert channel!

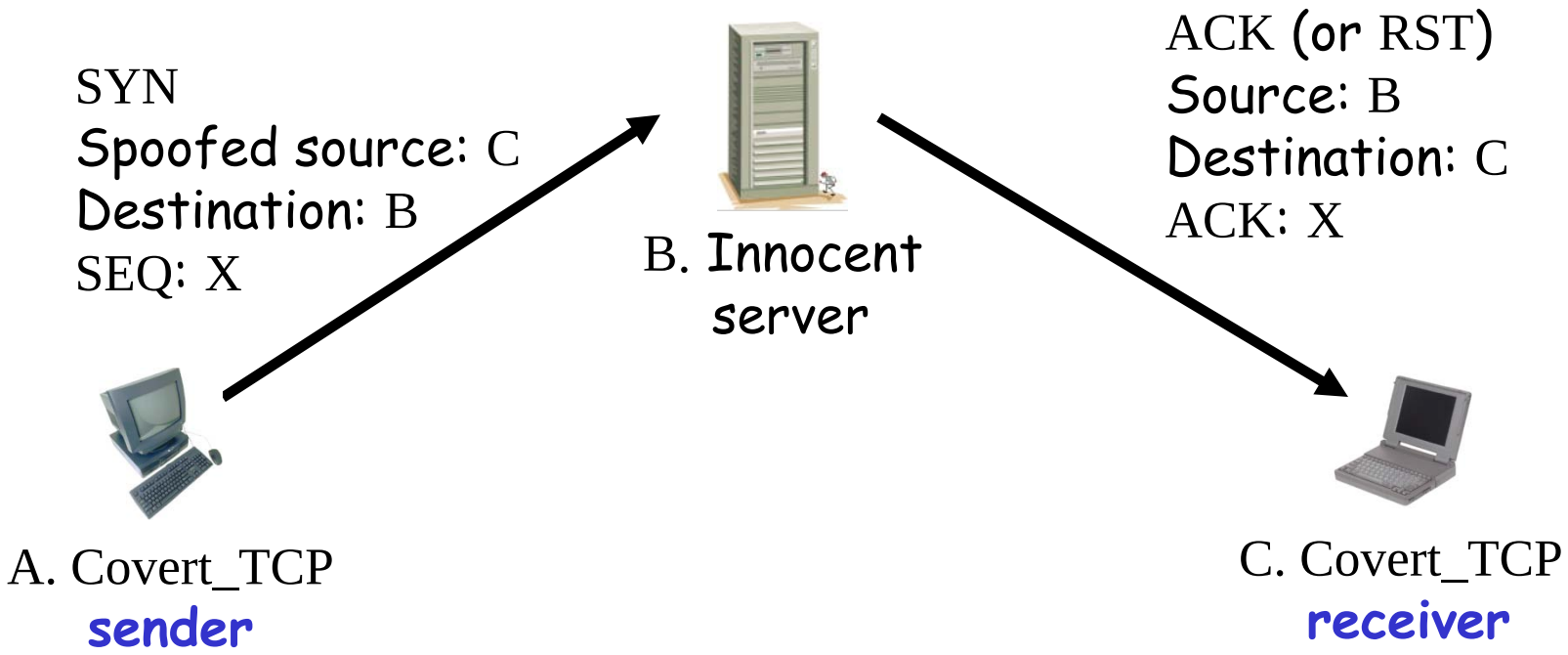
Real-World Covert Channel



- Hide data in TCP header "reserved" field
- Or use covert_TCP, tool to hide data in
  - Sequence number
  - ACK number

Real-World Covert Channel

- Hide data in TCP sequence numbers
- Tool: covert_TCP
- Sequence number X contains covert info



Inference Control

Inference Control Example

- Suppose we query a database
  - Question: What is average salary of female CS professors at SJSU?
  - Answer: $95,000
  - Question: How many female CS professors at SJSU?
  - Answer: 1
- Specific information has leaked from responses to general questions!

Inference Control and Research

- For example, medical records are private but valuable for research
- How to make info available for research and protect privacy?
- How to allow access to such data without leaking specific information?

Naïve Inference Control

- Remove names from medical records?
- Still may be easy to get specific info from such "anonymous" data
- Removing names is not enough
  - As seen in previous example
- What more can be done?

Less-naïve Inference Control

- Query set size control
  - Don't return an answer if set size is too small
- N-respondent, k% dominance rule
  - Do not release statistic if k% or more contributed by N or fewer
  - Example: Avg salary in Bill Gates' neighborhood
  - Used by the US Census Bureau
- Randomization
  - Add small amount of random noise to data
- Many other methods — none satisfactory

Inference Control: The Bottom Line

- Robust inference control may be impossible
- Is weak inference control better than no inference control?
  - **Yes**: Reduces amount of information that leaks and thereby limits the damage
- Is weak crypto better than no crypto?
  - **Probably not:** Encryption indicates important data
  - May be easier to filter encrypted data

Next time …
CAPTCHA