CSE508 Network Security

11/2/2017 **Malware**

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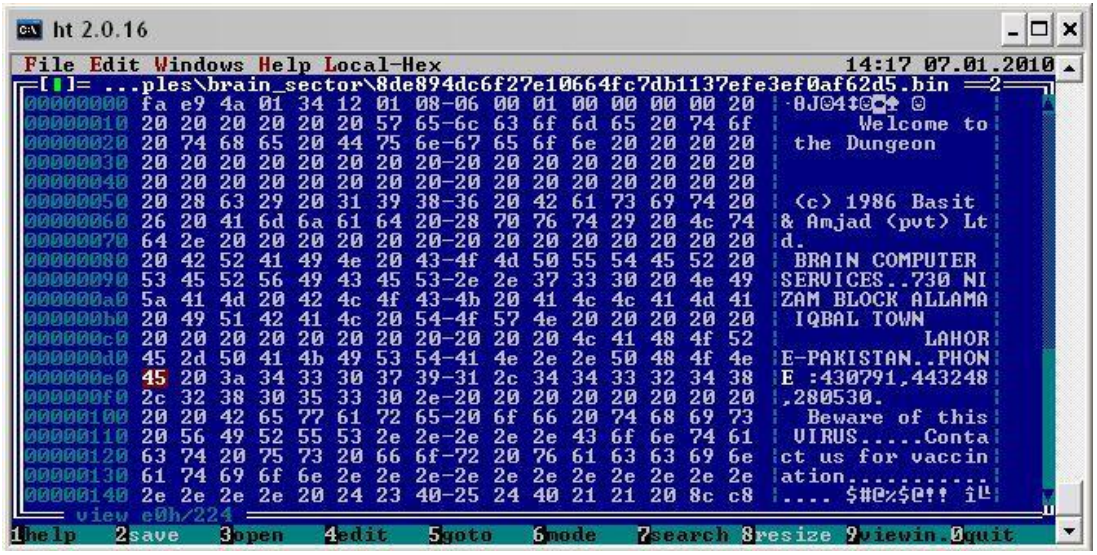
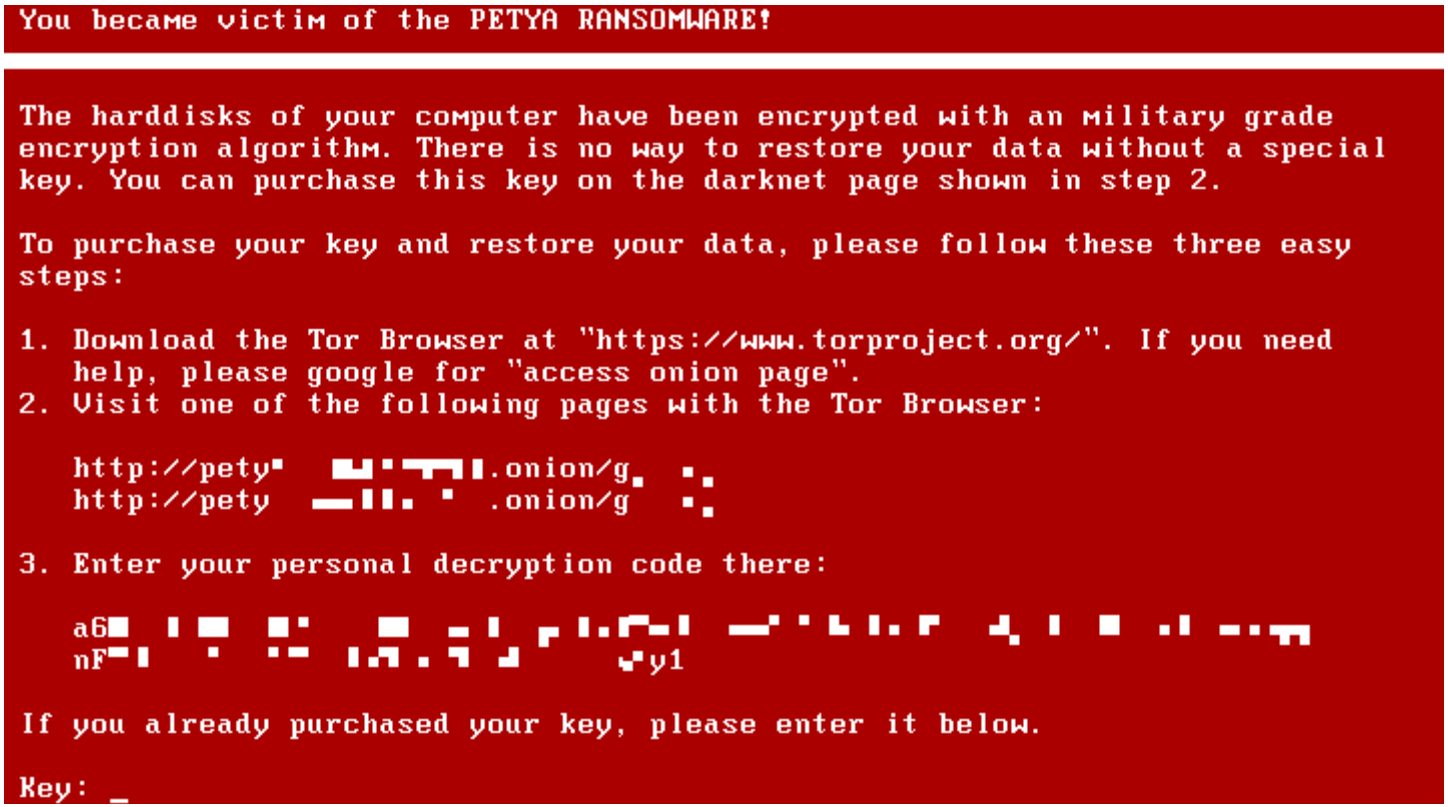
Malicious Software

viruses	*worms*	*rootkits*	*trojan horses*
keyloggers	*RATs*	*backdoors*	*downloaders*
droppers	*injectors*	*dialers*	*flooders*
adware	*spyware*	*ransomware*	…

