CSC 574
Computer and Network Security

Malicious Code

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(Derived from slides by Chris Kruegel)

Overview

- Introduction to malicious code
  - taxonomy, history, life cycle
- Virus
  - infection strategies, armored viruses, detection
- Worms
  - email- and exploit-based worms, spreading strategies
- Trojan horses
  - keylogger, rootkits, botnet, spyware

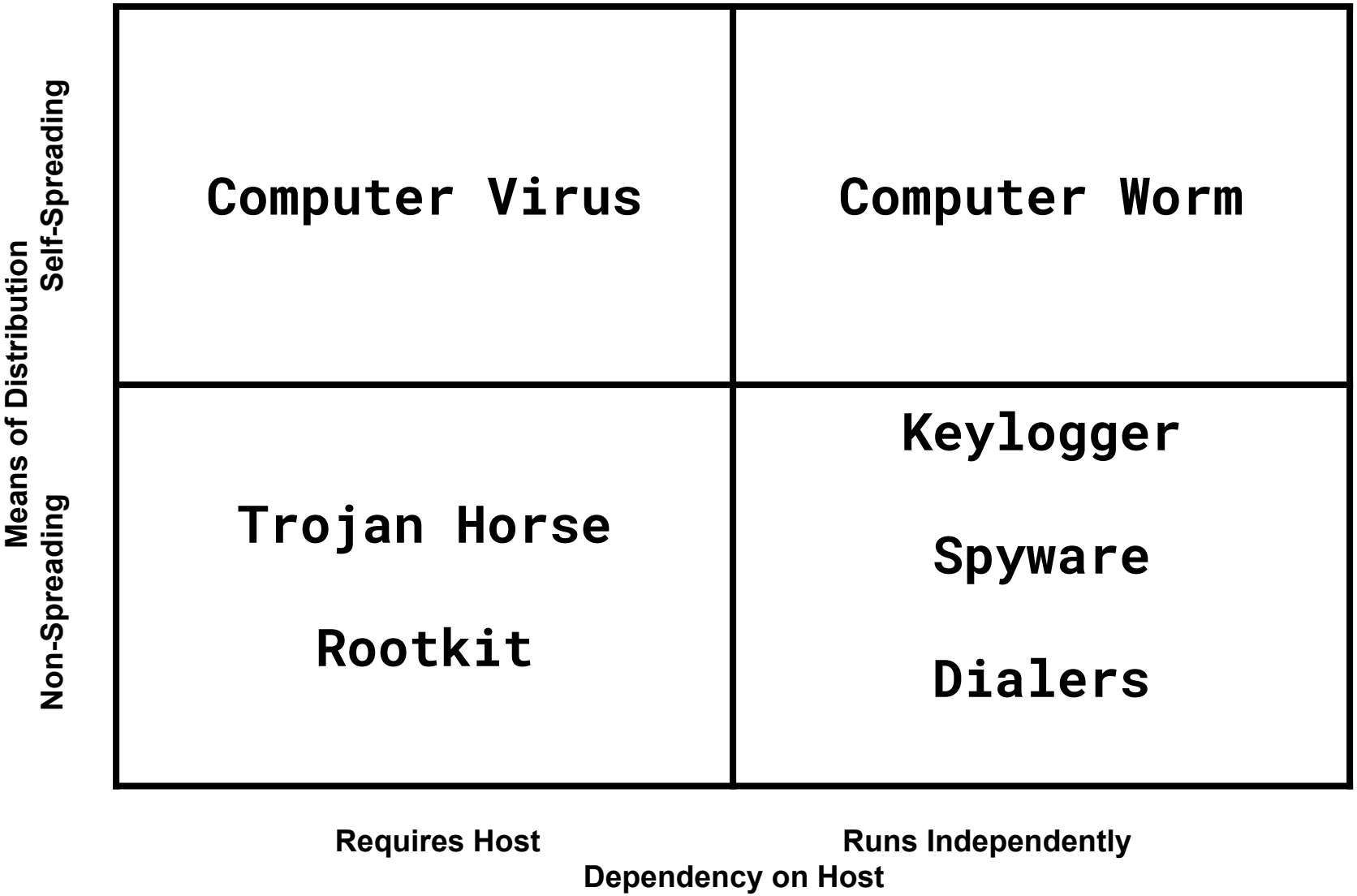
Introduction

- Malicious Code (Malware)
  - software that fulfills malicious intent of author
  - term often used equivalent with virus (due to media coverage)
  - however, many different types exist
  - classic viruses account for only 3% of malware in the wild

- Virus - Definition

  A virus is a program that reproduces its own code by attaching itself to other executable files in such a way that the virus code is executed when the infected executable file is executed

Taxonomy


Computer Virus
Computer Worm
Trojan Horse
Rootkit
Keylogger
Spyware
Dialers
Means of Distribution
Self-Spreading
Non-Spreading
Requires Host
Runs Independently
Dependency on Host

Taxonomy

- Virus
  - self-replicating, infects files (thus requires host)
- Worm
  - self-replicating, spreads over network
- Interaction-based worms (B[e]agle, Netsky, Sobig)
  - spread requires human interaction
  - double-click and execute extension
  - follow link to download executable
- Process-based worms (Code Red, Blaster, Slammer)
  - requires no human interaction
  - exploits vulnerability in network service

Reasons for Malware Prevalence

- Mixing data and code
  - violates important design property of secure systems
  - unfortunately very frequent
- Homogeneous computing base
  - Windows is just a very tempting target
- Unprecedented connectivity
  - easy to attack from safety of home
- Clueless user base
  - many targets available
- Malicious code has become profitable
  - compromised computers can be sold (e.g., spam, DoS, banking)

Virus Lifecycle

- Lifecycle
  - reproduce, infect, run payload
- Reproduction phase
  - viruses balance infection versus detection possibility
  - variety of techniques may be used to hide viruses
- Infection phase
  - difficult to predict when infection will take place
  - many viruses stay resident in memory (TSR or process)
- Attack phase
  - e.g., deleting files, changing random data on disk
  - viruses often have bugs (poor coding) so damage can be done
    - Stoned virus expected 360K, floppy, corrupted sectors

Infection Strategies

- Boot viruses
  - master boot record (MBR) of hard disk (first sector on disk)
  - boot sector of partitions
  - e.g., Pakistani Brain virus
  - rather old, but interest is growing again
    - diskless work stations, virtual machine virus (SubVirt)
    - *MebRoot*
- File infectors
  - simple overwrite virus (damages original program)
  - parasitic virus
    - append virus code and modify program entry point
  - cavity virus
    - inject code into unused regions of program code

