Topics We’ll Cover

• User login authentication (local and remote)
• Cryptographic primitives, how to use them, and how not to use them
• Kerberos distributed authentication system
• Secure Sockets Layer (SSL)/Transport Layer Security (TLS) authentication and encryption system
• TAOS: logic for reasoning formally about authentication
• Software vulnerabilities and exploits
• Exploit Defenses
• Software Fault Isolation (SFI): containing untrusted code
• OKWS: a least-privilege isolated web server for UNIX
A Simple Example

• Suppose you place an order with Amazon

• Goals:
  – You get the item you ordered
  – Amazon gets payment in the amount you agreed to pay on the payment page
A Simple Example

- Suppose you place an order with Amazon

How might this go wrong?
Let us count the ways...

- You get the item you ordered
- Amazon gets payment in the amount you agreed to pay on the payment page

You

Credit card number

Amazon
Worries for Amazon Order

• What if an eavesdropper taps Internet link?
  – Network cables usually not physically secure
• What if someone has broken into Internet router? (They’re just computers...)
• How do you know you’re communicating with Amazon?
• How does Amazon know you are authorized to use the credit card number you provide?
• What if a dishonest Amazon employee learns my credit card number?
• What if Amazon sends me wrong book, in error
Worries for Amazon Order (2)

- What if someone has **broken into my desktop PC? Or my file server?**
- Where did my web browser **come from?** How about my **OS?**
- What if my display or keyboard **radiates a signal** that can be **detected at some distance?**
Worries for Amazon Order (2)

- What if someone has broken into my desktop PC? Or my file server?
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Fundamental security question: “Whom or what am I trusting?”

Weakest item on list of answers determines system security!
Whom or What Am I Trusting?

“They showed me a telephone, and said they were worried about ‘the microphone.’ When I look at a telephone, I see one high-fidelity microphone and one ‘low-fidelity microphone.’”

“Most people call this a telephone cord. I call it an antenna.”

– Bob Morris, Sr., former Chief Scientist of the National Computer Security Center, NSA
**Whom or What Am I Trusting? (2)**

I would never buy something over the Internet. I’d hate to have my credit card number floating around out there.

There are a lot of unscrupulous people on the Net.

...Bottom line, it just isn’t common sense.
Example Secure System Design

- Secure telephone line between FBI and CIA
- Goal: only people in FBI and CIA buildings can learn what’s said in calls
- Plan:
  - Radiation-proof buildings
  - One entrance/exit per building
  - Armed guards at entrances
  - Guards check ID cards, record all people in/out
  - Pressurized, shielded cable between two buildings
  - No other cables allowed to leave buildings
  - Pass laws to punish people who reveal government secrets
  - Invite NSA to try to steal content of calls
  - Send dummy information, spy on KGB, see if they learn it
Perfect Security: An Unattainable Goal

• Merely a question of how motivated adversary is, and how much money he has
• No individual technique perfect
  – Pressurized cable only raises cost for attacker
  – Can’t completely shield a building
  – People can be bribed, blackmailed
• Could meet stated goal, but it could be inappropriate
  – What if FBI, CIA allow in uncleared visitors?
  – What if employees go home and talk in sleep?
    • Solution: forbid employees from leaving the building...
Definitions

• **Security**: techniques to control who can access/modify system

• **Principal**: unit of accountability in a system (e.g., user)

• **Access control**: techniques to restrict operations to particular principals

• **Authentication**: verification of identity of principal making request

• **Authorization**: granting of request to principal
Attacks on Security

• Violation of secrecy
  – Attacker reads data without authorization

• Violation of integrity
  – Attacker modifies data without authorization
  – e.g., attacker modifies data on disk
  – e.g., attacker modifies network reply to “read file” request

• Denial of service
  – Attacker makes system unavailable to legitimate users
  – e.g., overload the system, or cause a deadlock
  – e.g., trigger security mechanism (wrong ATM PIN 3 times)
Building Secure Systems: General Approach

- Figure out what you want to protect, what it’s worth
- Figure out which attacks you want to defend against
- State goals and desired properties clearly
  - Not “impossible to break”
  - Better: “attack X on resource Y should cost $Z”
- Structure system with two types of components:
  - Trusted: must operate as expected, or breach
  - Untrusted: subverted operation doesn’t lead to breach
- Minimize size of trusted components
  - Maybe we should have built secure room, not building...
- Analyze resulting system, monitor success
Security Is a Negative Goal

• Ensure nothing happens without authorization
  – How do you reason about what a system will not do?

