Introduction to Security and User Authentication

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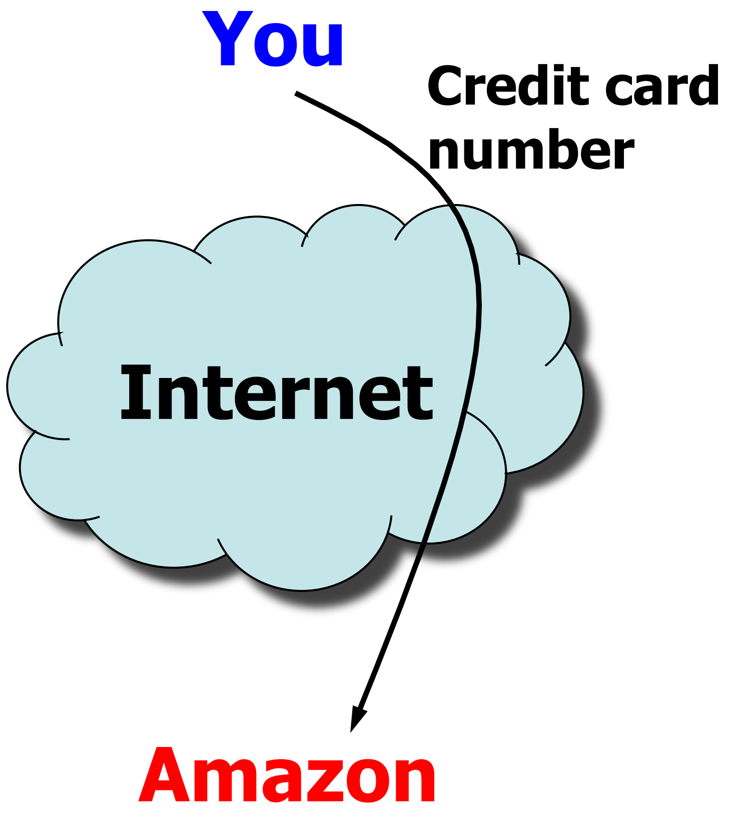
CS GZ03 / M030
16th November 2012

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



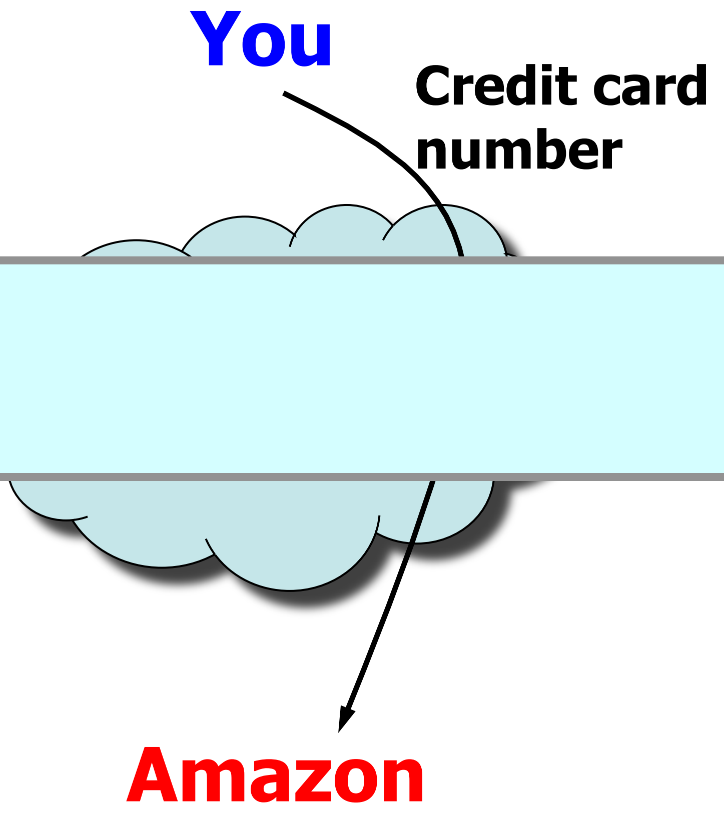
A Simple Example

- Suppose you place an order with Amazon

How might this go wrong?

Let us count the ways…

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



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

Fundamental security question:
"Whom or what am I trusting?"
Weakest item on list of answers determines system security!

- What if my display or keyboard radiates a signal that can be detected at some distance?

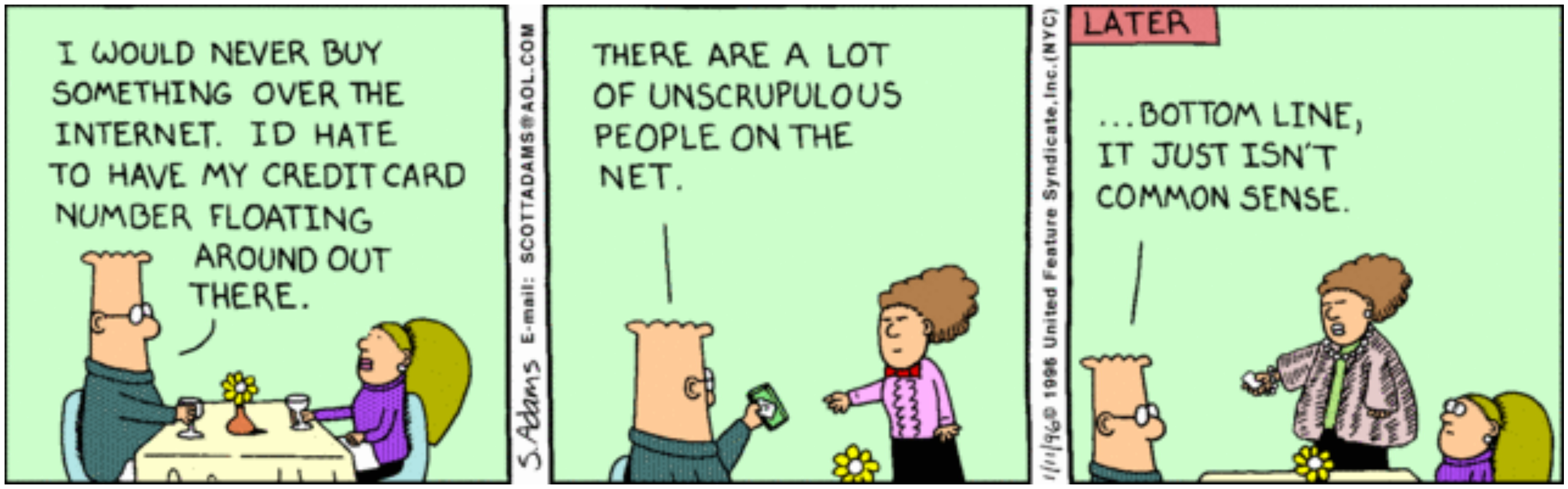
Whom or What Am I Trusting?

"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. ID HATE TO HAVE MY CREDIT CARD NUMBER FLOATING AROUND OUT THERE.
S.Adams E-mail: SCOTTADAMS@AOL.COM
THERE ARE A LOT OF UNSCRUPULOUS PEOPLE ON THE NET.
1/11/96 © 1996 United Feature Syndicate, Inc.(NYC)
LATER
...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:secretpw
mjh: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’≠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; on verge of being 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() 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?

  $c^n/2$

  e.g., 8 characters, each ~90 possibilities, **2.15×10^{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!**