Infection Strategies

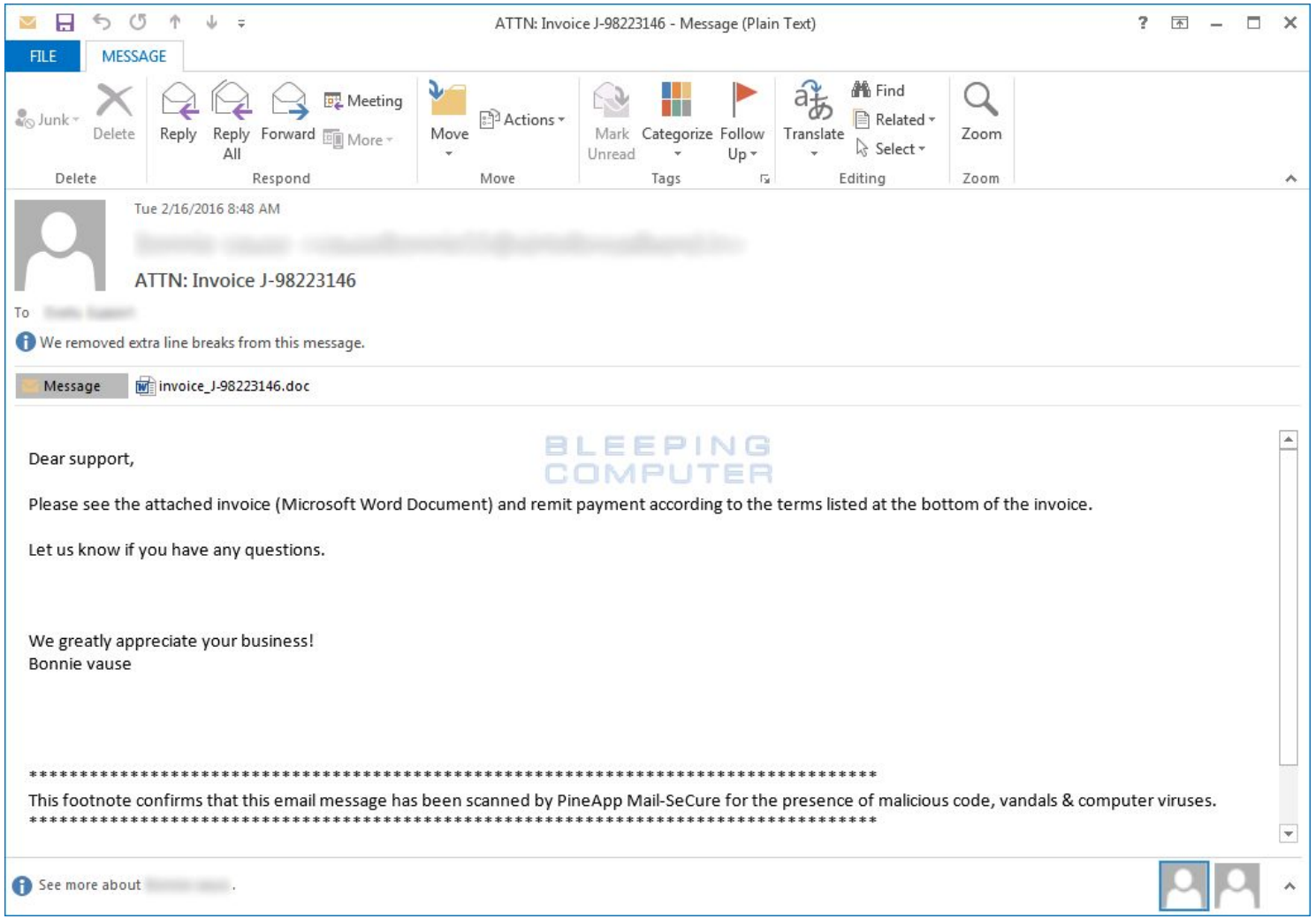
- Entry Point Obfuscation
  - virus scanners quickly discovered to search around entry point
  - virus hijacks control later (after program is launched)
  - overwrite import table addresses
  - overwrite function call instructions

- Code Integration
  - merge virus code with program
  - requires disassembly of target
    - difficult task on x86 machines
  - W95/Zmist is a classic example for this technique

