Reading Quiz
Announcements

• Please sign the ethics form this week to continue
• Update your preferences for the midterm exams.
• Please choose partnerships for Lab 1 (EdStem)
Recap: What is “Security”? 

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Security is about computing or communicating in the presence of adversaries.
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Recap: What is "Security"?

• Normally, we are concerned with the achieving correctness
  • e.g., does this software achieve the desired behavior

• Security is a form of correctness
  • does this software prevent "undesired" behavior?

• Security involves an adversary who is active and malicious
  • Attackers seek to circumvent protective measures
Recap: What is “Security”? 

• General security goals: “CIA”
  • Confidentiality
  • Integrity
  • Availability
Confidentiality (Privacy)

Confidentiality is concealment of information
Integrity

Integrity is prevention of unauthorized changes

Intercept messages, tamper, release again

network

Adapted from Franzi Roesner, Yoshi Kohno
Availability

Availability is the ability to use information or resources

Overwhelm or crash servers, disrupt infrastructure
Recap: What is “Security”?

• General security goals: “CIA”
  • Confidentiality
  • Integrity
  • Availability

• ...
  • Authenticity
  • Accountability and non-repudiation
  • Access Control
  • Privacy of collected information
Today

• Security Policy & Mechanism
  • Examples of security attacks
• Design principles of security
• Software Security
Security: System View: not just for computers

- Smartphones
- Voting machines
- EEG headsets
- Medical devices
- Wearables
- RFID
- Mobile sensing platforms
- Game platforms
- Cars
- Airplanes
Functionality & Security

• A system normally has a desired functionality: what ("good") things it should do in the absence of adversaries.

• The system also normally has a security policy or security objective: what ("bad") activities or events should be prevented and/or detected?
Security Policy

• Usually stated in terms of
  1. Principals – actors or participants (perhaps in terms of their roles, including Adversary)
  2. Set of *impermissible actions (or states)*
  3. Relating to (classes of) objects
Security Mechanism

• AKA “Security Control”
• Component, technique, or method for (attempting to) achieve or enforce security policy.
Come up with security policies for the following systems

1. Voting in an election
2. Access to /etc/shadow file on Unix Machines
3. Email delivery to Swat Mail users
4. Text messages sent from Alice to Bob

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Two types of security mechanisms

• Prevention: keep security policy from being violated.
  • Examples: Fence, password, encryption

• Detection: Detect when security policy is violated.
  • Examples: Motion sensor, tamper-evident seal, storing hash of executable, virus scanner
Goal of Prevention

• to stop the "bad thing" from happening at all

• if prevention works its great
  • E.g. if you write in a memory-safe language (like Python) you are immune from buffer overflow exploits

• if prevention fails, it can fail hard
  • E.g. $68M stolen from a Bitcoin exchange, can’t be reversed
Detection & Recovery

• A detection mechanism often comes with an associated recovery mechanism.
  • E.g.: Remove intruder, remove virus, load files from backup.
• Detection may involve deterrence:
  • (Adversary risks being identified & being held accountable for security breach), which may help with prevention.
Detection & Response

- Detection: See that something is going wrong
- Response: Do something about it
  - Example: Reverse the harmful actions (restore from backup),
  - prevent future harm (block attacker)
  - Need both — no point in detection without a way to respond and remediate
False Positive and False Negatives

• False positive:
  • You alert when there is nothing there

• False negative:
  • You fail to alert when something is there

• Cost of detection:
  • Responding to false positives is not free, and if there are too many false positives, detector gets removed or ignored
  • False negatives mean a security failure
Design Principles of Security

• Least Privilege
• Use Fail-Safe Defaults
• Separation of Privilege/Separation of responsibility
• Defense in Depth
• Complete Mediation: check access to every object
• Security *not* through obscurity
• Design Security as a core principal
• Keep it simple silly
• Ease of use

-Saltzer, J. “Protection and the Control of Information Sharing in MULTICS”, CACM - 1974
Defense in Depth

• The notion of layering multiple types of protection together

• e.g., the Theodosian Walls of Constantinople:
  • Moat -> wall -> depression -> even bigger wall
  • Idea: attacker needs to breach all the defenses to gain access

• But defense in depth isn't free
  • You are throwing more resources at the problem
Password authentication

• People have a hard time remembering multiple strong passwords, so they reuse them on multiple sites
• Consequence: security breach of one site causes account compromise on other sites
• Solution: password manager
  • Remember one strong password, which unlocks access to site passwords
• Solution: two-factor authentication
  • Need both correct password and separate device to access account
• Free advice: to protect yourself, use a password manager and two-factor authentication
Least Privilege

• *Every program and every user of the system should operate using the least set of privileges necessary to complete the job*

• A subject should be given only those privileges necessary to complete its task
  – Function, not identity, controls
  – Rights added as needed, discarded after use
  – Minimal protection domain
Does this follow the principle of least privilege?