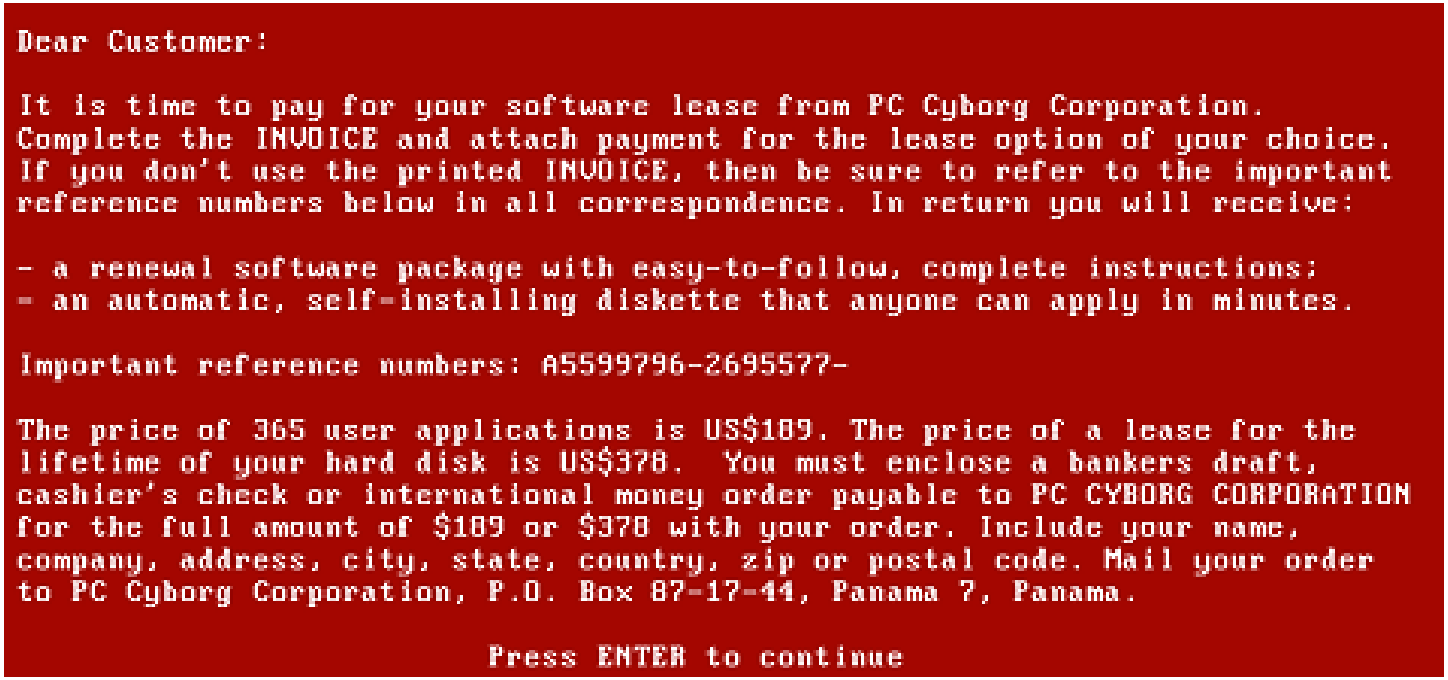


Brain – first IBM PC virus

Petya Ransomware, 2016



AIDS Ransomware, 1989



Malware Characteristics

Code Environment

Machine code (executables, DLLs, drivers, shellcode), higher-level languages/interpreters (VB, macro, JS, Java), shell scripts, …

Attack vector

Network packet/request, web page, email, document, USB, …

Infection point

SMM/BIOS, firmware, boot sector, kernel, services/daemons, executable files, memory-only, browser-only…

Propagation strategy

File infection (local disk, remote shares, cloud drives), network scanning, contact/host/peer list, physical access, …

Armoring techniques

Packing, polymorphism, obfuscation, anti-VM/sandbox tricks, anti-debugging tricks, …

(Some) Common Malware Types

Downloaders/droppers

Fetch additional modules from remote locations and plant them

Launchers/loaders

(unpack and) drop a more complex module

Backdoors

Provide access to infected system

Reverse shells, RATs (remote access Trojan), bots, …

Keyloggers/credential stealers

Capture passwords and authentication tokens

User/kernel space keyloggers, hash dumpers, …

Worms vs. Viruses

Worm

- A program that self-propagates across a network exploiting security or policy flaws in widely-used services
- Malicious code (standalone or file-infecting) that propagates over a network, with or without human assistance

Classification not always clear

Main differences of worms from typical viruses

- May not require user intervention
- May not need to infect files
- Network-oriented infection strategy

Worms: It all started back in 1988…

Morris worm

- Created with no malicious intent
- “Gauge the size of the internet”

Exploited multiple vulnerabilities

- `finger` (stack smashing)
- `sendmail` (DEBUG command allowed for remote cmd exec)
- Weak passwords (cracking using dictionary)
- `rsh/rexec` (*`/etc/hosts.equiv`* or *`.rhosts`* host-based authentication)

Infected about 10% of the internet

- 6.000 out of 60.000 hosts

Hacking

DDoS attack that disrupted internet was largest of its kind in history, experts say

Probably less sophisticated than Morris worm…

Dyn, the victim of last week's denial of service attack, said it was orchestrated using a weapon called the Mirai botnet as the 'primary source of malicious attack'

Major cyber attack disrupts internet service across Europe and US

Nicky Woolf in San Francisco

@nickywoolf

Wednesday 26 October 2016 16.42 EDT

Most popular in US


End this misogynistic horror show. Put Hillary Clinton in the White House | Barbara...


Somali migrants are 'disaster' for Minnesota, says Donald Trump


US election: Trump and Clinton in tight race on campaign's final day – live

And then…

13 July 2001 – CodeRed: Buffer overflow in Microsoft IIS

```
GET /default.ida?NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN
NNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNNN%u9090%u6858%ucbd3%u7801%u
9090%u6858%ucbd3%u7801%u9090%u6858%ucbd3%u7801%u9090%u9090%u8190%u00c3%u0003%u8b00%u531b%
u53ff%u0078%u0000%u00=a HTTP/1.0
```

Defaced affected website:

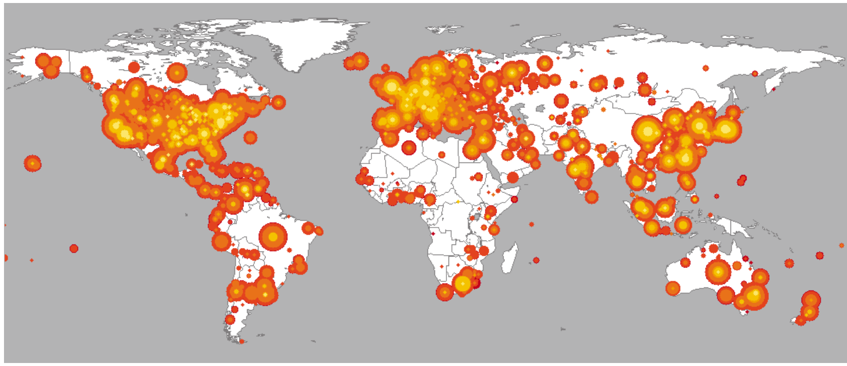
HELLO! Welcome to http://www.worm.com! Hacked By Chinese!