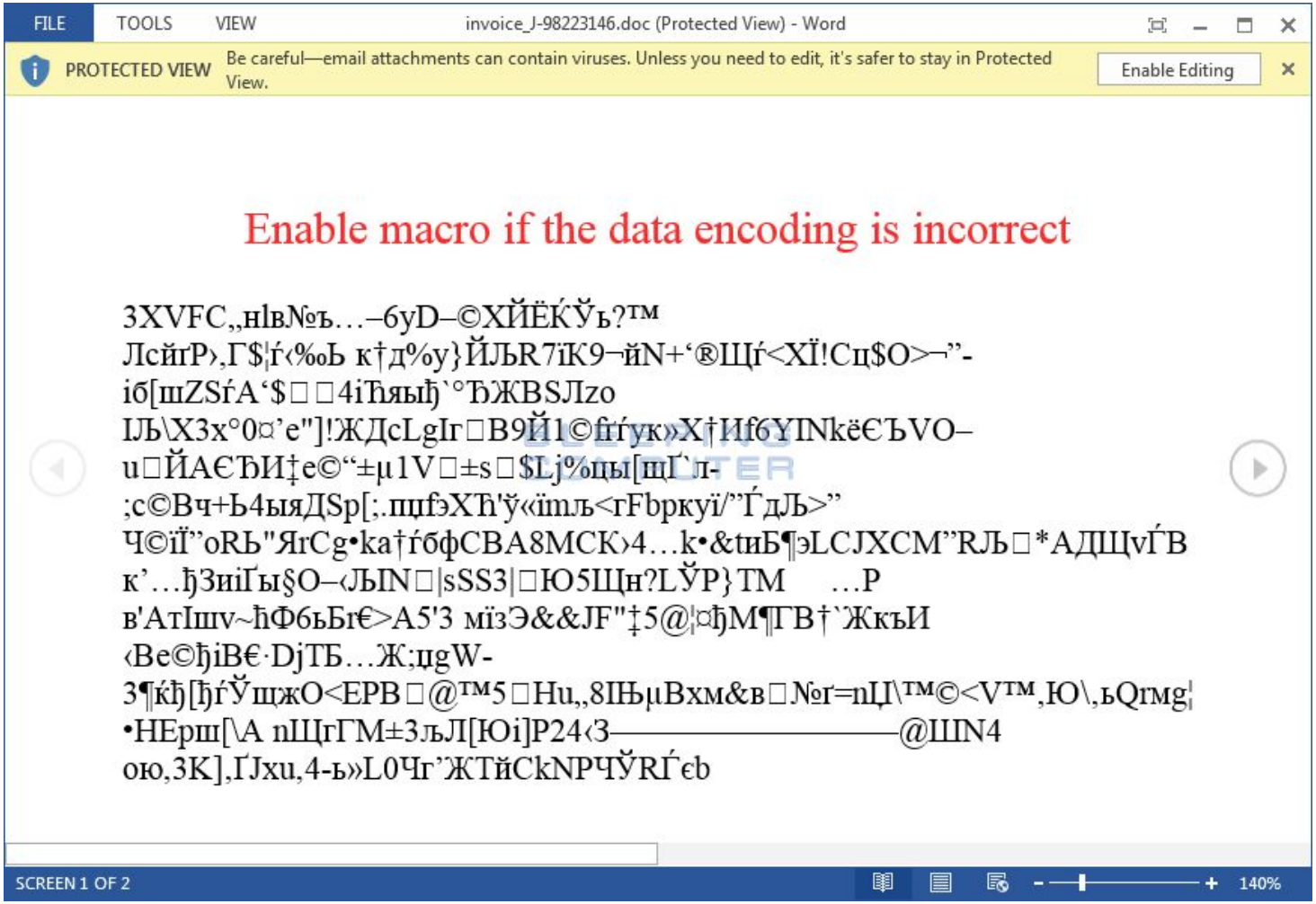
Macro Viruses

- Many modern applications support macro languages
  - Microsoft Word, Excel, Outlook
  - macro language is powerful
  - embedded macros automatically executed on load
  - mail app. with Word as an editor
  - mail app. with Internet Explorer
    to render HTML

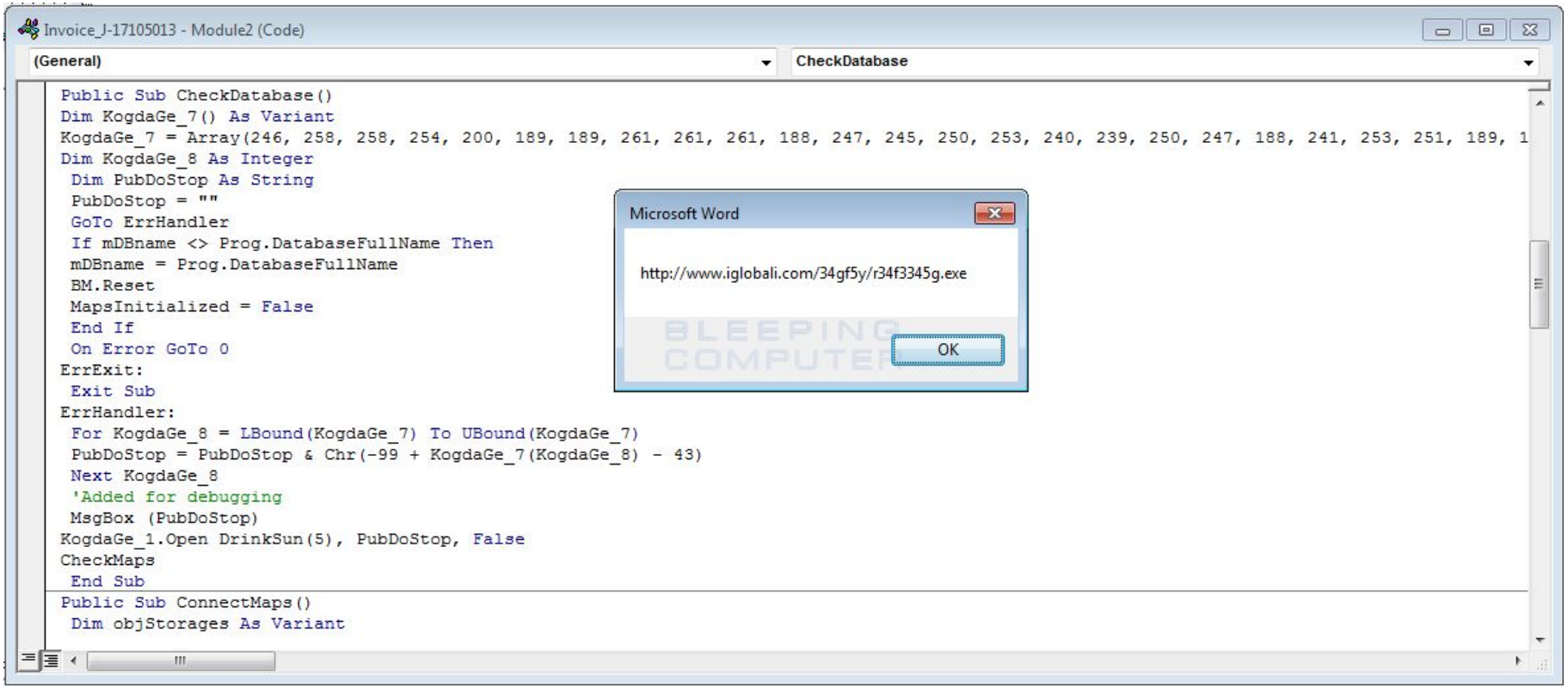
Locky Ransomware



Locky Ransomware



Locky Ransomware



Source:
http://www.bleepingcomputer.com/news/security/the-locky-ransomware-encrypts-local-files-and-unmapped-network-shares/

Virus Defense

- Antivirus Software
  - working horse is signature based detection
    - database of byte-level or instruction-level signatures that match virus
    - wildcards can be used, regular expressions
  - heuristics (check for signs of infection)
    - code execution starts in last section
    - incorrect header size in PE header
    - suspicious code section name
    - patched import address table
- Sandboxing
  - run untrusted applications in restricted environment
  - simplest variation, do not run as Administrator

Tunneling and Camouflage Viruses

- To minimize the probability of its being discovered, a virus could use a number of different techniques
- A tunneling virus attempts to bypass antivirus programs
  - idea is to follow the interrupt chain back down to basic operating system or BIOS interrupt handlers
  - install virus there
  - virus is “underneath” everything – including the checking program
- In the past, possible for a virus to spoof a scanner by camouflaging itself to look like something the scanner was programmed to ignore
  - false alarms of scanners make “ignore” rules necessary

Polymorphism and Metamorphism

- Polymorphic viruses
  - change layout (shape) with each infection
  - payload is encrypted
  - using different key for each infection
  - makes static string analysis practically impossible
  - of course, encryption routine must be changed as well
  - otherwise, detection is trivial

- Metamorphic techniques
  - create different “versions” of code that look different
    but have the same semantics (i.e., do the same)

Chernobyl (CIH) Virus

```
5B 00 00 00 00      pop ebx
8D 4B 42            lea ecx, [ebx + 42h]
51                      push ecx
50                      push eax
50                      push eax
0F 01 4C 24 FE      sidt [esp - 02h]
5B                      pop ebx
83 C3 1C            add ebx, 1Ch
FA                      cli
8B 2B               mov ebp, [ebx]
```

```
5B 00 00 00 00 8D 4B 42 51 50 50 0F 01 4C 24 FE 5B
83 C3 1C FA 8B 2B
```

