Security Principles (continued)

Adapted from CS 161 Spring 2022 - Lecture 2

Next: Security Principles (continued)

- Security principles
  - Know your threat model
  - Consider human factors
  - Security is economics
  - Detect if you can’t prevent
  - Defense in depth
  - Least privilege
  - Separation of responsibility
  - Ensure complete mediation
  - Don’t rely on security through obscurity
  - Use fail-safe defaults
  - Design in security from the start

Know Your Threat Model

- **Threat model**: A model of who your attacker is and what resources they have
- It all comes down to people: The attackers
  - No attackers = No problem!
  - One of the best ways to counter an attacker is to attack their reasons
- Why do people attack systems?

Money

Advertisers

Politics

Anonymous

NSA

Fun

To watch the world burn

Threat Model: Common Assumptions for Attackers

- Assume the attacker…
  - Can interact with systems without notice
  - Knows general information about systems (operating systems, vulnerabilities in software, usually patterns of activity, etc.)
  - Can get lucky
    - If an attack only succeeds 1/1,000,000 times, the attacker will try 1,000,000 times!
  - May coordinate complex attacks across different systems
  - Has the resources required to mount the attack
    - This can be tricky depending on who your threat model is
  - Can and will obtain privileges if possible

Trusted Computing Base

- **Trusted computing base** (**TCB**): The components of a system that security relies upon
- Question: What would you want from a TCB?
- Properties of the TCB:
  - Correctness
  - Completeness (can't be bypassed)
  - Security (can't be tampered with)
- Generally made to be as small as possible
  - A smaller, simpler TCB is easier to write and audit.
  - **KISS principle**: Keep It Simple, Stupid

Security is Economics

Textbook Chapter 1.3

Security is Economics

- Cost/benefit analyses often appear in security
  - The cost of your defense should be less than the cost of attacks happening
  - More security (usually) costs more
  - If the attack costs more than the reward, the attacker probably won't do it
- Example: You don't put a $10 lock on a $1 rock…
  - … unless a $1 rock can be used to attack something even more valuable
- Example: You have a brand-new, undiscovered attack that will work on anybody's computer. You wouldn't expose it on a random civilian.
  - iPhone security vulnerabilities are often sold for ~$1M on the market

Physical Safes

- We want our safes to stop people from breaking in, so let's measure them by how long it takes an expert to break into one:

TL-15 ($3,000)
15 minutes with common tools

TL-30 ($4,500)
30 minutes with common tools

TRTL-30 ($10,000)
30 minutes with common tools and a cutting torch

TXTL-60 (>$50,000)
60 minutes with common tools, a cutting torch, and up to 4 oz of explosives

Takeaway: Security is economics

Burglar Alarms

- Security companies are supposed to detect home break-ins
  - Problem: Too many false alarms. Many alarms go unanswered
  - Why is it useful to place a sign?
  - Placing a sign helps deter burglars from entering at risk of being caught…
    - … even if you don't have an alarm installed!
  - An attacker might prefer the neighbor without a sign

Detect If You Can’t Prevent

Textbook Chapter 1.4

Detect if You Can’t Prevent

- **Deterrence**: Stop the attack before it happens by making the attacker prefer to do something else
- **Prevention**: Stop the attack before it happens by making the attack fail
- **Detection**: Learn that there was an attack (after it happened)
  - If you can’t stop the attack from happening, you should at least be able to know that the attack has happened.
- **Response**: Do something about the attack (after it happened)
  - Once you know the attack happened, you should respond
  - Detection without response is pointless!

Response: Mitigation and Recovery

- Assume that bad things will happen! You should plan security in way that lets you to get back to a working state.
- Example: Earthquakes
  - Have resources for 1 week of staying put
  - Have resources to travel 50 miles from my current location
- Example: Ransomware
  - Ransomware: An attacker steals your data and demands payment in exchange for recovering your data
  - Keep offsite backups!
  - If your computer and house catch on fire, it should be no big deal.

Detection but no Response

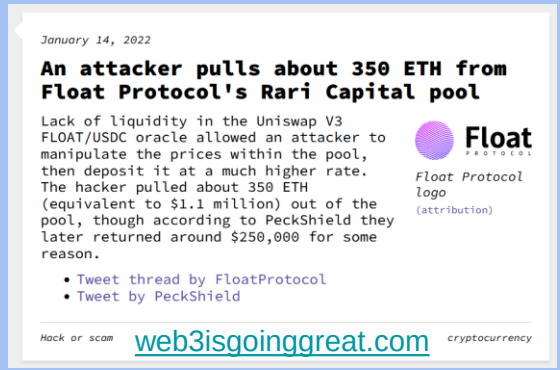
- Cryptocurrency transactions are irreversible. If you are hacked, you can never recover your Bitcoins.
  - $68M stolen from NiceHash exchange in December 2017
  - Four multi-million-dollar attacks on Ethereum in July 2018
  - Coinbase: One *detected* theft per day
  - Keep track of the fun at web3isgoinggreat.com
- **Takeaway:** Prevention is great, but depending only on prevention can be *brittle*: When prevention fails, the system fails catastrophically

