CS 134:
Operating Systems
Security

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Overview

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Introduction to Security
Classification

Cryptography

Attacks

A Note on Time-Wasting

Security offers many stories

Most are entertaining

Relatively few are edifying

Please don’t waste class time with unsolicited stories

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Understanding Security

Many OSes need security

Security is different from reliability:

Reliability is robustness in the face of *failures*

Security is robustness in the face of *attackers*

To understand security, we must understand

- Threats
- Breaches
- Defenses

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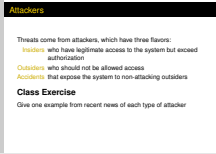
Attackers

Threats come from attackers, which have three flavors:

- **Insiders** who have legitimate access to the system but exceed authorization
- **Outsiders** who should not be allowed access
- **Accidents** that expose the system to non-attacking outsiders

Class Exercise

Give one example from recent news of each type of attacker



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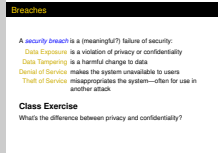
Breaches

A *security breach* is a (meaningful?) failure of security:

Data Exposure	is a violation of privacy or confidentiality
Data Tampering	is a harmful change to data
Denial of Service	makes the system unavailable to users
Theft of Service	misappropriates the system—often for use in another attack

Class Exercise

What's the difference between privacy and confidentiality?



Motivations

Attackers can have many motivations:

- **Exploration** for curiosity or as a prelude to another attack
- **Financial Gain** by direct theft of funds, theft of salable information, classroom cheating, financial manipulation, etc.
- **Vandalism** or simple maliciousness
- **Political Gain** often in the international arena
- **Revenge** of many kinds
- **Investigation** either by the state or by private entities

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Defenses

Defenses are much more varied than the attacks:

Obscurity	a la *The Purloined Letter*
Physical Security	to prevent outsider access
Authorization	to validate access
Enforcement	of access rules
Encryption	to hide secrets or aid validation
Monitoring	of access to detect attacks
Destruction	of unneeded sensitive data
Limitation	of unnecessary capabilities
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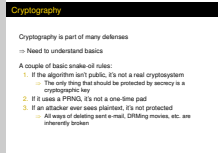
Cryptography

Cryptography is part of many defenses

⇒ Need to understand basics

A couple of basic snake-oil rules:

1. If the algorithm isn't public, it's not a real cryptosystem
   ⇒ The only thing that should be protected by secrecy is a cryptographic key
2. If it uses a PRNG, it's not a one-time pad
3. If an attacker ever sees plaintext, it's not protected
   ⇒ All ways of deleting sent e-mail, DRMing movies, etc. are inherently broken



Key Types

Two types of encryption/decryption keys:

1. Secret (“symmetric”) key shared between sender and receiver
   - Typically very fast
   - Prohibits many useful applications
   - Problem with getting key to both parties
   - Special case of one-time pad is only provably secure algorithm
     - All others (including public keys) boil down to “well, we haven’t cracked it *yet*”
2. Public/private key pair: one is published, the other secret
   - Usually symmetric in that either key can decrypt what the other encrypted
   - Typically quite slow
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Simple Public-Key Applications

Anybody can send me a secret message:

1. Look up my public key (it's on my Web page)
2. Encrypt with that key
3. Only I have the private key to decrypt it
4. If I have your public key, I can reply

I can broadcast an authenticated message:

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2. Anybody can decrypt with public one
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Maybe your public key was even included in the message—but subject to MITM attacks

Cryptographic Hashes

Public keys are slow ⇒ so is sending large authenticated message

Solution: authenticate only a *hash* or *checksum* of message; if somebody tampers, hash will reveal that fact

Problem: suppose somebody tampers in such a way that the hash doesn't change?

This is called *hash collision* and destroys authenticity

Solution: *cryptographic hash* that makes it (effectively) impossible to find such a collision

Examples:

- MD4 (long since broken)
- MD5 (now broken!)
- SHA-1 (might be broken in next five years?)
- SHA-256, -512, etc.

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Diffie-Hellman Key Exchange

Problem: Not everybody has usable public key

- Amazon can publish theirs, but don't know yours
- No standard solution for people to publish PKs
- Besides, PKs are too slow

Solution: agree on a secret key on the fly

- Party A picks random numbers x and y, sends $x, x^y \mod m$ to B for some m
- Party B picks z, sends $x^z \mod m$ to A
- A can calculate $x^{yz} \mod m = (x^z)^y \mod m$ to use as key
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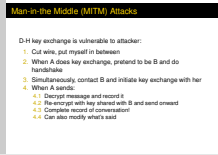
Man-in-the Middle (MITM) Attacks

D-H key exchange is vulnerable to attacker:

1. Cut wire, put myself in between
2. When A does key exchange, pretend to be B and do handshake
3. Simultaneously, contact B and initiate key exchange with her
4. When A sends:
   - 4.1 Decrypt message and record it
   - 4.2 Re-encrypt with key shared with B and send onward
   - 4.3 Complete record of conversation!
   - 4.4 Can also modify what's said



The Key-Exchange Problem

All cryptographic schemes suffer from a fundamental, insoluble problem: a local party cannot know whether the desired partner or an intruder is on the other end of a wire

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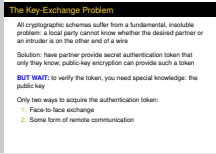

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Failed solution: have them publish public keys on their Web pages

Class Exercise

Why doesn't that work?