Dead Code Insertion

```
5B 00 00 00 00       pop ebx
8D 4B 42            lea ecx, [ebx + 42h]
51                      push ecx
50                      push eax
90                      nop
50                      push eax
40                      inc eax
0F 01 4C 24 FE      sidt [esp - 02h]
48                      dec eax
5B                      pop ebx
83 C3 1C            add ebx, 1Ch
FA                      cli
8B 2B               mov ebp, [ebx]
```

```
5B 00 00 00 00 8D 4B 42 51 50 90 50 40 0F 01 4C 24
FE 48 5B 83 C3 1C FA 8B 2B
```

Instruction Reordering

```
5B   00 00 00 00      pop ebx
EB   09               jmp <S1>
S2:
50                    push eax
0F 01 4C 24 FE        sidt [esp - 02h]
5B                    pop ebx
EB   07               jmp <S3>
S1:
8D 4B 42              lea ecx, [ebx + 42h]
51                    push ecx
50                    push eax
EB   F0               jmp <S2>
S3:
83 C3 1C              add ebx, 1Ch
FA                    cli
8B 2B                 mov ebp, [ebx]
```

```
5B 00 00 00 00 EB 09 50 0F 01 4C 24 FE 5B EB 07 8D
4B 42 51 50 EB F0 83 C3 1C FA 8B 2B
```

Instruction Substitution

```
5B 00 00 00 00    pop ebx
8D 4B 42          lea ecx, [ebx + 42h]
51                    push ecx
89 04 24          mov eax, [esp]
83 C4 04          add 04h, esp
50                    push eax
0F 01 4C 24 FE    sidt [esp - 02h]
83 04 24 0C       add 1Ch, [esp]
5B                    pop ebx
8B 2B             mov ebp, [ebx]
```

```
5B 00 00 00 00 8D 4B 42 51 89 04 24 83 C4 04 50 0F
01 4C 24 FE 83 04 24 0C 5B 8B 2B
```

Advanced Virus Defense

- Most virus techniques very effective against static analysis
- Thus, dynamic analysis techniques introduced
  - virus scanner equipped with emulation engine
  - executes actual instructions (no disassembly problems)
  - runs until polymorphic part unpacks actual virus
  - then, signature matching can be applied
  - emulation must be fast
  - Anubis
- Difficulties
  - virus can attempt to detect emulation engine
  - time execution, use exotic (unsupported) instructions, …
  - insert useless instructions in the beginning of code to deceive scanner

Advanced Virus Defense

- Stalling loops
  - exploit overhead of analysis system
  - execute “slow” operation many (millions of) times

```
1 unsigned count, tick;
2
3 void helper() {
4   tick = GetTickCount();
5   tick++;
6   tick++;
7   tick = GetTickCount();
8 }
9
10 void delay() {
11   count=0x1;
12   do {
13     helper();
14     count++;
15   } while (count!=0xe4e1c1);
16 }
```

Figure 1. Stalling code found in real-world malware (W32.DelfInj)

Real host - A few milliseconds
Anubis - Ten hours

Advanced Virus Defense

- Mitigate stalling loops
  - detect that program does not make progress
  - find loop that is currently executing
  - reduce logging for this loop (until exit)

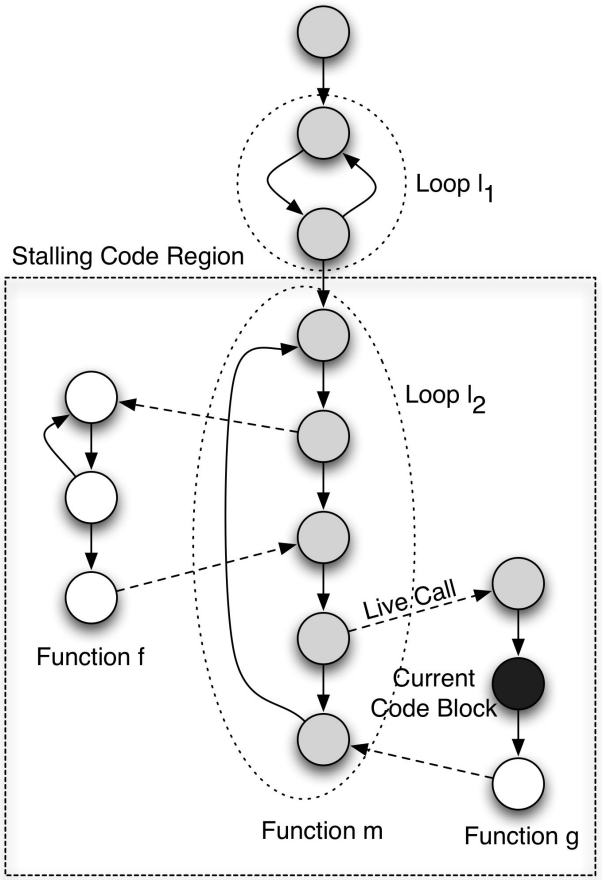
- Progress checks
  - based on system calls

    too many failures, too few, always the same, …

- When reduced logging is not sufficient
  - actively interrupt loop

Advanced Virus Defense

- Finding code blocks (white list) for which logging should be reduced
  - build dynamic control flow graph
  - run loop detection algorithm
  - identify live blocks and call edges
  - identify first (closest) *active* loop (loop still in progress)
  - mark all regions reachable from this loop



Advanced Virus Defense

- Active mitigation
  - mark all memory locations (variables) written by loop body
  - find conditional jump that leads out of white-listed region
  - simply invert it the next time control flow passes by

- Problem
  - program might later use variables that were written by loop
    but that do not have the proper value and fail

- Solution
  - dynamically track all variables that are marked (taint analysis)
  - whenever program uses such variable, extract slice that computes this value, run it, and plug in proper value into original execution

Computer Worms

A self-replicating program able to propagate itself across networks, typically having a detrimental effect.

(Oxford English Dictionary)

- Worms either
  - exploit vulnerabilities that affect large number of hosts
  - send copies of worm body via email
- Difference to classic virus is *autonomous* spread over network
- Speed of spreading is constantly increasing
- Make use of techniques known by virus writers for long time

Worm Components

- Target locator
  - how to choose new victims
- Infection propagator
  - how to obtain control of victim
  - how to transfer worm body to target system
- Life cycle manager
  - control different activities depending on certain circumstances
  - often time depending
- Payload
  - nowadays, often a Trojan horse (we come back to that later)

Target Locator

- Email harvesting
  - consult address books (W32/Melissa)
  - files might contain email addresses
    - inbox of email client (W32/Mydoom)
    - Internet Explorer cache and personal directories (W32/Sircam)
  - even Google searches are possible
    - search worms (W32/MyDoom.O)

- Network share enumeration
  - Windows discovers local computers, which can be attacked
  - some worms attack everything, including network printers
    prints random garbage (W32/Bugbear)