Days 1–19: propagate through random scanning

Days 20–27: DoS attack against www.whitehouse.gov

4 August 2001 – CodeRed II

Localized scanning

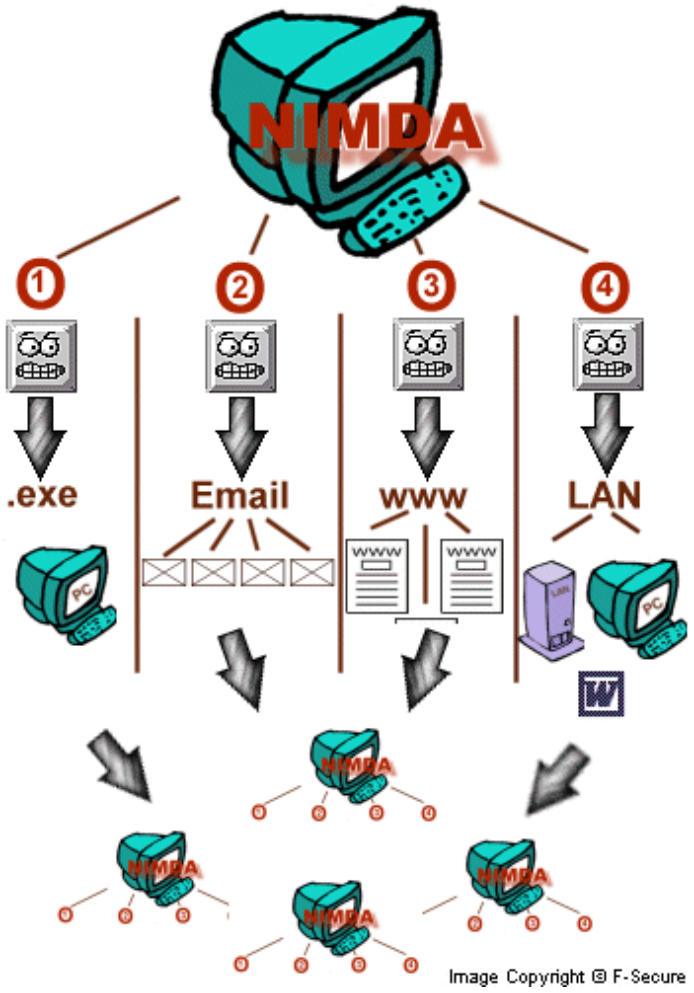


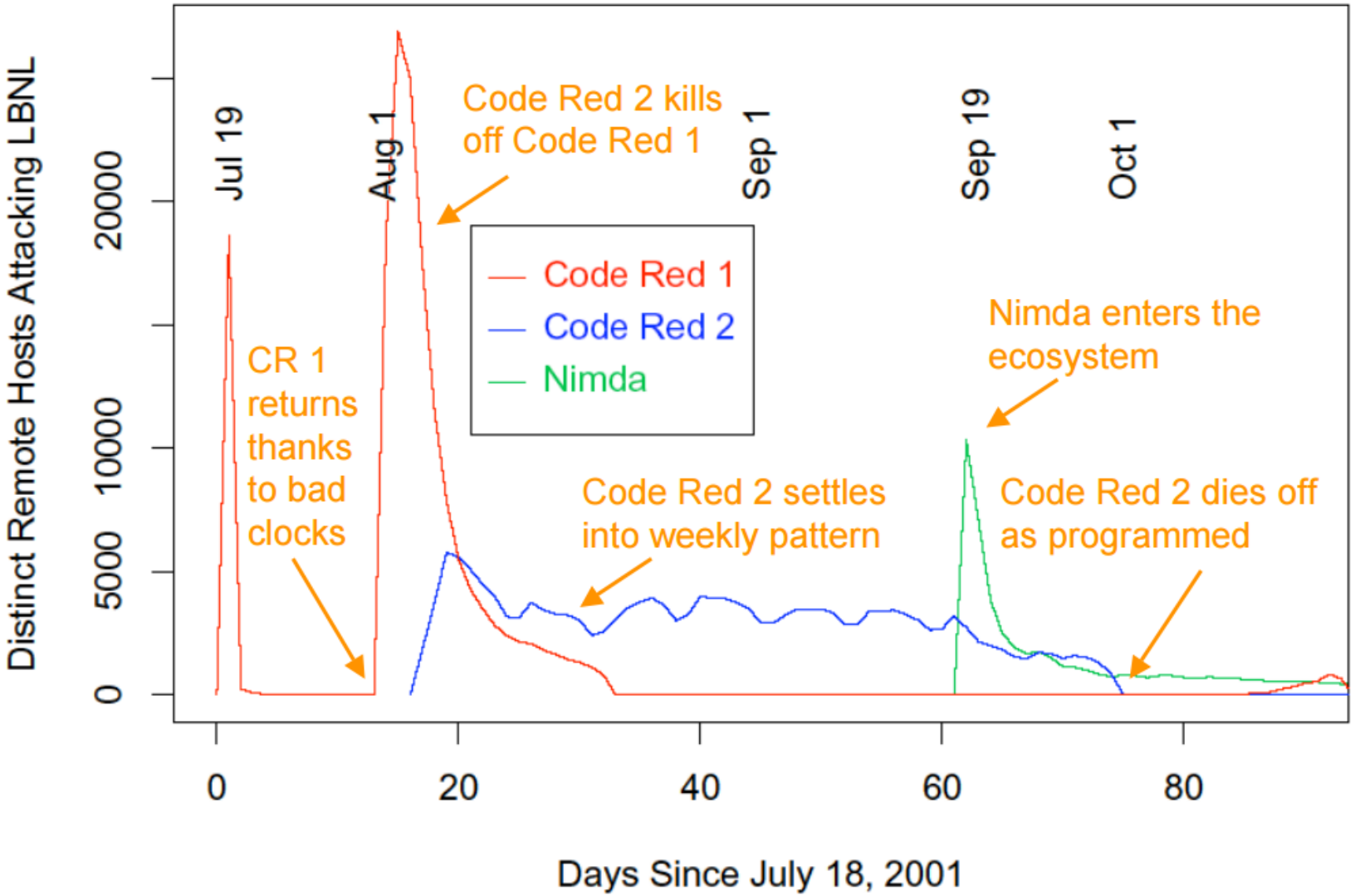
More to come…

18/9/2001 – Nimda

Many infection vectors

- Code Red IIS buffer overflow
- Bulk email to harvested addresses from victim host
- Open network shares
- Infect visitors of compromised web sites
- Microsoft IIS 4.0/5.0 directory traversal vulnerabilities
- Backdoors left behind by the Code Red II and Sadmind/IIS worms