Bloomberg

Link

Hacked Bitcoin Exchange Says Users May Share $68 Million Loss

Lulu Yilun Chen and Yuji Nakamura *August 5, 2016*



Defense in Depth

Textbook Chapter 1.5

Defense in Depth

- Multiple types of defenses should be layered together
- An attacker should have to breach all defenses to successfully attack a system
  - Ideally the strength of the defenses compounds somehow
- However, remember: security is economics
  - Defenses are not free.
  - Diminishing returns: Defenses are often less than the sum of their parts
    - 2 walls is much better than 1 wall
    - 101 walls is not much better than 100 walls

The Theodosian Walls of Constantinople

- The ancient capital of the Byzantine empire had a wall…
  - Well, they had a moat…
  - then a wall…
  - then a depression…
  - … and then an even bigger wall
- It also had towers to rain fire and arrows upon the enemy…
- Lasted until the Ottoman empire came along with cannons in 1453…
  - And now it's Istanbul not Constantinople
- **Takeaway**: Defense in depth: An attacker needed to breach all the walls
- **Takeaway**: Changing attacker technology changes defensive requirements

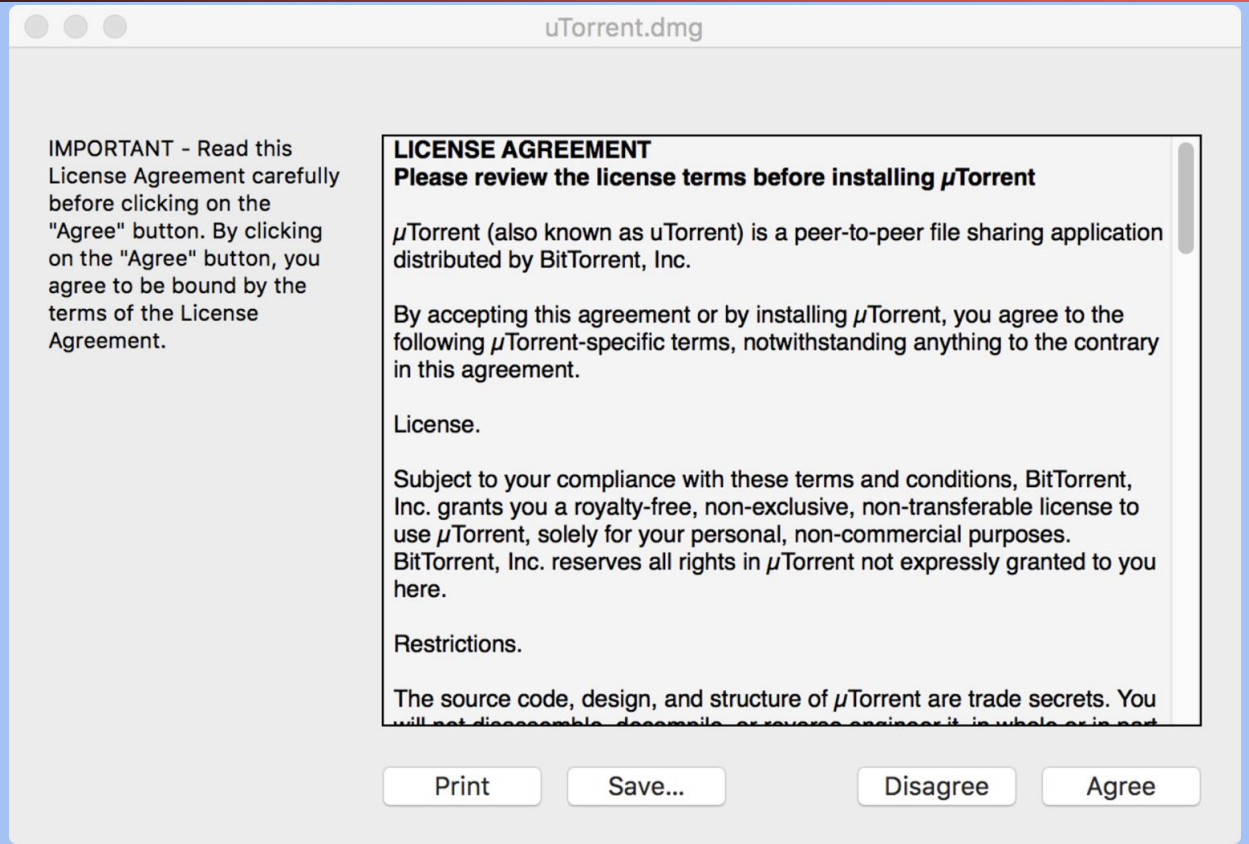
Least Privilege

Textbook Chapter 1.6

Least Privilege

- Consider the minimum permissions an entity or program *needs* to be able to do its job correctly, and grant only those permissions
  - If you grant unnecessary permissions, a malicious or hacked program could use those permissions against you