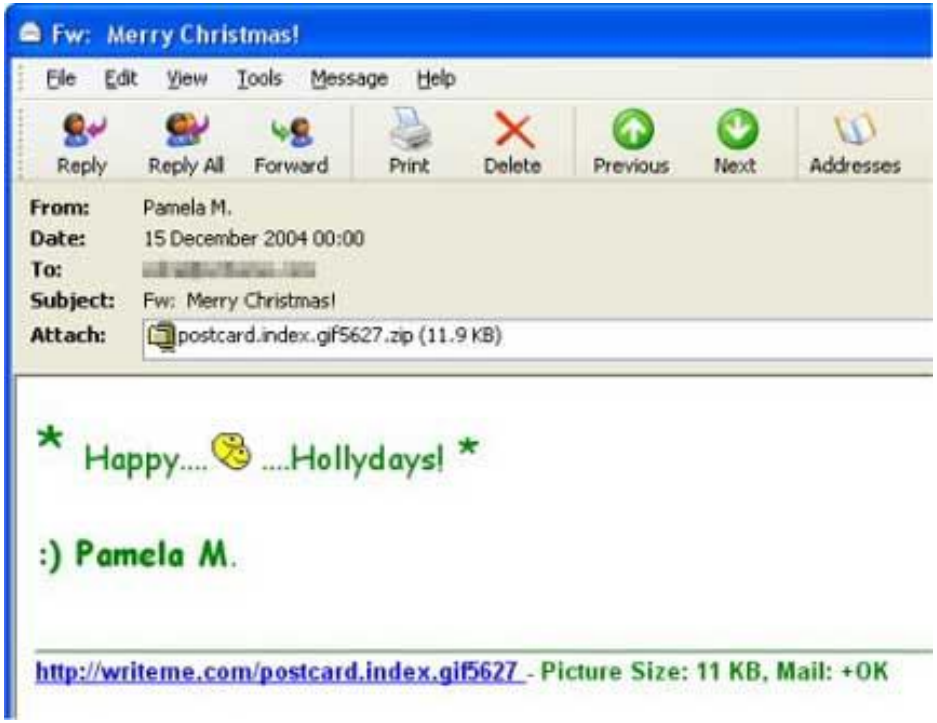
Target Locator

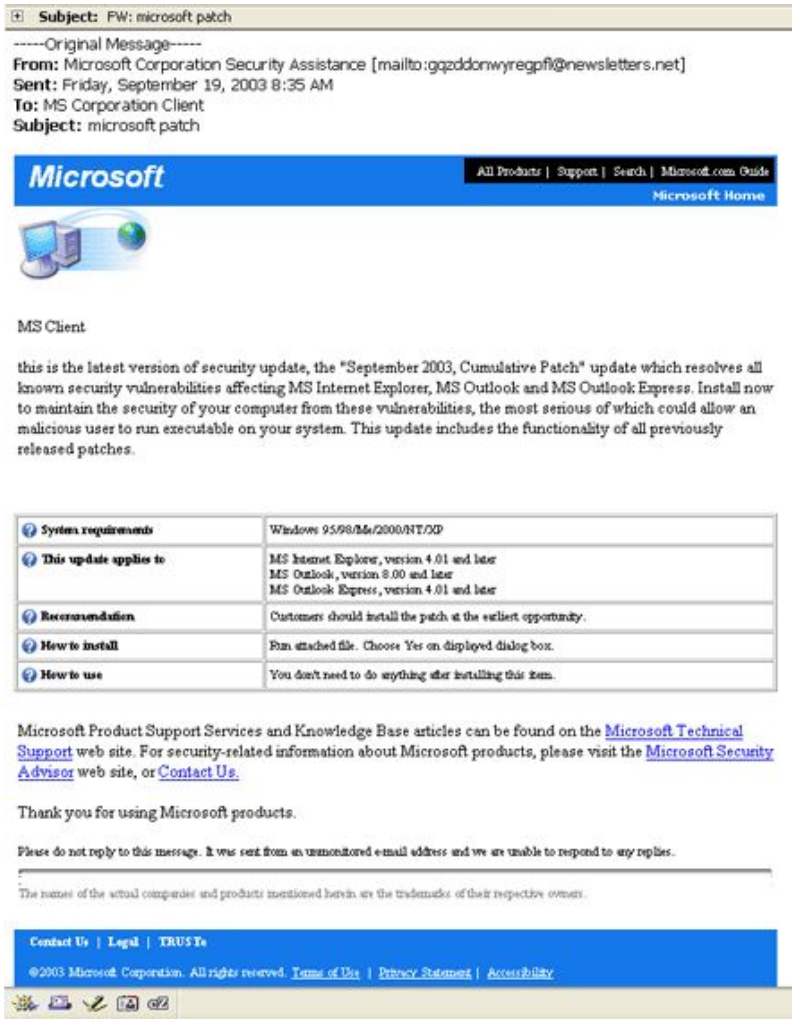
- Scanning
  - more Google searches
    - search for vulnerable web applications (Santy)
  - randomly generate IP addresses and send probes
  - interestingly, many random number generators flawed
    - static seed
    - not complete coverage of address space
  - scanning that favors local addresses (topological scanning)
  - some worms use hit-list with known targets (shorten initial phase)
- Service discovery and OS fingerprinting performed as well