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1. You have to trust that the key list issued with the browser is correct. Unless you personally visited (and trust) the browser manufacturer, a third party could have introduced a substitute.
2. The PKI is as secure as its weakest link. If a repository's private key is leaked, anybody can pretend to be Amazon. This has happened.

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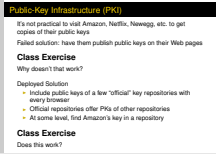
Deployed Solution

- Include public keys of a few "official" key repositories with every browser
- Official repositories offer PKs of other repositories
- At some level, find Amazon's key in a repository

Class Exercise

Does this work?



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Key Management

Suppose your homework is encrypted with a passphrase of “CS 134 is cool”. You decrypt your homework to work on it.

- Is the key still in memory? It could be in:
  - Terminal buffers
  - Local memory of decryption program (stack, heap)
  - Swap space
  - Memory of intermediate programs like X server and `screen`
- Have you ever accidentally typed into the wrong window?
- Are you *certain* there’s no key logger on your machine?
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Defense Rule #1

Rule #1 of defending against bad guys is the same regardless of whether you're doing computer security, neighborhood crime patrols, or interstellar warfare: think like the enemy.

This means you need to develop a nasty attitude. When you walk out of here today, look for all the ways an off-campus thief could (try to) get rich. Could they succeed?

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HMC depends a lot on a combination of the honor code and the fact that we have good mechanisms for keeping outsiders off campus.

Common Attacks

We've already seen MITM. Other common attacks include:

- Logic bombs
- Back doors
- Random probes
- Password guessing
- Privilege escalation
- Buffer overflows (oh my!)
- Trojan horses
- Viruses
- Worms
- Social engineering

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The point here is that no list of attacks is comprehensive.

The Rounding Attack

This really happened:

- Banks have to round interest to nearest penny
- Programmer rewrote rounding code:
  1. If < 0.5, round down normally
  2. If ≥ 0.5, *still* round down

  ... But that leaves bank out of balance, so credit leftover penny to own account and everything works out just fine!
- Every month, hits 50% of customers on average
- Even small bank has thousands of customers. . . big one has hundreds of thousands or millions

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The point of talking about this attack is that it doesn't fall into the neat categories from the previous slide.
The bad guy was caught because a "little old lady" checked her statement carefully, and when it didn't make sense she went to the bank and asked for help.
But there's another enduring principle here: greed. The bad guy could have fled before he was uncovered, but the money was rolling in every month and so he kept wanting more.

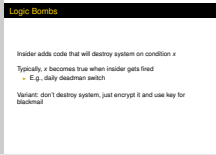
Logic Bombs

Insider adds code that will destroy system on condition x

Typically, x becomes true when insider gets fired

- E.g., daily deadman switch

Variant: don't destroy system, just encrypt it and use key for blackmail



Back Doors

Rewrite login program to accept hardwired account and password

Insider can now get root access even after being fired and having account deleted

For insidiously nasty variant, read “Reflections on Trusting Trust,” Ken Thompson’s Turing Award lecture

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Random Probes

Myth: “Sure, they attack Google all the time. But nobody knows my machine even exists.”

Reality: Bad guys don’t need to know your name or where you are. They just have to try all possible IP addresses. (Even in IPv6, this can be done.)

⇒ *Assume intruders will find you and probe you, unless a firewall protects you*

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Password Guessing

Having probed, log into an account:

- User `guest`, password `guest`
- `admin`/`admin`
- `root`/<null> (really!)

Bad guys have huge lists of common accounts (e.g., `phpadmin`, `cisco`, `help`) and passwords

Variation: acquire encrypted passwords and rather than decrypting, run common passwords through one-way encryption algorithm to search for hits (“dictionary attack”)

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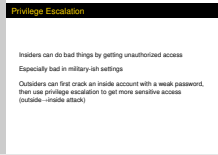
Privilege Escalation

Insiders can do bad things by getting unauthorized access

Especially bad in military-ish settings

Outsiders can first crack an inside account with a weak password, then use privilege escalation to get more sensitive access (outside→inside attack)



Buffer Overflows

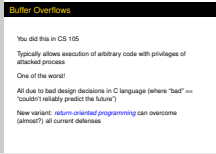
You did this in CS 105

Typically allows execution of arbitrary code with privileges of attacked process

One of the worst!

All due to bad design decisions in C language (where “bad” == “couldn’t reliably predict the future”)

New variant: *return-oriented programming* can overcome (almost?) all current defenses



ROP is a bit like level 0 of the buffer bomb, where you just called a preexisting function. The only defense I can see is to arrange that every time a new stack frame is created, the VM tables are adjusted such that nothing above the local variables is writable. I don’t think that’s practical, for several reasons.

Trojan Horses

Pretend to be what you're not

Canonical example:

```
clear_screen();
printf("Login: ");
gets(login_name);
printf("Password: ");
gets(password);
    /* record the stolen information */
printf("Login failed\n");
execv("/bin/login", NULL);
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User reveals password, thinks she just mistyped it

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Viruses and Worms

Both are self-propagating programs: make new copies in places that will let them spread further

Virus: attaches itself to a legitimate program; when real program is run, spreads

Worm: standalone program that tries to infect other systems, either via network or “sneakernet” (e.g., USB drive)

Worm propagation is often via weaknesses such as phishing or buffer overflows

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Note that the USB-drive attack only works because Windows will stupidly auto-run software from an unknown source.

Kevin Mitnick’s book has a wealth of social-engineering attacks.

Basic principle: carry a clipboard and people will trust you.

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Basic idea: trick humans into doing what you want

Usually depends on fact that people are either (a) helpful or (b) venal:

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