CSE 451: Operating Systems

Security

Outline

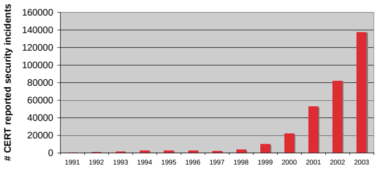
- "Classic" security topics
  - goal: safe sharing
  - general principles
  - Trusted Computing Base (TCB)
- Contemporary security problems
  - worms
  - botnets
  - spyware

Safe sharing

- Protecting a non-networked PC with one user is easy
  - Nobody can access the data on your computer
  - Nobody can install new code
  - Nobody can attack you over the network
- Sharing resources safely is hard
  - Prevent some users from reading private data
    - yet allow authorized users to access it
    - e.g., grades, keystrokes
  - Prevent some users from using too many resources
    - e.g., disk space
  - Prevent users from interfering with others' programs
    - spoofing displays, replacing programs with malicious code, killing off processes…

Much of security is art, not science

- Difficult to "prove" a system secure
- Security is based on principles and best practices
  - experience reveals commonly occurring types of flaws
  - but clearly we need to do better…



Principle of Least Privilege

- Figure out exactly which capabilities a program needs to run, and grant it only those
  - start out by granting none
    - run program, and see where it breaks
    - add new privileges as needed.

- Unix: concept of root is not a good example of this
  - some programs need root just to get a small privilege
    - e.g., FTP daemon requires root:
      - to listen on network port < 1024
      - to change between user identities after authentication
    - but root also lets you read any file in filesystem

Principle of Complete Mediation

- Check **every** access to **every** object
  - in rare cases, can get away with less (caching)
    - but only if sure nothing relevant in environment has changed…and there is a lot that's relevant!
- A TLB caches access control information
  - page table entry protection bits
  - is this a violation of the principle?

“Security through Obscurity” = bad

- Security through obscurity
  - “gain security” by hiding system implementation details
  - should be secure even if implementation is open!
    - in fact, publishing makes it more secure, since people can scour implementation and find/fix flaws
- Counterexample: GSM cell phones
  - GSM committee designed own crypto algorithm, but hid it
    - “impossible to clone”
  - social + reverse engineering revealed the algorithm
    - it turned out to be very weak

Trusted Computing Base (TCB)

- Think carefully about what you are trusting with your information
  - if you type your password on a keyboard, you’re trusting:
    - the keyboard manufacturer
    - your computer manufacturer
    - your operating system
      - including the keyboard device driver
    - the password library
    - the application that’s checking the password
  - what about the compiler that compiled all of this software (!!)
- TCB = set of components (hardware, software, wetware) that you must trust to preserve your secrets
  - should be as small as possible
    - public web kiosks should *not* be in your TCB
    - how about your web browser?

Modern security problems

- Internet experiencing a plague of attacks
  - *remote exploits:* attackers breaking into your system
  - *worms:* self-replicating attack code
  - *botnets*: armies of compromised machines
  - *spyware:* software that tries to steal information from you
- Underlying issues
  - most of our code is buggy
  - the Internet was designed to be “open”
    - easy to build new services, but easy to find/attack victims
  - understanding security is hard
    - haven’t found simple conceptual models or usable UIs
    - e.g., what does the lock icon in IE really mean?

Remote exploit

- An exploitable bug in network-facing software
  - e.g.: buffer overflow attack

```
int main(int argc, char *argv[]){
  char buffer[10];
  strcpy(buffer, argv[1]);
  return 0;
}
```

    - exploit this bug, smash the stack, run code of your choice
  - e.g.: SQL injection attack
    - typing the following into a bookstore web search form:

“book tipping point; SELECT * FROM CREDITCARDS”

Using remote exploits -- worms

- Pseudocode for a simple worm

```
for (i = 0.0.0.0;  i < 255.255.255.255;  i++) {
    open network connection to IP address “i”;
    if succeed {
      try to exploit vulnerability x on  “i”;
      if succeed {
        send code for self to victim and run it;
      }
      close connection to “i”;
    }
}
```

- Will this worm propagate?
  - how quickly?

A “better” worm

```
while (1) {
    open network connection to random IP address “i”;
    if succeed {
        try to exploit vulnerability x on “i”;
        if succeed {
          send code for self to victim and run it;
        }
        close connection to “i”;
    }
}
```

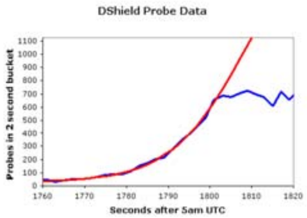
- Why is this “better”?
- How quickly will this propagate?
- How can you do even better?