Email-Based Worms

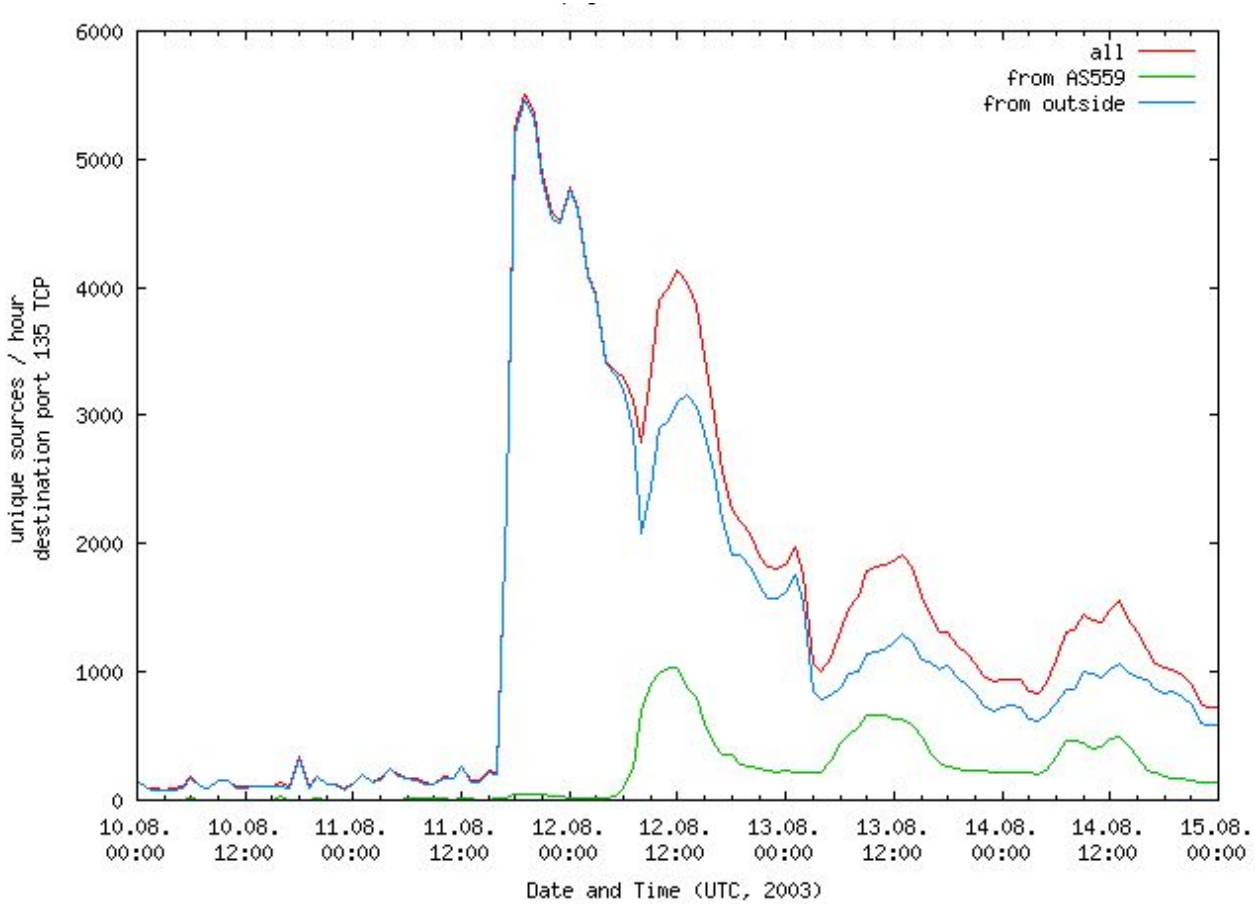
- Often use social engineering techniques to get executed
  - fake from address
  - promise interesting pictures or applications
  - hide executable extension (.exe) behind harmless ones (.jpeg)
- Many attempt to hide from scanners
  - packed or zipped
  - sometimes even with password (ask user to unpack)
- Some exploit Internet Explorer bugs when HTML content is rendered
- Significant impact on SMTP infrastructure
- Speed of spread limited because humans are in the loop
  - can observe spread patterns that correspond to time-of-day