uTorrent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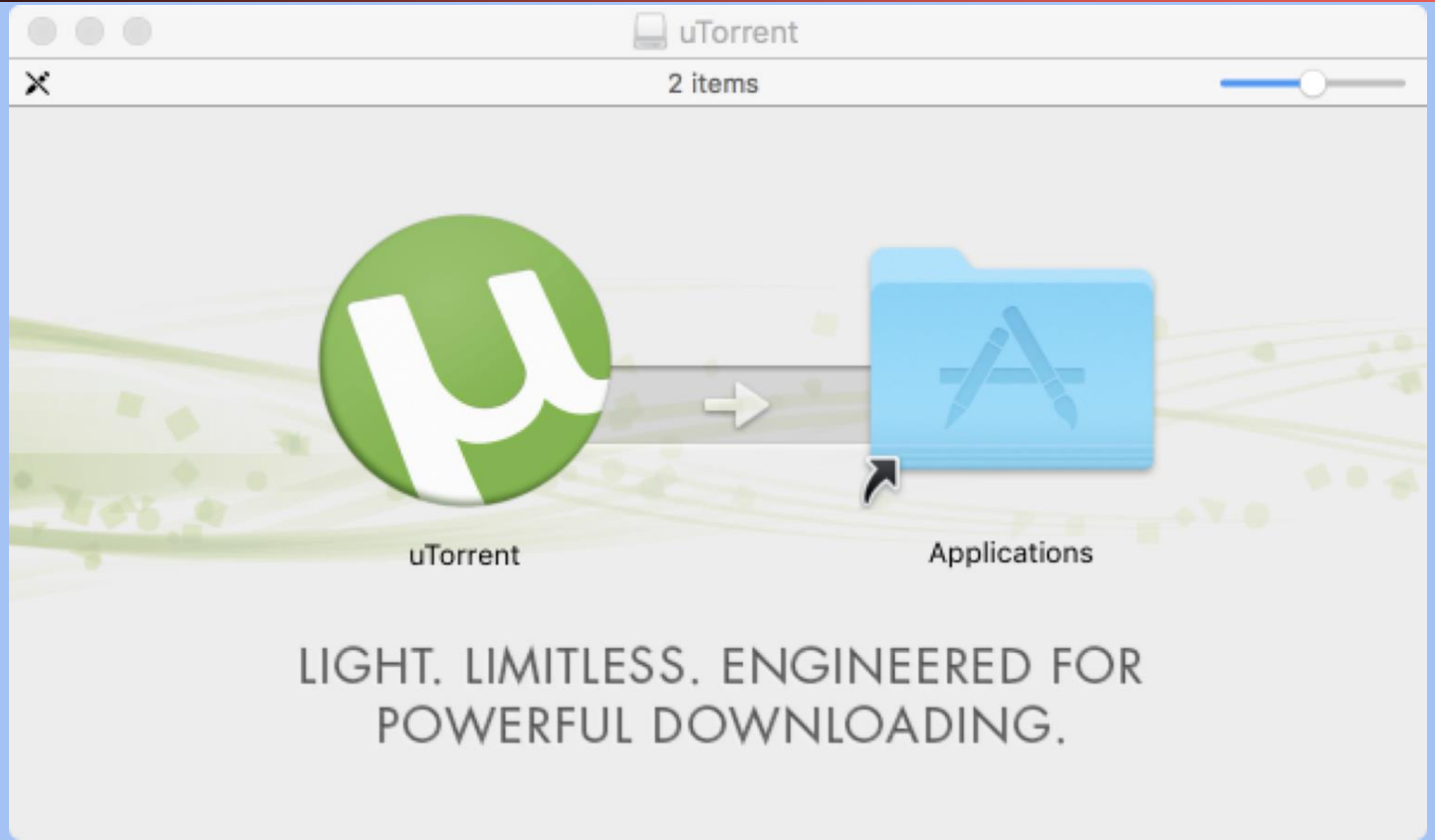
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2 items
uTorrent
Applications
LIGHT. LIMITLESS. ENGINEERED FOR
POWERFUL DOWNLOADING.