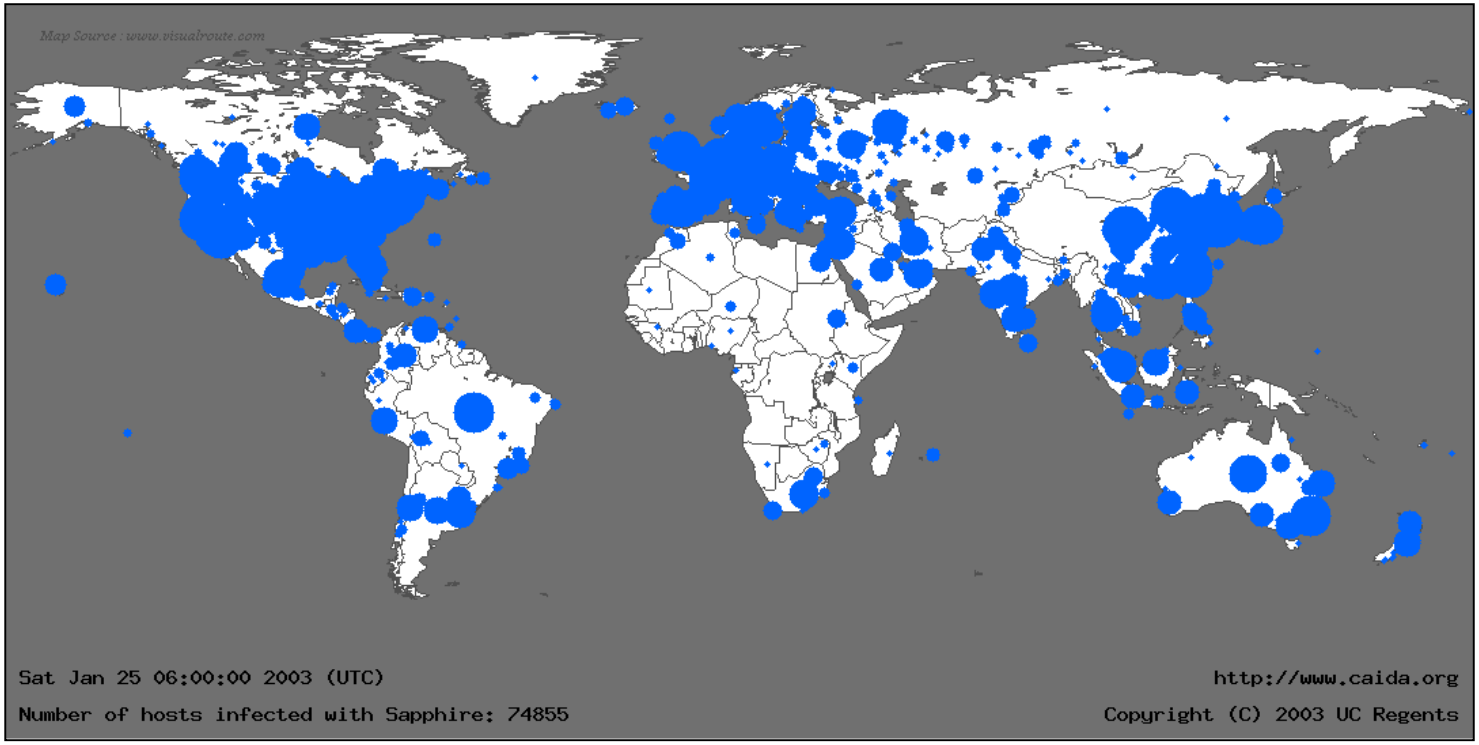


How to 0wn the Internet in Your Spare Time– USENIX Security 2002

Faster…

25 January 2003 – Slammer

Stack overflow in MS SQL Server 2000, 376-byte UDP packet



Slammer, 30 min after its release:
75.000+ infected hosts, 90% of the vulnerable population

Massive…

11 August 2003 – Blaster

- Buffer overflow in the DCOM RPC Windows service
- TFTP connect-back, download, and execute
- 6176-byte UPX-compressed binary