• First step: specify who authorized to do what
  – In other words, specify a policy
Policy

• Policy: goal security must achieve
  – Human intent—originates from outside system
• Often talked about in terms of subjects and objects
  – Subject: principal
  – Object: abstraction to which access requested (e.g., file, memory page, serial port)
  – Each object supports different kinds of access (e.g., read or write file, change permissions, ...)
• Access control: should operation be allowed?
  – What principal making request? (Authentication)
  – Is operation permitted to principal? (Authorization)
Access Control: Examples

- Machine in locked room, not on network
  - Policy: only users with keys can access computer
- Bank ATM card
  - Policy: only allowed to withdraw money present in your account
  - Authentication: must have card and know PIN
  - Authorization: database tracks account balances
- Private UNIX file (only owner can read)
  - Authentication: password to run software as user
  - Authorization: kernel checks file’s permission bits
- Military classified data
  - If process reads “top-secret” data, cannot write “secret” data
Next: User Authentication

• How to use passwords to authenticate users: at the console, and remotely, over a network
• Attacks against password-based authentication schemes
• Designing robust password-based authentication schemes
Authentication of Local Users

• Goal: only file’s owner can access file
• UNIX authentication policy:
  – Each file has an owner principal: an integer user ID
  – Each file has associated owner permissions (read, write, execute, &c.)
  – Each process runs with integer user ID; only can access file as owner if matches file’s owner user ID
  – OS assigns user ID to user’s shell process at login time, authenticated by username and password
  – Shell process creates new child processes with same user ID
• How does UNIX know the correspondence among <username, user ID, password>, for all users?
Straw Man: Plaintext Password Database

- Keep password database in a file, e.g.:
  - bkarp:3715:secret pw
  - mj h:4212:multicast
- Passwords stored in file in plaintext
- Make file readable only by privileged superuser (root)
- `/bin/login` program prompts for usernames and passwords on console; runs as root, so can read password database
- How well does this scheme meet original goal?
Cryptographic Primitive: Cryptographic Hash Function

• Don’t want someone who sees the password database to learn users’ passwords
• Cryptographic hash function, \( y = H(x) \) such that:
  – \( H() \) is preimage-resistant: given \( y \), and with knowledge of \( H() \), computationally infeasible to recover \( x \)
  – \( H() \) is second-preimage-resistant: given \( y \), computationally infeasible to find \( x' \neq x \) s.t. \( H(x) = H(x') = y \)
• Widely used cryptographic hash functions:
  – MD-5: output is 128 bits, broken
  – SHA-1: output is 160 bits; broken
  – SHA-256: output is 256 bits, best current practice
Better Plan: Hashed Password Database

• Keep password database in a file:
  bkarp:3715:Xc8zOP0ZHJkp
  mjh:4212:p6FsAtQl4cwi

• Instead of password plaintext x, store $H(x)$

• Make file readable by all (!)

• One-wayness of $H(\cdot)$ means no one can recover x from $H(x)$, right?
  – WRONG! Users choose memorable passwords…
Insight: Counting Possible Passwords

• If users pick random n-character passwords using c possible characters, how many guesses expected to guess one password?
  \[ \frac{c^n}{2} \]
e.g., 8 characters, each \( \sim 90 \) possibilities, \( 2.15 \times 10^{15} \)

• Do users pick random passwords?
  – Of course not; very hard to remember
  – Common choice: word in native language

• How many words in common use in modern English?
  – 50,000-70,000 (or far fewer, if you read Metro)
Dictionary Attack on Hashed Password Databases

• Suppose hacker obtains copy of password file (until recently, world-readable on UNIX)
• Compute $H(x)$ for 50K common words
• String compare resulting hashed words against passwords in file
• **Learn all users’ passwords that are common English words after only 50K computations of $H(x)$!**
• **Same hashed dictionary works on all password files in world!**