Even better worms…

- Local scanning
  - probe nearby IP addresses preferentially
- Increased scan rate ==> faster spread
  - Code Red: approximately 5 scans per second
  - Sapphire worm: approximately 4000 scans per second
    - single UDP packet contains worm
- Sapphire worm data
  - worm doubled in size every 8.5 seconds
  - saturated susceptible population of ~75,000 hosts in about 5-10 minutes (!!)

Sapphire fallout

- It propagated too fast for its own good!
  - no per-host damage
  - but massively clogged Internet backbones with scans
  - self-interference slowed its propagation rate



Using remote exploits - Botnets

- Step 1: compromise a remote computer
- Step 2: upload “botnet” software
  - sits silently in the background
  - gives attacker remote control of the “zombie” computer
- Step 3: repeat steps 1 and 2 10,000 times
  - amass a giant “zombie” army
- Step 4: control army using botnet “controller”
  - rent out time on botnet army
  - use zombies to perform spam relay, click spam
  - perform “denial of service” attack on a victim
    - flood it with requests

Example: Phatbot

- Some of its features:
  - polymorphs on install to evade anti-virus signature
  - sends email probes to test for spam relay capability
  - can steal windows product keys
  - runs an FTP server to distribute itself to other hosts
  - runs a redirection service for TCP connections
    - (launders network traffic)
  - can scan and spread using many exploits
    - (worm-like behavior!)
  - kills worms, other bots to defend turf
  - kills anti-virus processes
  - steals various website account passwords
  - harvests email addresses for spam purposes

Recent, local example

- UW Medical Center
  - some unpatched machines were compromised
    - added to a botnet
  - attackers used foothold to get UWMC password database
  - things started to fall apart
    - some key cards would no longer open operating room doors
    - some computers in the ICU stopped working
    - some doctors’ pagers stopped working
- Impossible to know which accounts got compromised
  - 20,000 people had to changed their UW NetID passwords!
  - hopefully no confidential data was taken…

Spyware

- Software that is installed that collects information and reports it to third party
  - key logger, adware, browser hijacker, …
- Installed one of two ways
  - piggybacked on software you choose to download
  - “drive-by” download
    - your web browser has vulnerabilities
    - web server can exploit by sending you bad web content
- Estimates
  - majority (50-90%) of Internet-connected PCs have it
  - 1 in 20 executables on the Web have it
  - about 0.5% of Web pages attack you with drive-by-downloads

kingsofchaos.com

- A benign web site for an online game
  - earns revenue from ad networks by showing banners
  - but, it relinquishes control of the ad content

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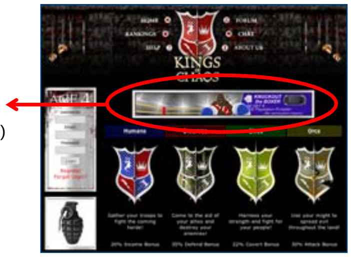

banner ad from
adworldnetwork.com
(a legitimate ad network)

inline javascript loads
HTML from ad provider

Incident

- kingsofchaos.com was given this “ad content”

```
<script type="text/javascript">document.write('
\u003c\u0062\u006f\u0064\u0079\u0020\u006f\u006e\u0055\u006f\
u0077\u0050\u006f\u0070\u0075\u0070\u0028\u0029\u003b\u0073\u
0068\u006f\u0077\u0048\u0069 …etc.
```

- This “ad” ultimately:
  - bombarded the user with pop-up ads
  - hijacked the user’s homepage
  - exploited an IE vulnerability to install spyware

What’s going on?

- The advertiser was an ex-email-spammer
- His goal:
  - **force** users to see ads from his servers
  - **draw revenue** from ad “affiliate programs”
    - Apparently earned several millions of dollars
- Why did he use spyware?
  - control PC and show ads even when not on the Web

Parting thoughts…

- Security is hard
  - fundamentally an adversarial, escalating game
  - we’re getting better, but so are the “bad guys”
- Our systems are insecure
  - OS software one of the most complex artifacts of humankind
  - no surprise it has flaws!
- Current trends
  - reduce TCB to exclude OS
  - develop stronger sandboxes to contain flaws
    - virtual machine software (e.g., Vmware)
  - program with safer languages than C