SYN-flooding DDoS attack against windowsupdate.com

18 August 2003 – Welchia

- "helpful" worm: deletes Blaster and downloads patch
- Caused side-effects…

More…

19 March 2004 – Witty worm

Vulnerability in ISS firewall products

30 April 2004 – Sasser

Vulnerability in LSASS Windows service

13 August 2005 – Zotob

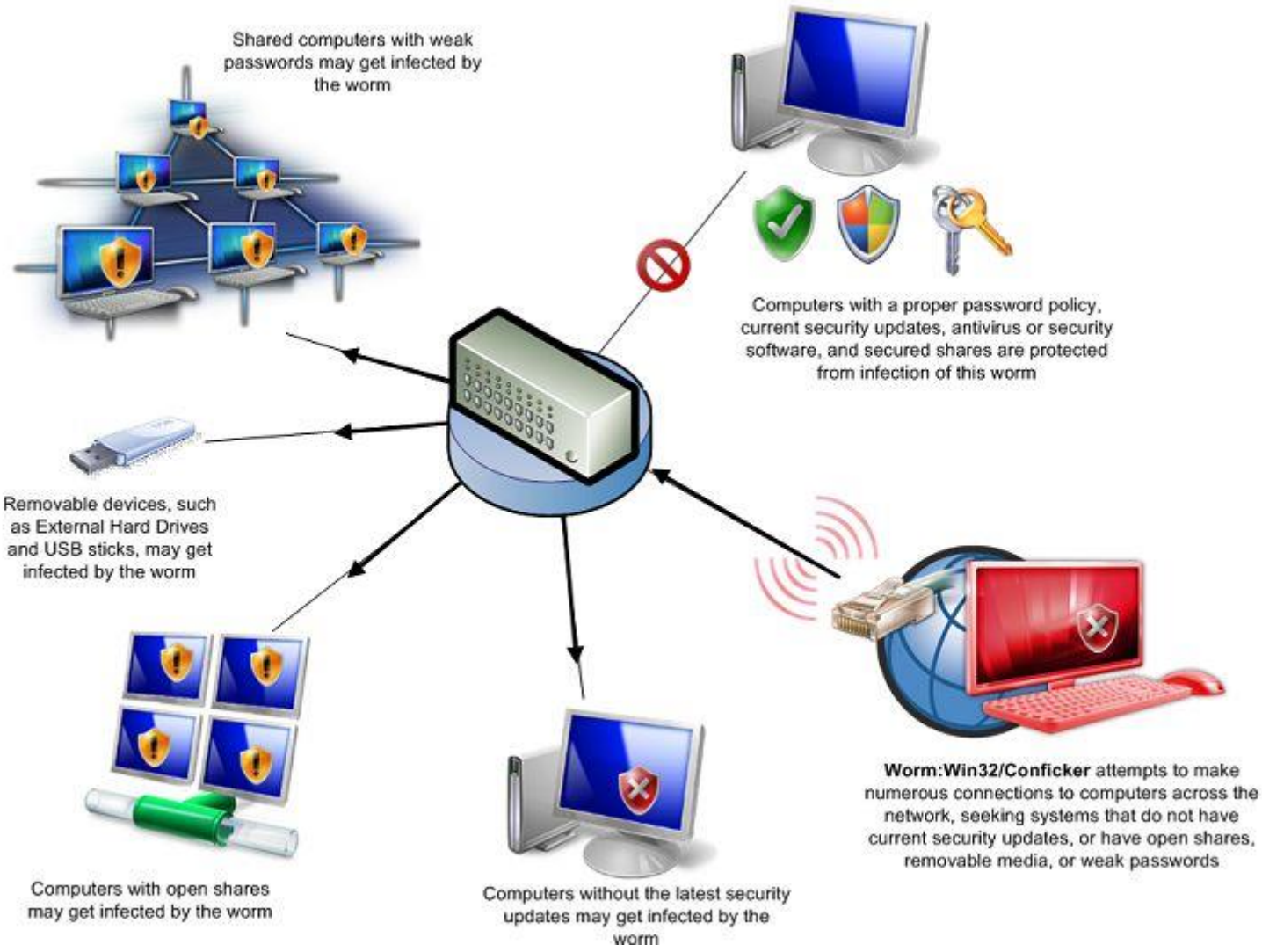
MS05-039 PnP vulnerability

17 January 2007 – Storm

Mass-mailing worm, built P2P botnet

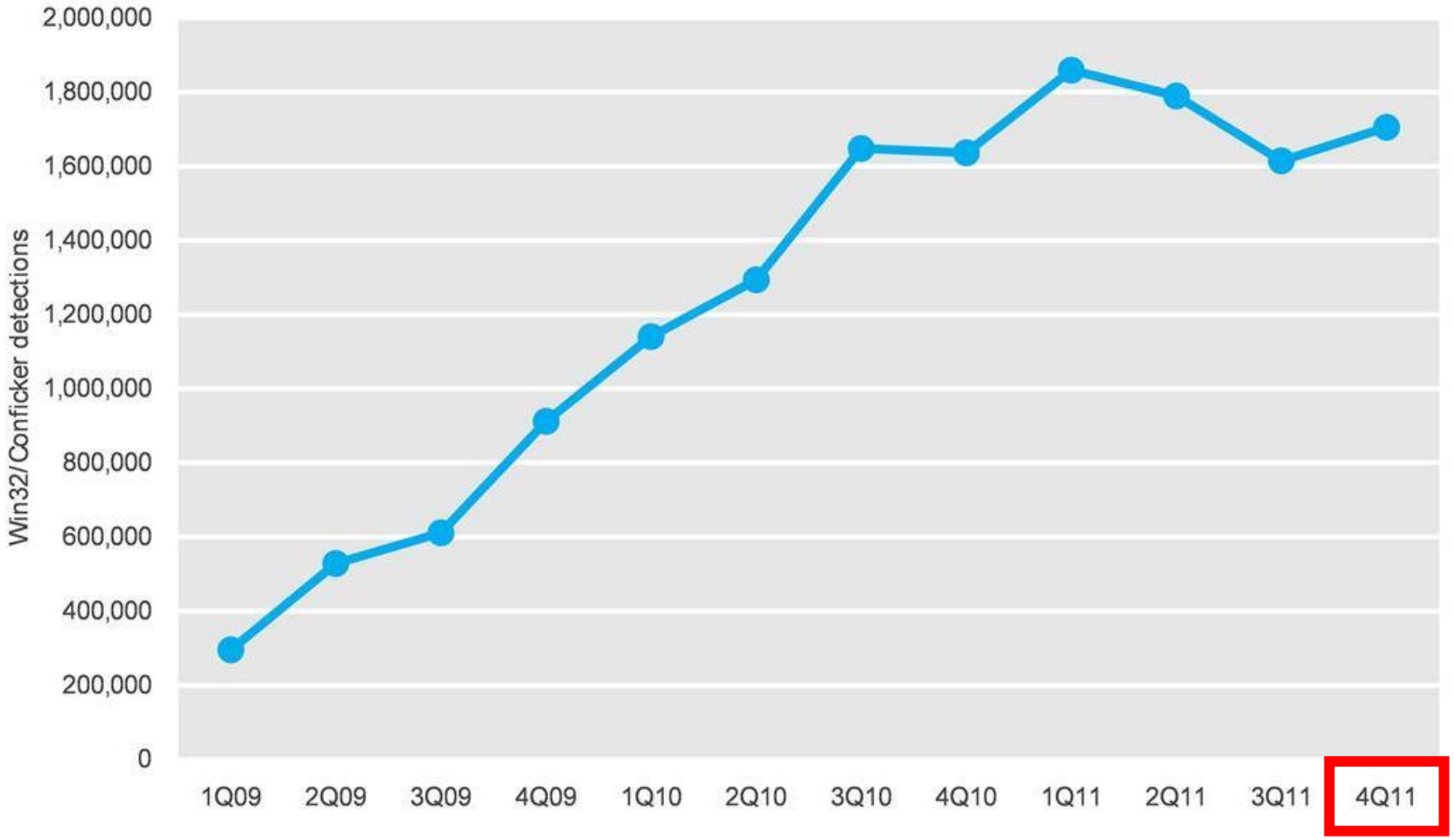
21 November 2008 – Conficker

MS08-067 RPC vulnerability



Added by Conficker

By selecting it the worm runs and begins to spread to other computers



Win32/Conficker detections by Microsoft antimalware products, 1Q '09 – 4Q '11

Conficker: Still spamming after all these years

How pathetic is the security in many enterprises? Almost six years since the patch to stop it was issued, Conficker is still one of the most common threats.

By Larry Seltzer for Zero Day July 3, 2014 - 11:08 GMT (04:08 PDT) | Topic: Security

A recent TrendLabs Security Intelligence Blog entry reminds us of just how immune some enterprises are to reasonable security practices. It turns out that Conficker (which they call DOWNAD, one of a few names for this threat) is still the most common form of malware found in enterprises and small businesses.

Conficker was quite a big deal back in late 2008 and early 2009. When Microsoft released MS08-067 ("Vulnerability in Server Service Could Allow Remote Code Execution") out of band on October 23, 2008,

Generic Structure of Internet Worms

Target discovery

Infection propagator

Activation

Payload

Target Discovery

Network scanning

- Random scanning (CodeRed, Sasser, Slammer, Witty)
- Localized random scanning (CodeRed II)
- Linear subnet scanning (Blaster)
- Combinations (Slapper, Welchia)

E-mail address harvesting

- Address books, files, web crawling, monitoring SMTP activity, …

Network share enumeration/topology

- Network Neighborhood, `/etc/hosts`, `known_hosts`, …

Other mediums

- P2P shared folders, IM, Google (MyDoom.O, Santy), …

A Decade Later

Worms rely mostly on lateral movement techniques

- Credentials harvesting (Mimikatz, keyloggers, sniffing, …)
- Internal reconnaissance (network shares, VPN conections, …)
- Pivoting attacks (RDP, PsExec, VBScript, WMI, …)

WannaCry (May 2017)

- Internal/external spreading via the patched MS17-010 SMB bug

NotPetya (June 2017)

- PsExec pass the hash, WMI, Mimikatz, MS17-010

BadRabbit (October 2017)

- Propagation strategy similar to NotPetya

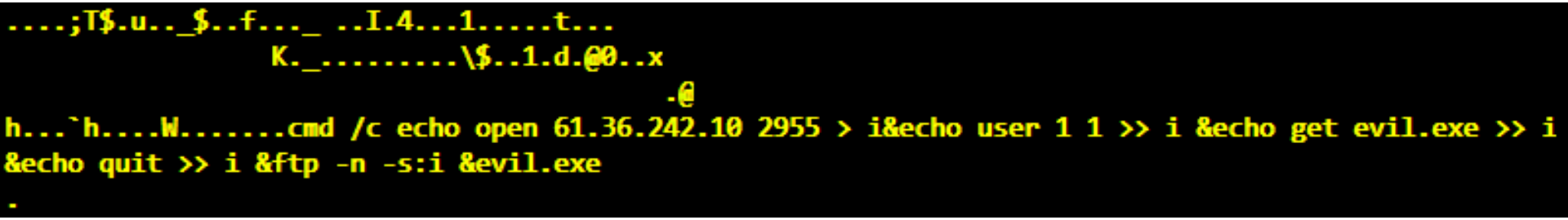
Infection Propagator

Self-carried

- CodeRed, Slammer, Witty, …

Second channel

- Blaster, Conficker, …
- TFTP, FTP, HTTP, SMB, …



Activation

Self-activation

Vulnerability exploitation, file infection, …

Human activation

Social engineering

“Attached is an important message for you” [Melissa virus, 1999]

“Open this message to see who loves you” [ILOVEYOU virus, 2000]