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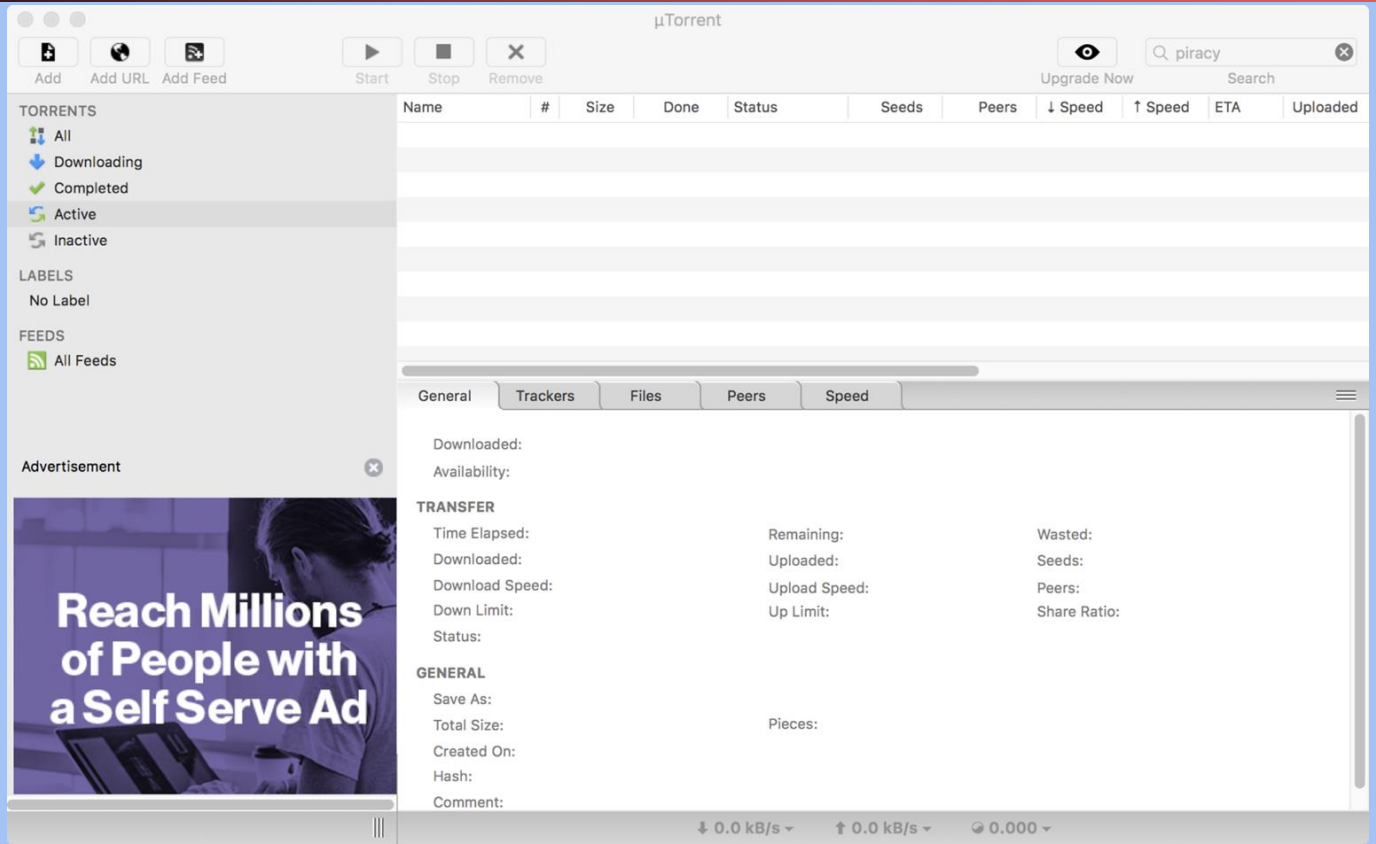
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Share Ratio:
Status:
GENERAL
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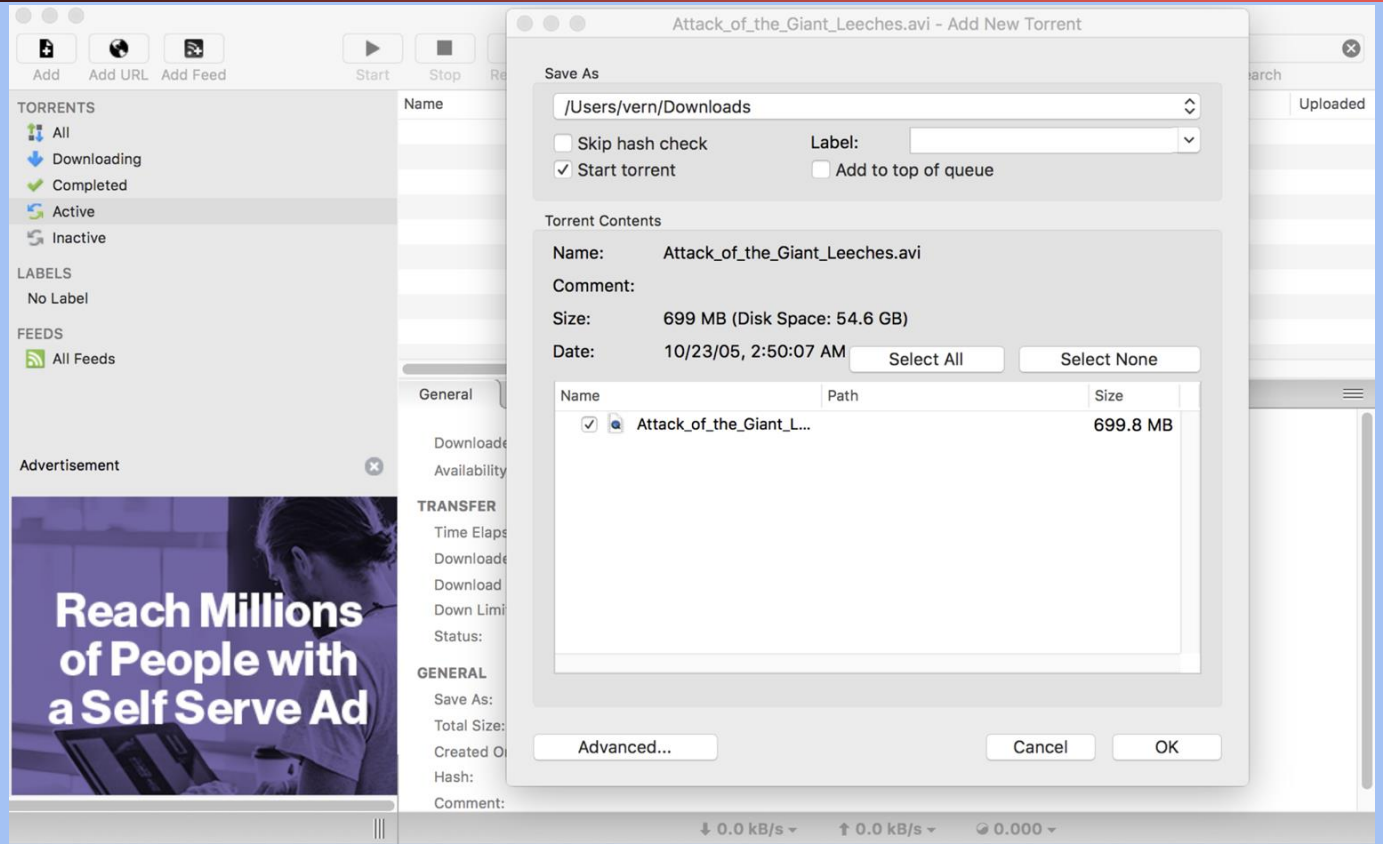
uTorrent