Email-Based Worms





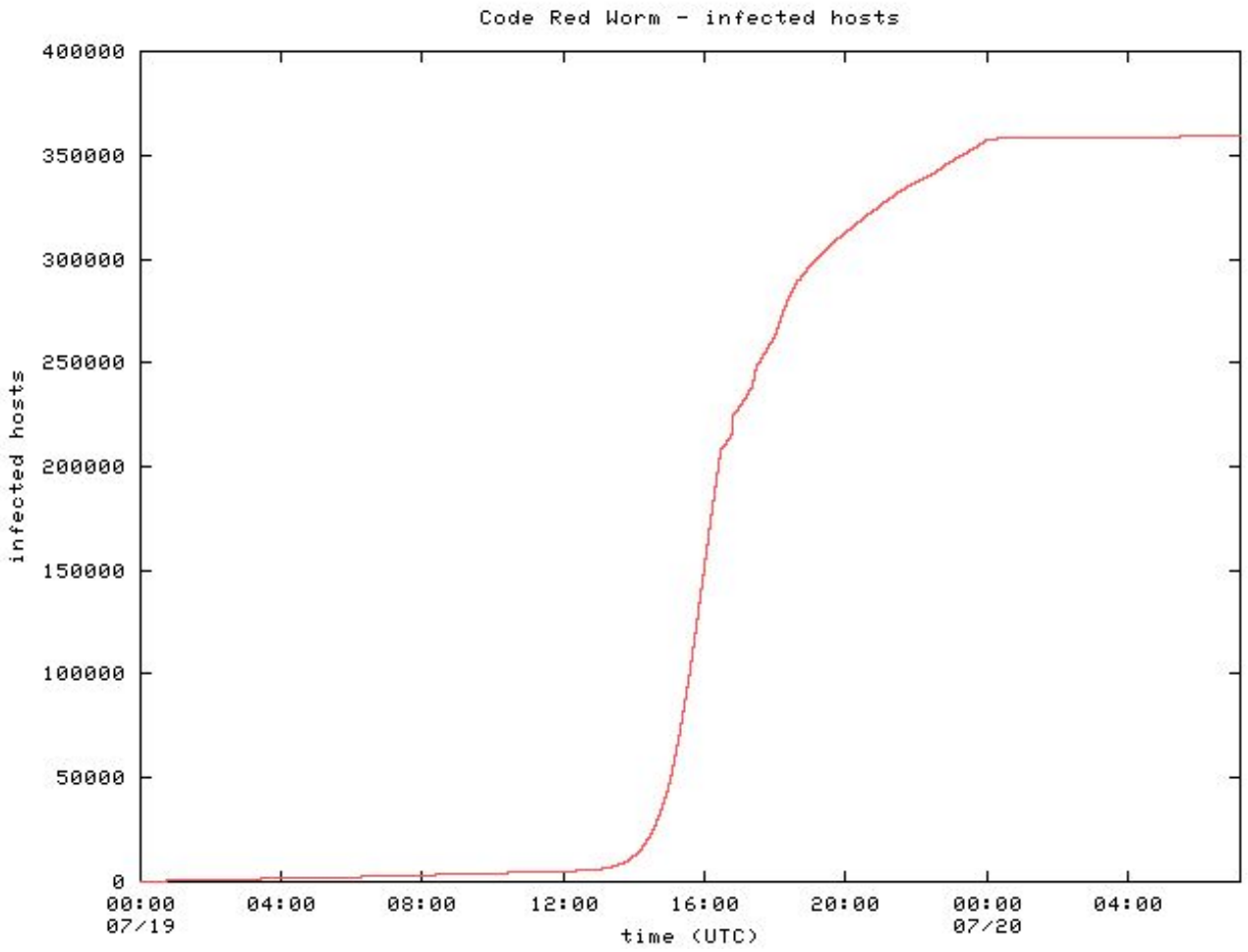
Email-Based Worms



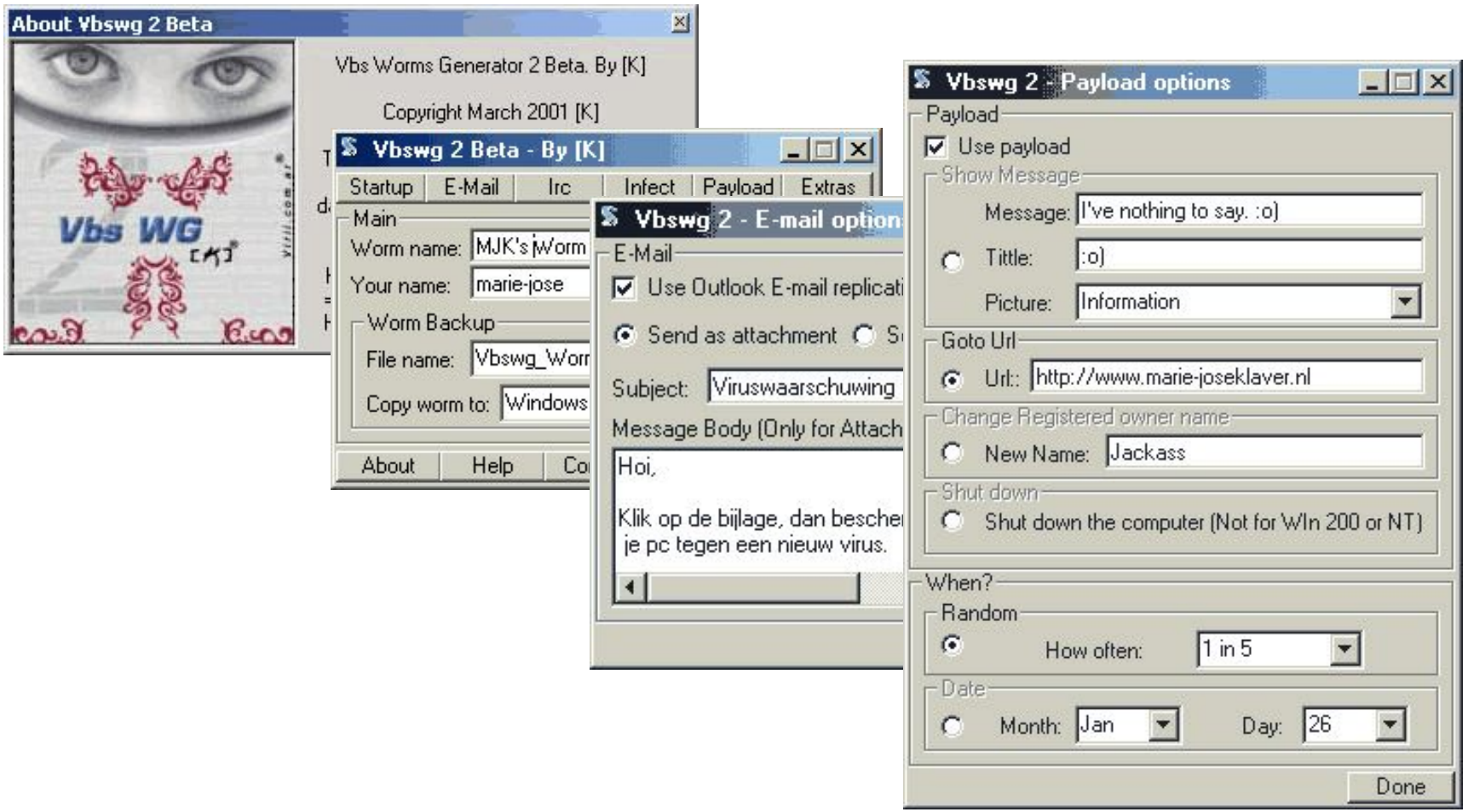
Exploit-Based Worms

- Require no human interaction
  - typically exploit well-known network services
  - can spread much faster
- Propagation speed limited either
  - by network latency
    worm thread has to establish TCP connection (Code Red)
  - by bandwidth
    worm can send (UDP) packets as fast as possible (Slammer)
- Spread can be modeled using classic disease model
  - worm starts slow (only few machines infected)
  - enters phase of exponential growth
  - final phase where only few uncompromised machines left

Exploit-Based Worms



Worm Generators



Worm Defense

- Virus scanners
  - effective against email-based worms
  - email attachments can be scanned as part of mail processing

- Host level defense
  - mostly targeted at underlying software vulnerabilities
  - code audits
  - stack-based techniques
    - StackGuard, MS VC compiler extension
  - address space layout randomization (ASLR)
    - attempt to achieve diversity to increase protection

Worm Defense

- Network level defense
  - intrusion detection systems
    - scan for known attack patterns
    - automatic signature generation (Early Bird, Autograph, Polygraph)
  - rate limiting
    - allow only certain amount of outgoing connections
    - helps to contain worms that perform scanning
  - personal firewall
    - block outgoing SMTP connections (from unknown applications)

Trojan Horse

- Trojan horse is a malicious program that is disguised as legitimate software
  - software may look useful or interesting (or at the very least harmless)
  - term derived from the classical myth of the Trojan Horse

- Two types of Trojan horses
  1. malicious functionality is included into useful program
     - disk utility, screensaver, weather alert program
     - famous compiler that generated backdoor into code
  2. malware is stand-alone program
     - possibly disguised file name (sexy.jpg.exe)

Trojan Horse

- Many different types and functions
  - spy on (sensitive) user data
    - log keystrokes, monitor surfing activity
  - disguise presence
    - rootkits
  - allow remote access
    - file transfer, remote program execution
    - base for further attacks, mail relay (for spammers)
    - Back Orifice, NetBus, SubSeven
  - damage routines
    - corrupting files
    - participate in denial of service attacks

Rootkits

- Tools used by attackers after compromising a system
  - hide presence of attacker
  - allow for return of attacker at later date
  - gather information about environment
  - attack scripts for further compromises
- Traditionally trojaned set of user-space applications
  - system logging (syslogd)
  - system monitoring (ps, top)
  - user authentication (login, sshd)

Kernel Rootkits

- Kernel-level rootkits
  - kernel controls view of system for user-space applications
  - malicious kernel code can intercept attempts by user-space detector to find rootkits
- Modifies kernel data structures
  - process listing
  - module listing
- Intercepts requests from user-space applications
  - system call boundary
  - VFS fileops struct

Linux Kernel Rootkits

- Linux kernel exports well-defined interface to modules
- Examples of legitimate operations
  - registering device with kernel
  - accesses to devices mapped into kernel memory
  - overwriting exported function pointers for event callbacks
- Kernel rootkits violate these interfaces
- Examples of illegal operations
  - replacing system call table entries (knark)
  - replacing VFS fileops (adore-ng)