Human activity-related activation

Double-click, user login, reboot, …

Payload

click fraud

port scanning

extortion

phishing

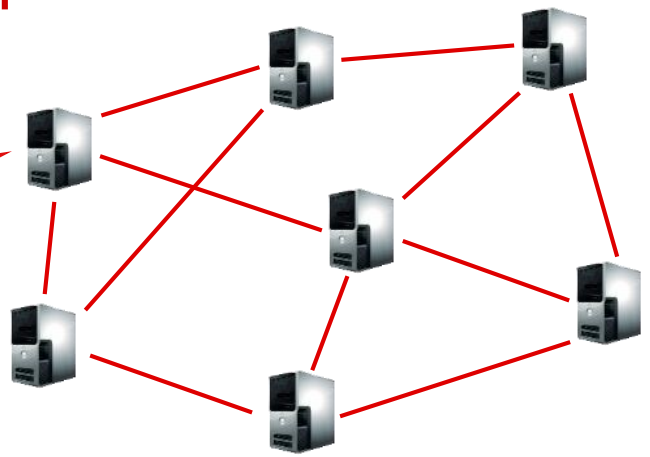
illegal content

DDoS

code injection

malicious websites

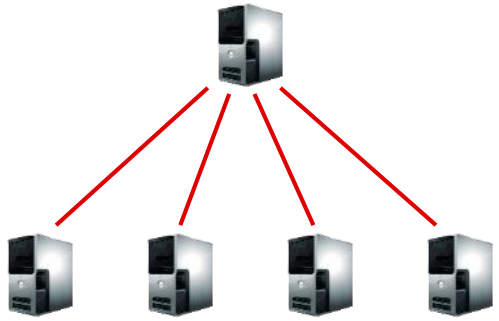
spam



Botnets

Networks of compromised hosts

- Controlled remotely by an attacker
- Used for malicious activities

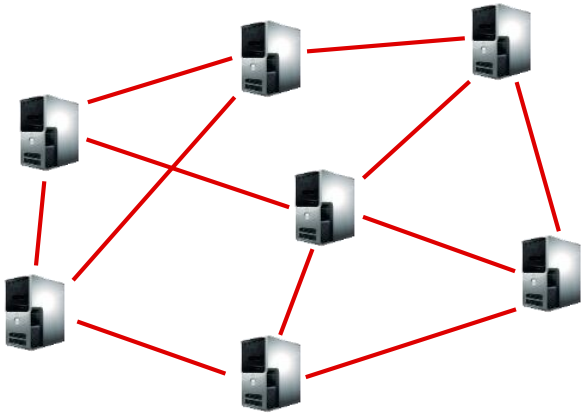


Command and Control (C&C)

- Centralized, P2P, web-based, …

Early botnets: bots just join an IRC channel

- Origin: benign IRC bots that perform automated actions



Push vs. pull model

- Example: IRC vs. HTTP

Botnets: what for?

Spam relaying

DDoS (for hire)

Mass information/identity theft

Extortion (DoS, ransomware)

Spreading new malware

Malicious page proxying/hosting

Manipulating online polls/games

Click fraud

Adware affiliate programs

Phishing web servers

Bitcoin mining

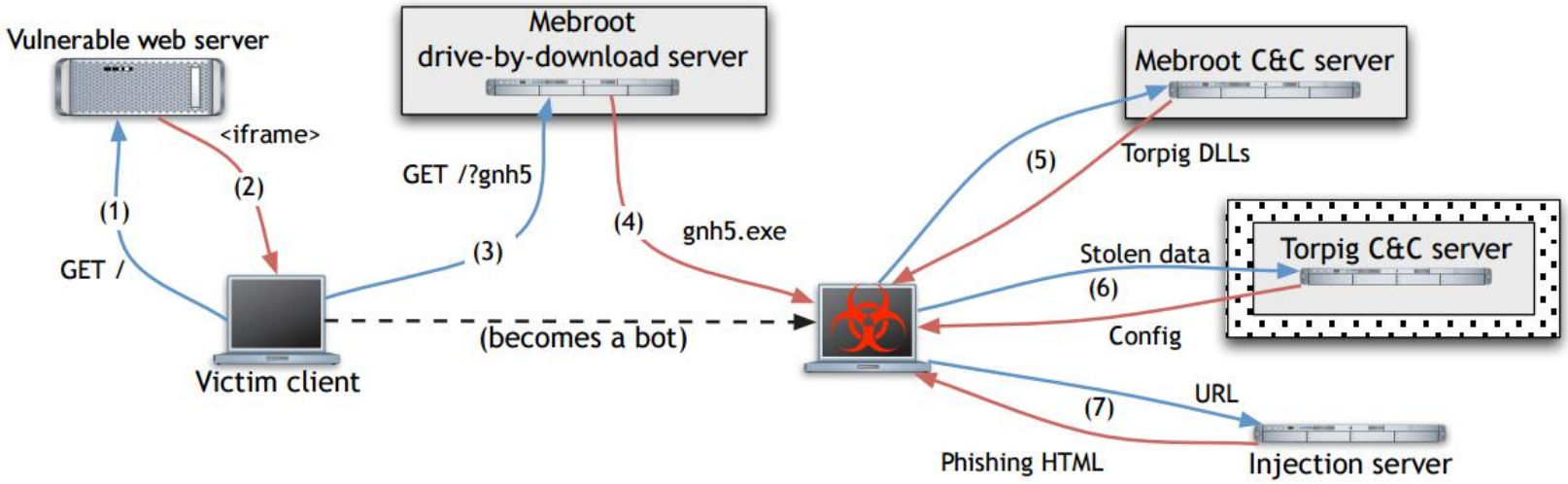
…


```
Some files are coded.
To buy decoder mail: <user>@yahoo.com
with subject: PGCoder000000000032
```