Add
Add URL
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Start
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All
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Reach Millions of People with a Self Serve Ad
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Attack_of_the_Giant_Leeches.avi - Add New Torrent
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Name: Attack_of_the_Giant_Leeches.avi
Comment:
Size: 699 MB (Disk Space: 54.6 GB)
Date: 10/23/05, 2:50:07 AM
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699.8 MB
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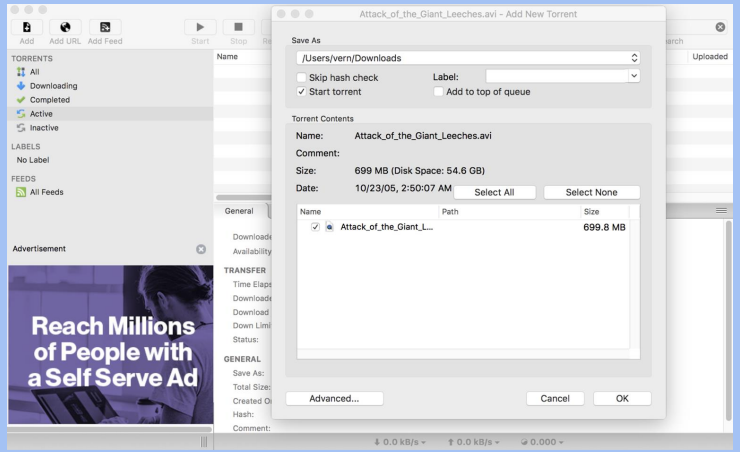
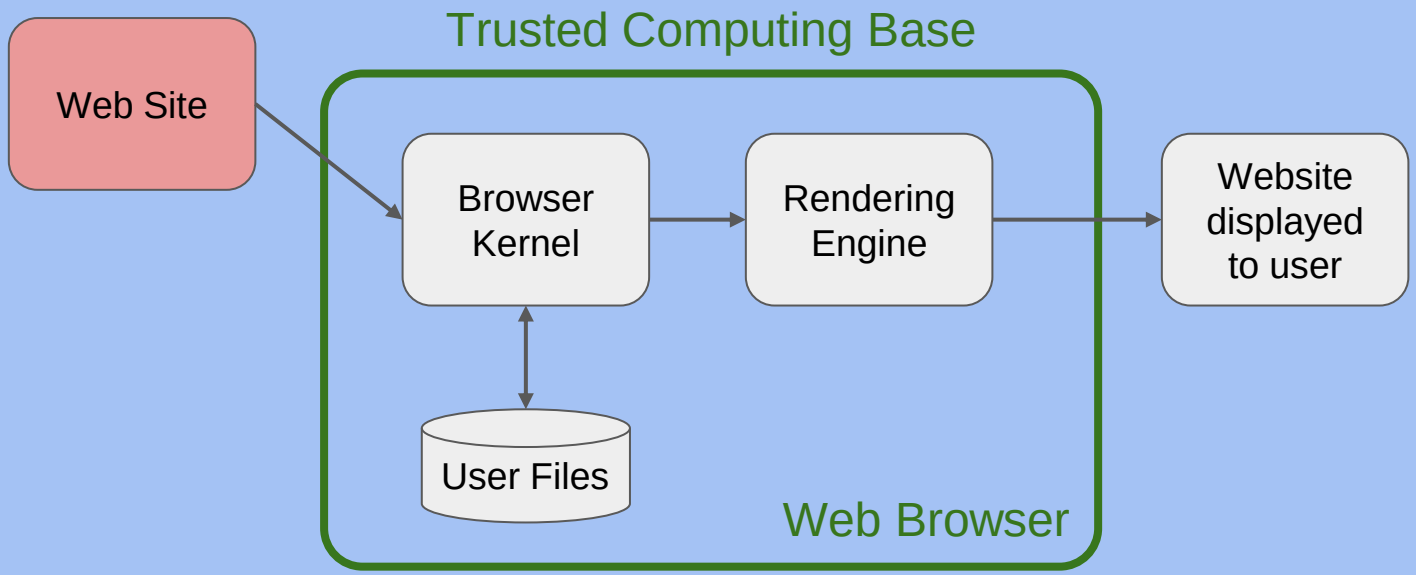
uTorrent