A. Yes
B. No
C. Maybe (Be prepared to explain)
Thinking About Least Privilege

• When assessing the security of a system’s design, identify the Trusted Computing Base (TCB).

• What components does security rely upon?

• Security requires that the TCB:
  • Is correct
  • Is complete (can’t be bypassed)
  • Is itself secure (can’t be tampered with)

• Best way to be assured of correctness and its security?
  • KISS = Keep It Simple, Silly!
  • Generally, Simple = Small

• One powerful design approach: privilege separation
  • Isolate privileged operations to as small a component as possible
Ensuring Complete Mediation

• To secure access to some capability/resource, construct a reference monitor
  • Single point through which all access must occur
    • E.g.: a network firewall
    • Desired properties: • Un-bypassable (“complete mediation”) •
      • Tamper-proof (is itself secure)
      • Verifiable (correct)
  • One subtle form of reference monitor flaw concerns race conditions
A Failure of Complete Mediation

Every security-relevant action must be checked for authenticity, integrity and authorization
procedure withdraw(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. dispense $w to user

Suppose that here an attacker arranges to suspend first call, and calls withdraw again concurrently

TOCTTOU = Time of Check To Time of Use
Time of Check to Time of Use Vulnerability: Race Condition

• Ethereum is a cryptocurrency which offers "smart" contracts
• Like a digital vending machine:
  • money + snack selection = snack dispensed
• The DAO (Distributed Autonomous Organization) venture capital fund for crypto
  • Participants could vote on "investments" that should be made
  • The DAO supported withdrawals as well
A "Feature" In The Smart Contract

• Code
  • Check the balance,
  • then send the money,
  • then update the balance

• Recursive call:
  • attacker asks the smart contract to give Ether back multiple times before the smart contract could update its balance
Software Security
When is a program secure?

• Formal approach: When it does exactly what it should
  • not more
  • not less

• But how do we know what it is supposed to do?
When is a program secure?

- Formal approach: When it does exactly what it should
  - not more
  - not less
- But how do we know what it is supposed to do?
  - somebody tells us (do we trust them?)
  - we write the code ourselves (what fraction of s/w have you written?)
When is a program secure?

• Pragmatic approach: when it doesn’t do bad things
• Often easier to specify a list of “bad” things:
  • delete or corrupt important files (integrity)
  • crash my system (availability)
  • send my password over the internet (confidentiality)
  • send phishing email
When is a program secure?

• But .. what if the program doesn’t do bad things, but could?

• is it secure?
Weird machines

• complex systems contain unintended functionality

• attackers can trigger this unintended functionality
  • i.e. they are exploiting vulnerabilities
What is a software vulnerability?

• A bug in a program that allows an unprivileged user capabilities that should be denied to them.

• There are a lot of types of vulnerabilities
  • bugs that violate “control flow integrity”
    • why? lets attacker run code on your computer!

• Typically these involve violating assumptions of the programming language or its run-time
Exploiting vulnerabilities (the start)

- Dive into low level details of how exploits work
  - How can a remote attacker get a victim program to execute their code?

- Threat model: victim code is handling input that comes from across a security boundary
  - what are examples of this?

- Security policy: want to protect integrity of execution and confidentiality of data from being compromised by malicious and highly skilled users of our system.
Today: stack buffer overflows

- **Understand** how buffer overflow vulnerabilities can be exploited
- **Identify** buffer overflows and assess their impact
- **Avoid** introducing buffer overflow vulnerabilities
- Correctly **fix** buffer overflow vulnerabilities
Buffer Overflows

• An anomaly that occurs when a program writes data beyond the boundary of a buffer

• Canonical software vulnerability
  • ubiquitous in system software
  • OSes, web servers, web browsers

• If your program crashes with memory faults, you probably have a buffer overflow vulnerability
Recall: Instructions in Memory

Function A:

... 
call funcB
...

funcB:
pushl %ebp
movl %esp, %ebp
...

Slide 54
Recall: Instructions in Memory

![Diagram of memory segments and function calls]

- **Operating system**
- **Text**
- **static data segment**
- **runtime heap**
- **shared libs**
- **Stack**
- **funcA:**
  - ...
  - call funcB
  - ...
- **funcB:**
  - pushl %ebp
  - movl %esp, %ebp
  - ...

**Function A**

**Function B**