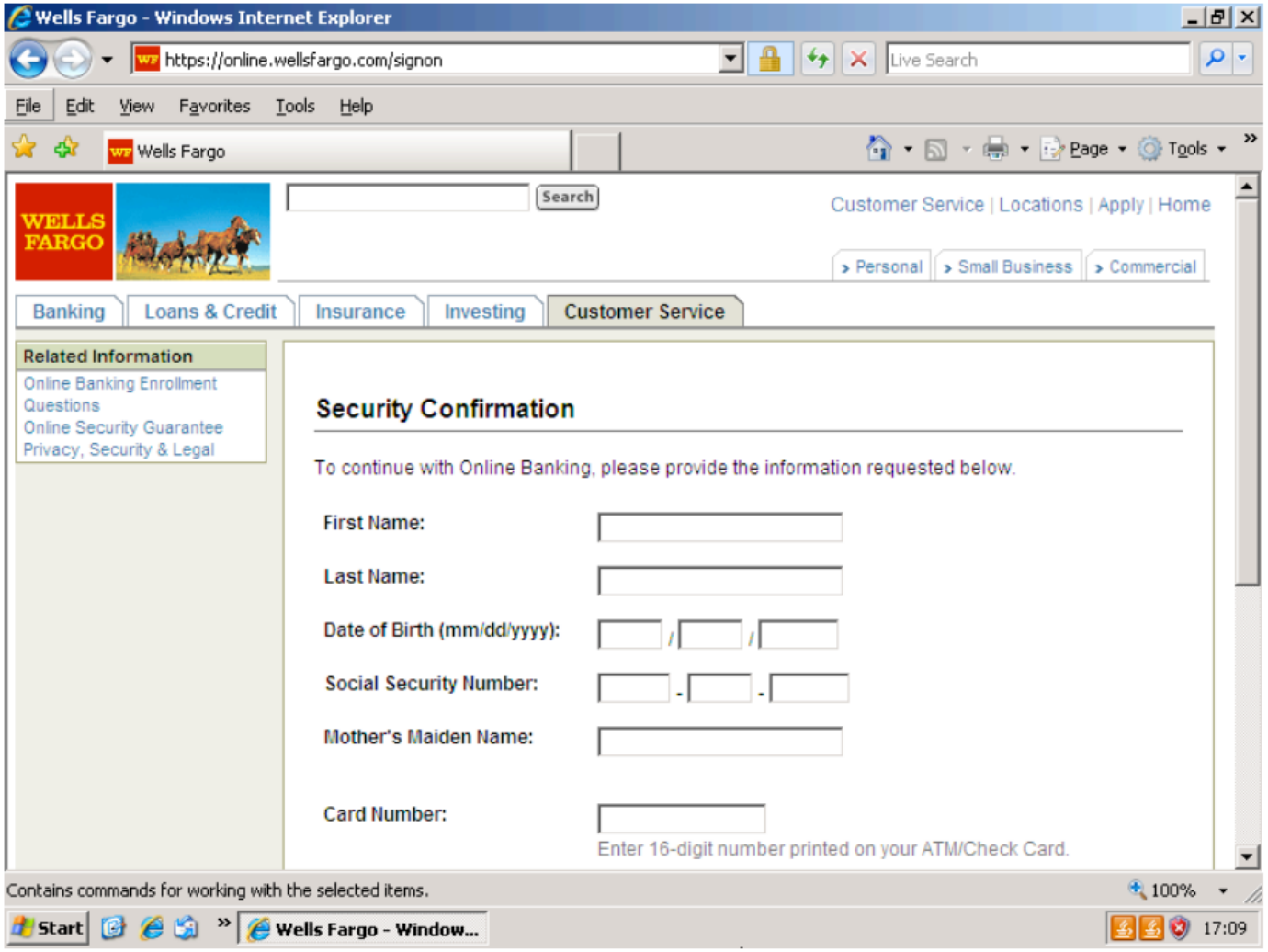
– *Trojan.Gpcoder.C, 2005*

Use Case: Torpig

Trojan distributed as part of Mebroot (MBR rootkit)



1: Victim visits malicious/infected website
2-4: Mebroot infection through a drive-by download attack
5: Mebroot downloads and installs Torpig
6: Torpig exfiltrates stolen data
7: Torpig downloads page templates to opportunistically launch man-in-the-browser attacks against online banking websites



Torpig's man-in-the-browser phishing attack

DGA Botnets

What if the C&C server is gone?

- Hardcoding domains or IP addresses in the bots not a good idea

Domain Generation Algorithm

- Resilient C&C communication: generate and contact new domains periodically
- If a domain is not available, just move on to the next one

Torpig's DGA

- Initial seed: current date
- Weekly and daily domains
- Hard-coded fall-back domains refreshed with each config file received from the C&C server

```
def generate_domain(t, p):
    if t.year < 2007:
        t.year = 2007
    s = scramble_date(t, p)
    c1 = (((t.year >> 2) & 0x3fc0) + s) % 25 + 'a'
    c2 = (t.month + s) % 10 + 'a'
    c3 = ((t.year & 0xff) + s) % 25 + 'a'
    if t.day * 2 < '0' ||  t.day * 2 > '9':
        c4 = (t.day * 2) % 25 + 'a'
    else:
        c4 = t.day % 10 + '1'
    return c1 + 'h' + c2 + c3 + 'x' + c4 +
        suffix[t.month - 1]
```

Botnet Infiltration

Step 1: register future domains, step 2: profit

Sample URL requested by a Torpig bot:

```
POST /A15078D49EBA4C4E/qxoT4B5uUFFqw6c...SZG1at6E0AaCxQg6nIGA
```

Corresponding unencrypted submission header:

```
ts=1232724990&ip=192.168.0.1:&sport=8109&hport=8108&os=5.1.2600
&cn=United%20States&nid=A15078D49EBA4C4E&bld=gnh5&ver=229
```

The availability of a unique bot ID allowed for an accurate estimation of the botnet's size

Previous studies relied on the number of unique IP addresses observed, which is less accurate

- NAT ➔ underestimation: many bots behind the same IP address
- DHCP ➔ overestimation: the same bot uses many IP addresses

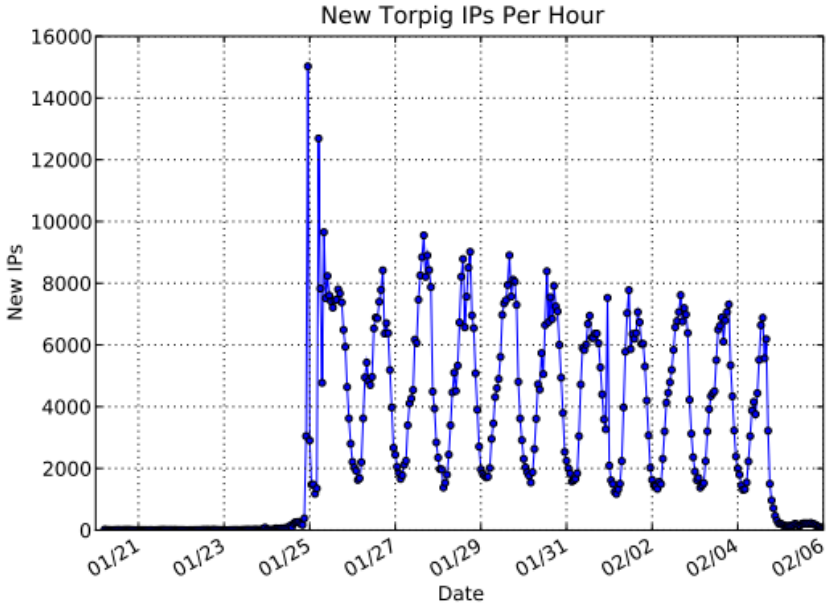


Figure 5: New unique IP addresses per hour.

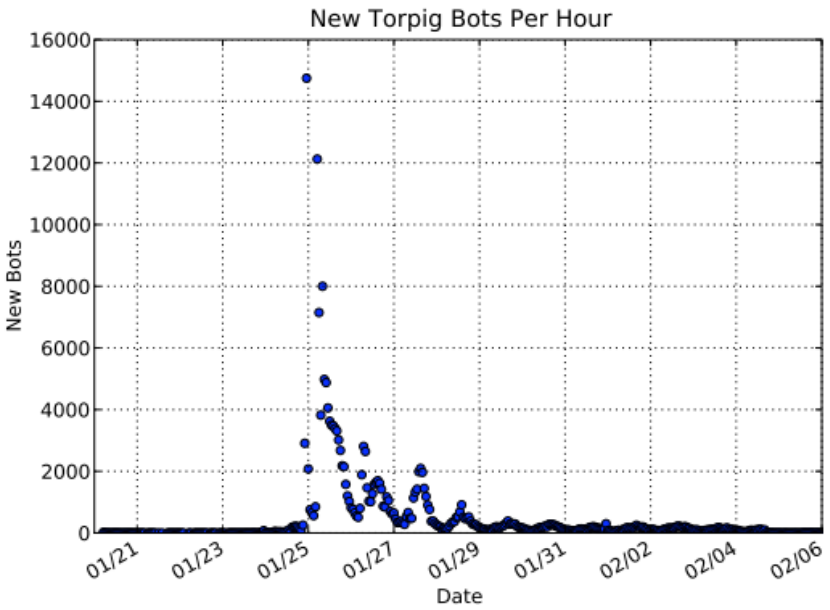


Figure 6: New bots per hour.