- What was this program able to do?
  - Leak your files
  - Delete your files
  - Send spam
  - Run another malicious program
- What does this program need to be able to do?
  - Access the screen
  - Manage some files (but not all files)
  - Make some Internet connections (but not all Internet connections)
- **Takeaway**: Least privilege



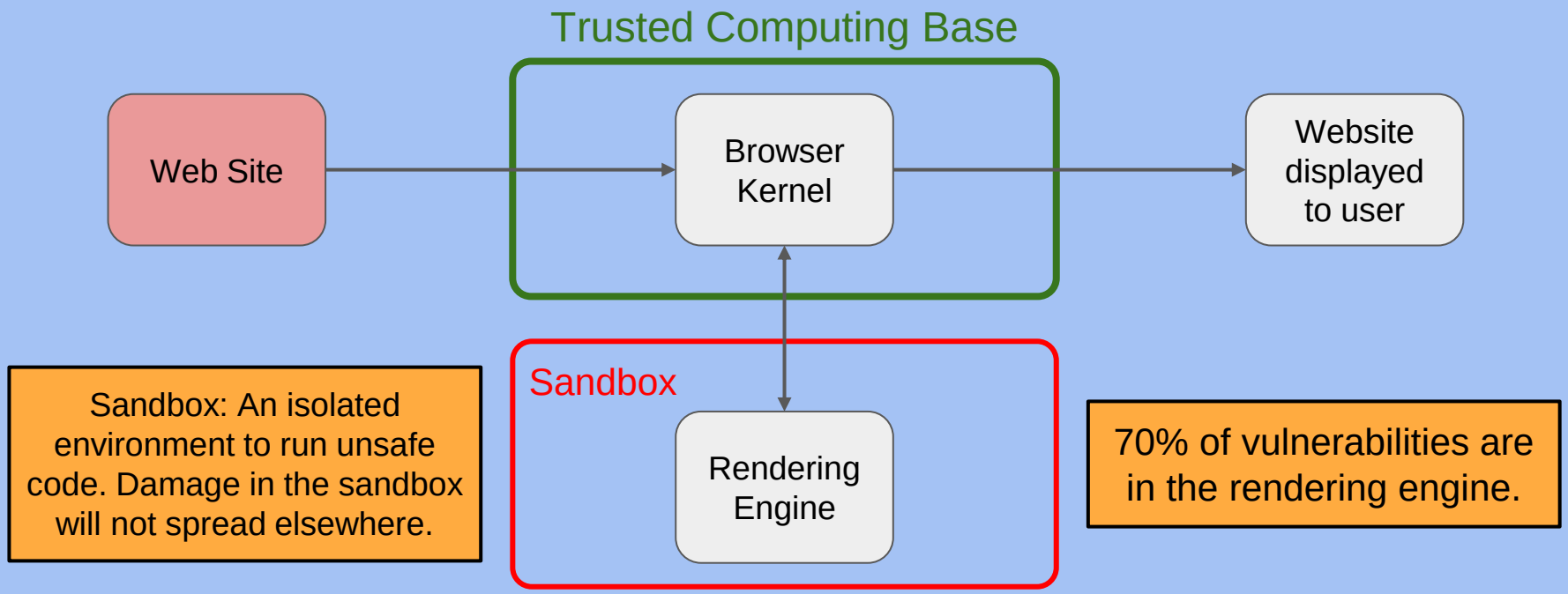
Browser Design with Poor Least Privilege

The contents of the web site come from an untrusted source (possibly malicious)



“Drive-by malware”: A malicious web page exploits a browser bug to infect local files

Google Chrome Design: Apply Least Privilege



Prevent "drive-by malware," where a malicious webpage exploits a browser bug to infect local files

Enabling Least Privilege: Access Control

- How to control who has access to particular data
  - Access needs to be *necessary* to accomplish the tasks
  - Least privilege: Excessive access can be a problem
- Example: Access control for DSP data in CS 161
  - Separate Google shared Drive from the main Drive
    - This allows independent access control *defaults*
  - *Limit* access to that Drive to those who have a need to know
    - Nick, head TAs, DSP TAs, course manager