Linux Kernel Rootkits

- System call table hijacking

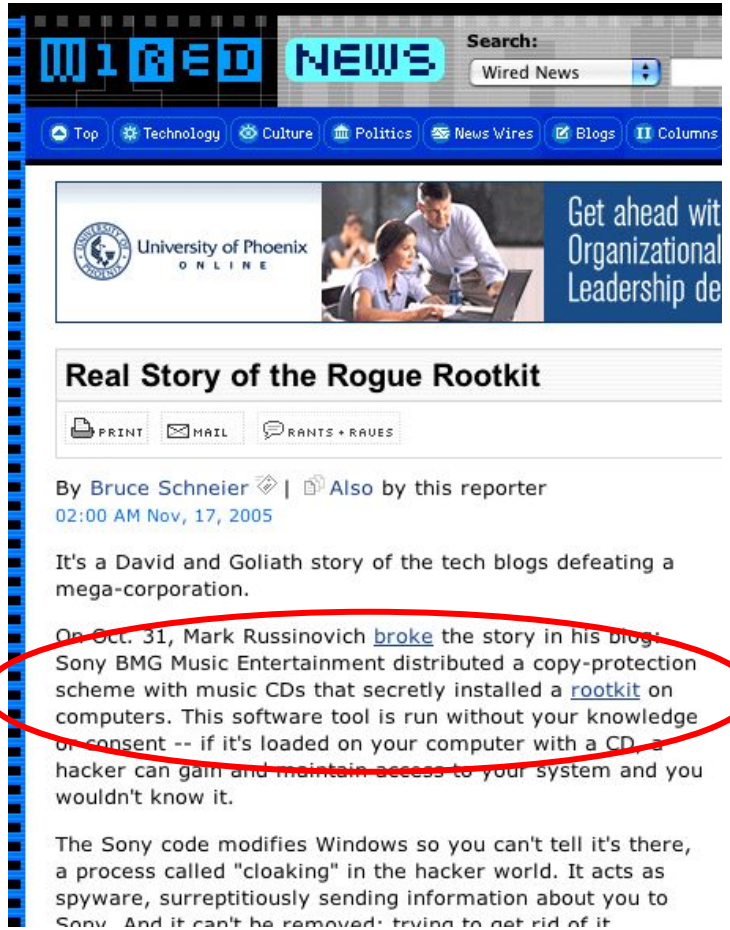
```
 orig_getuid = sys_call_table[__NR_getuid];
sys_call_table[__NR_getuid] = give_root;
```

- VFS hijacking

```
pde = proc_find_tcp();
o_get_info_tcp = pde->get_info;
pde->get_info = n_get_info_tcp;
```

- Works pretty much the same for Windows
  - anyone remember the Sony rootkit discussion?

Windows Kernel Rootkits



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Real Story of the Rogue Rootkit

PRINT MAIL RANTS + RAVES

By Bruce Schneier | Also by this reporter
02:00 AM Nov, 17, 2005

It's a David and Goliath story of the tech blogs defeating a mega-corporation.

On Oct. 31, Mark Russinovich broke the story in his blog: Sony BMG Music Entertainment distributed a copy-protection scheme with music CDs that secretly installed a rootkit on computers. This software tool is run without your knowledge or consent -- if it's loaded on your computer with a CD, a hacker can gain and maintain access to your system and you wouldn't know it.

The Sony code modifies Windows so you can't tell it's there, a process called "cloaking" in the hacker world. It acts as spyware, surreptitiously sending information about you to Sony. And it can't be removed; trying to get rid of it

Windows Kernel Rootkits

- Sony rootkit filters out any files/directories, processes and registry keys that contain `$sys$`
- System call dispatcher
  - uses system service dispatch table (SSDT)
  - Windows NT kernel equivalent to system call table
  - entries can be manipulated to re-route call to custom function

`ZwCreateFile`
- used to create or open file

`ZwQueryDirectoryFile`
- used to list directory contents (i.e. list subdirectories and files)

`ZwQuerySystemInformation`
- used to get the list of running processes (among other things)

`ZwEnumerateKey`
- used to list the registry keys below a given key

Rootkit Defense

- `tripwire`
  - user-space integrity checker
- `chkrootkit`
  - user-space, signature-based detector
- `kstat, rkstat, St. Michael`
  - kernel-space, signature-based detector
  - implemented as kernel modules or use /dev/kmem
- Limitations
  - typically, rootkit must be loaded in order to detect it
  - thus, detectors can be thwarted by kernel-level rootkit
  - also suffer from limitations of signature-based detection

Rootkit Defense

- Kernel rootkits
  - have complete control over operating system
  - operating system is part of trusted computing base, thus applications can be arbitrarily fooled
  - this includes all rootkit or Trojan detection mechanisms
  - at best, an arms race can be started

- Proposed solutions
  - trusted computing platform
    - can enforce integrity of operating system
  - smart cards
    - attacker can not influence computations on card, but has still full control of computations performed on machine and information displayed on screen

Spyware

- Any software that monitors and collects information about a user in a covert and unsolicited manner
- Goal of spyware
  - collect sensitive user information and surfing habits
- Task of spyware
  - component must monitor user behavior
  - component must leak information to environment (OS, network)
- Often implemented as browser extensions
  - Internet Explorer Browser Helper Object (BHO)
  - COM object that can hook into Microsoft's Internet Explorer
  - monitor/modify events

Spyware

- Interaction
  - between browser and spyware component
    - COM function invocations (exported by Internet Explorer)
  - between spyware component and operating system
    - Windows API calls

- In addition, it typically has a real company behind it that is making money from the information gathered
  - Adware is any software that injects unsolicited advertisements into a user's workspace
  - Scumware is a specific type of adware that hides other advertisements with those from its own controlling source

Spyware

Typical routes of infection:

1. spyware is bundled with legitimate software package
   - end-user license agreement (EULA) even informs about this fact
   - EULA is very long (often hundreds of pages), user accepts
   - classic examples are shareware programs
     - P2P file-sharing clients (e.g., Kazaa)

2. “drive-by” downloads
   - exploit browser bug, in particular, vulnerabilities of Internet Explorer
   - WMF (Windows meta file) exploit, around Christmas 2005
   - arbitrary code execution via mismatched DOM objects (December 2005)
   - insufficient ActiveX security settings

3. fake dialogs
   - display “Would you like to optimize your Internet” and perform installation when user agrees

Malware and Vulnerable Software

- Malicious software (Malware) and benign software that can be exploited to perform malicious actions (Badware) are two facets of the same problem

  ⟶ execution of unwanted code

- Malware
  - viruses, worms, Trojan horses, rootkits, and spyware are evolving to become resilient to eradication and to evade detection
- Badware
  - services and applications (especially web-based) are vulnerable to a wide range of attacks, some of which novel

Conclusions

- Malware
  - sophisticated technology developed for more than 20 years
  - combined with automatic spread mechanisms
  - tools to generate malware significantly lower technological barrier
- Trojan Horses
  - particularly dangerous because they infest trusted computing base
  - typically full control of platform and applications
- Defense Techniques
  - mostly reactive
  - using signatures to detect known instances
  - use best programming practice for application development, educate employees, keep infrastructure well maintained (patched)

Your Security Zen

620 Gbps DDoS attack

Source:
https://krebsonsecurity.com/2016/09/the-democratization-of-censorship/