Access Control for Systems: The Operating System

- The OS is the TCB of most modern systems, and it provides access controls to restrict the privileges of user programs
- The OS provides the following “guarantees”:
  - **Isolation**: A process can’t read or write the memory of any other process
  - **Permissions**: A process can only change files, interact with devices, etc. if it has permission to

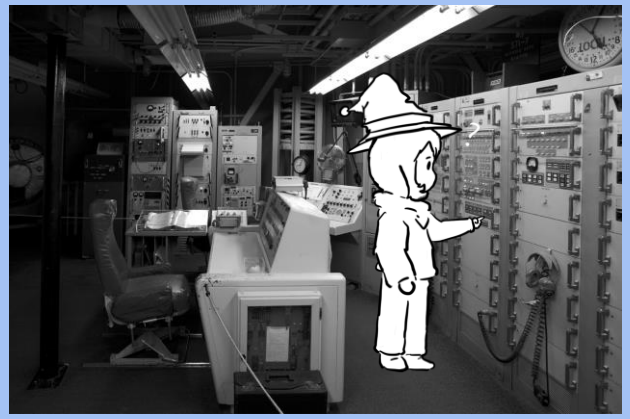
Separation of Responsibility

Textbook Chapter 1.7

Separation of Responsibility

- Also known as distributed trust
- If you need to have a privilege, consider requiring multiple parties to work together (collude) to exercise it
  - It’s much more likely for a single party to be malicious than for all multiple parties to be malicious and collude with one another

Welcome to a Nuclear Bunker



Welcome to a Movie Theater

Ensure Complete Mediation

Textbook Chapter 1.8 & 1.13

Security Principle: Ensure Complete Mediation

- Ensure that every access point is monitored and protected
- **Reference monitor**: Single point through which all access must occur
  - Example: A network firewall, airport security, the doors to the dorms
- Desired properties of reference monitors:
  - Correctness
  - Completeness (can't be bypassed)
  - Security (can't be tampered with)
  - Should be part of the TCB

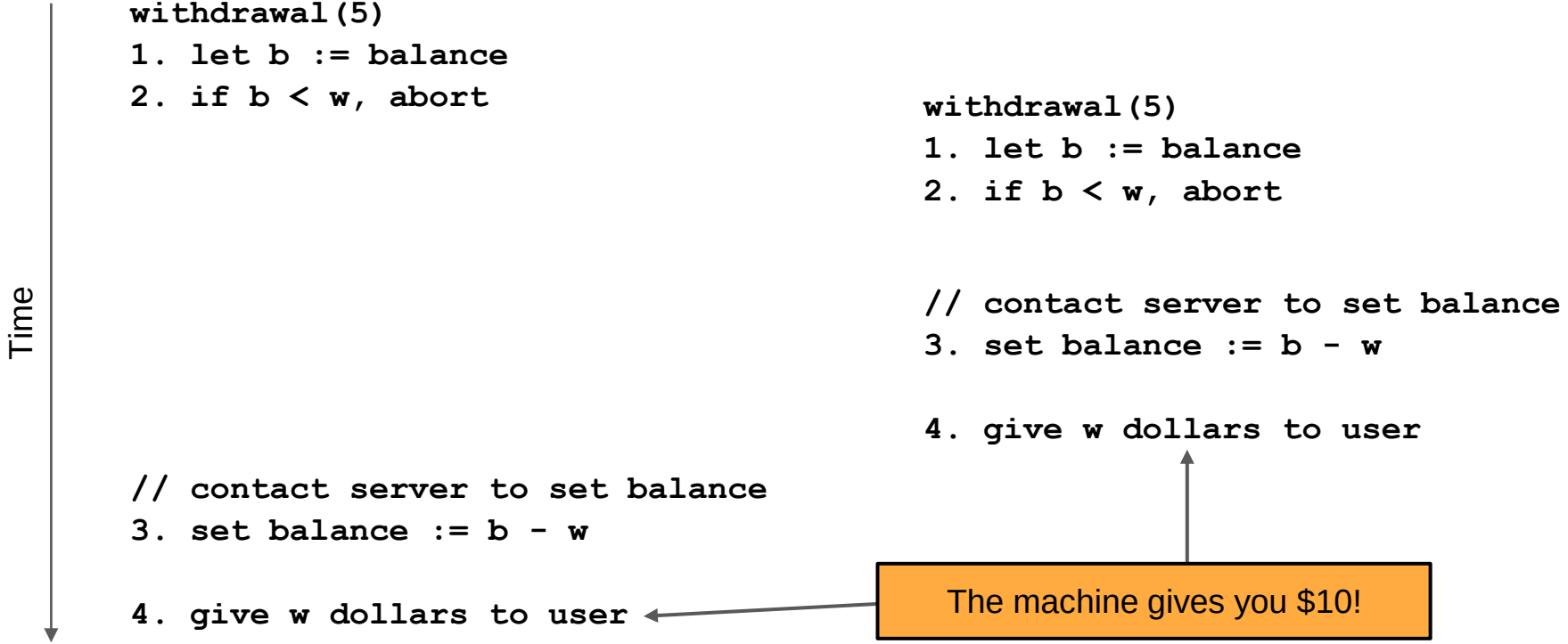
Time-of-Check to Time-of-Use

- A common failure of ensuring complete mediation involving race conditions
- Consider the following code:

```
procedure withdrawal(w)
        // contact central server to get
balance
        1. let b := balance

        2. if b < w, abort

        // contact server to set balance
        3. set balance := b - w

        4. give w dollars to user
```

Suppose you have $5 in your account. How can you trick this system into giving you more than $5?

Time-of-Check to Time-of-Use



Don’t Rely on Security Through Obscurity

Textbook Chapter 1.9

Don’t Rely on Security Through Obscurity

- Also known as **Shannon’s Maxim**
  - “The enemy knows the system”
- Also known as **Kerckhoff’s Principle**
  - “The only part of a cryptographic system unknown to the adversary is the cryptographic keys”

Highway Signs

Here's a highway sign.

Here's the hidden computer inside the sign.

Here's the control panel. Most signs use the default password, **`DOTS`**.

Highway Signs

Note/Takeaway: Do not **ever** do this. Yes, some former CS 161 students did it once.

Highway Signs

Takeaway: Don’t rely on security through obscurity

Don’t Rely on Security Through Obscurity

- Always assume that the attacker knows every detail about the system you are working with (algorithms, hardware, defenses, etc.)
  - Sometimes, obscurity *can help*
    - Example: We don’t tell you how we detect academic dishonesty
  - However, systems that *rely* on obscurity are brittle, since the attacker may find out!
- Don’t do security through obscurity!

Assume the attacker knows where the “secret” control panel is located, and knows the default password.

Use Fail-Safe Defaults

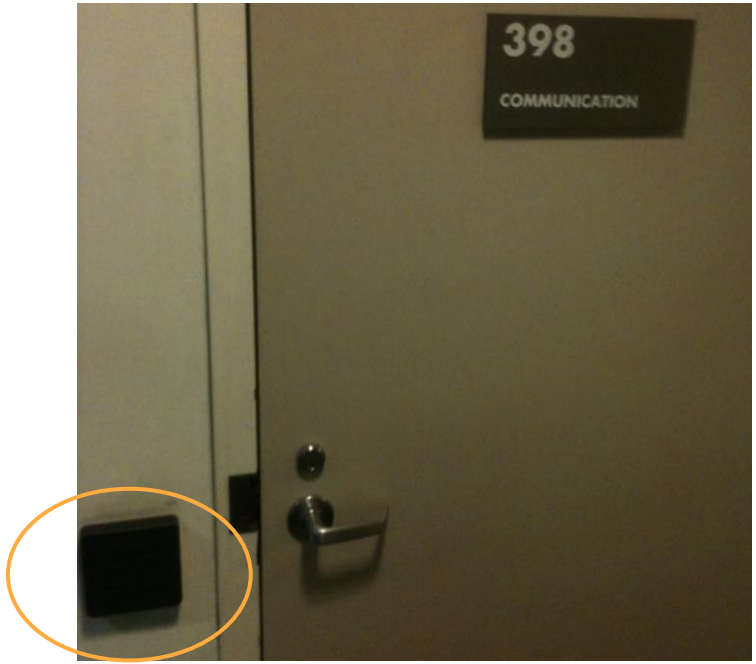
Textbook Chapter 1.10

Soda Hall

- Rooms in Berkeley's Soda Hall are guarded by electronic card keys
- What do you do if the power goes out?
  - Fail closed: No one can get in if the power is out
  - Fail open: Anyone can get in if the power goes out
- What's the best option to choose for closets with expensive equipment? What about emergency exit doors?
- **Takeaway**: Use fail-safe defaults… (if you can come up with one!)

Use Fail-Safe Defaults

- Choose default settings that “fail safe,” balancing security with usability when a system goes down
  - This can be hard to determine
- In the end, the right “default” often depends on context
  - Default open?
  - Default locked?



Design in Security from the Start

Textbook Chapter 1.11

Design in Security from the Start

- When building a new system, include security as part of the design considerations rather than patching it after the fact
  - A lot of systems today were not designed with security from the start, resulting in patches that don’t fully fix the problem!
- Keep these security principles in mind whenever you write code!

Summary: Security Principles

- **Know your threat model**: Understand your attacker and their resources and motivation
- **Consider human factors**: If your system is unusable, it will be unused
- **Security is economics**: Balance the expected cost of security with the expected benefit
- **Detect if you can't prevent**: Security requires not just preventing attacks but detecting and responding to them
- **Defense in depth**: Layer multiple types of defenses
- **Least privilege**: Only grant privileges that are needed for correct functioning, and no more
- **Separation of responsibility**: Consider requiring multiple parties to work together to exercise a privilege (code review and design review)
- **Ensure complete mediation**: All access must be monitored and protected, unbypassable
- **Don't rely on security through obscurity**: Assume the enemy knows the system
- **Use fail-safe defaults**: Construct systems that fail in a safe state, balancing security and usability.
- **Design in security from the start**: Consider all of these security principles when designing a new system, rather than patching it afterwards