Activity observed through the hijacked C&C domains involved:

182,800 unique identifiers

1,247,642 unique IP addresses

Fast Flux

Goal: resilient malicious server hosting

- Hide phishing and malware delivery sites behind an ever-changing network of compromised hosts acting as proxies
- Harder to take down

One domain, many IP addresses

- Periodic change in DNS responses, short TTL
- Return only a few from a pool of many IPs
- Usually belonging to compromised machines (“flux agents”)

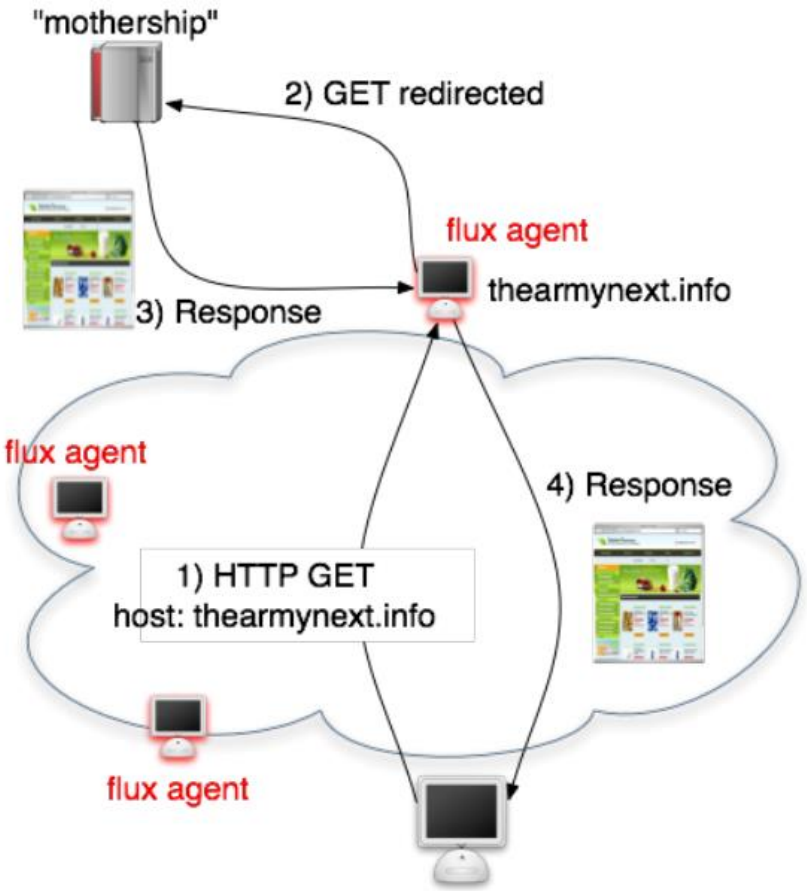
In essence, a malicious content distribution network using bots as proxies

DNS Lookup 1

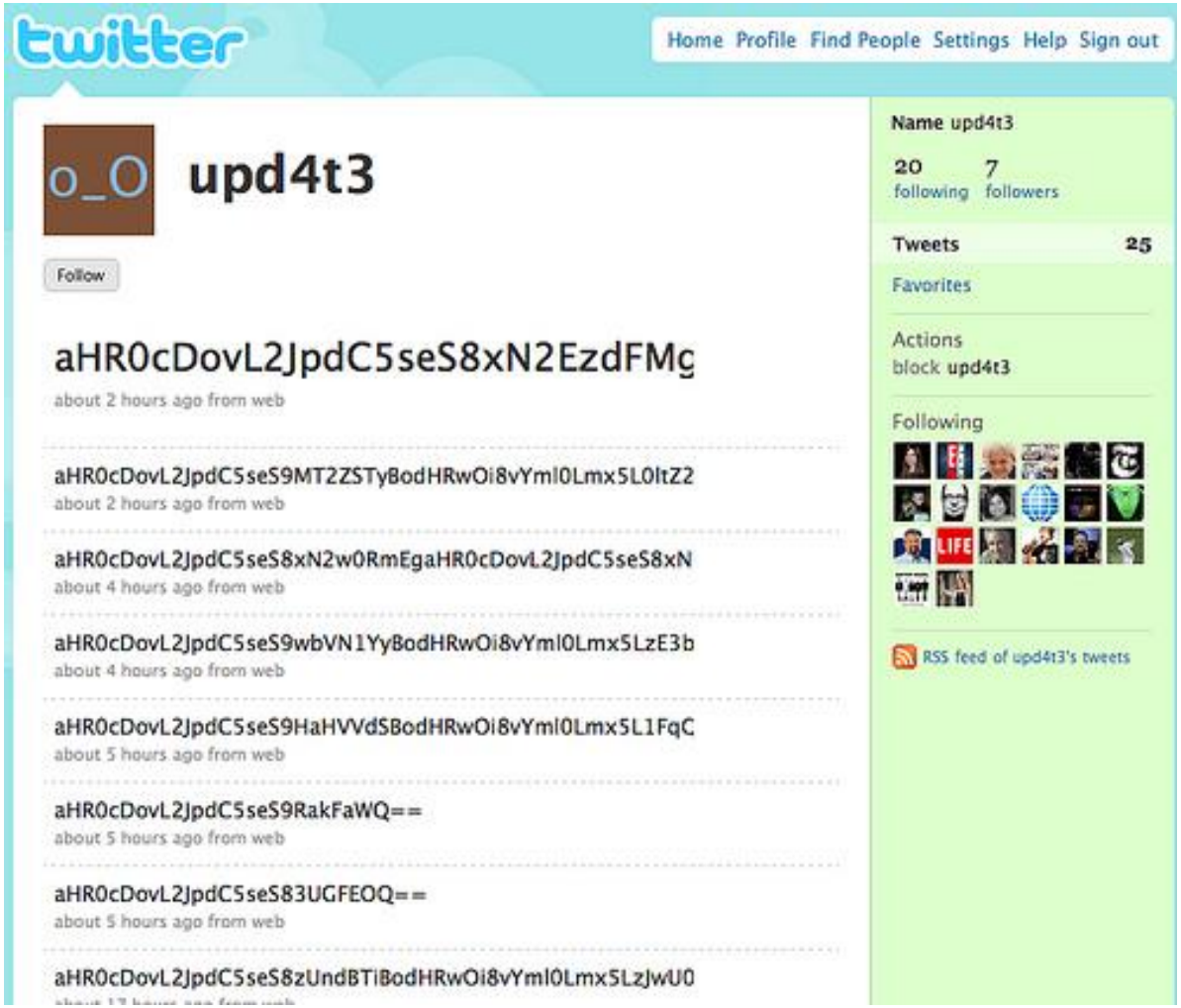
```
;; ANSWER SECTION:
thearmynext.info. 600 IN A 69.183.26.53
thearmynext.info. 600 IN A 76.205.234.13
thearmynext.info. 600 IN A 85.177.96.105
thearmynext.info. 600 IN A 27.129.178.13
thearmynext.info. 600 IN A 24.98.252.230
```

DNS Lookup 2

```
;; ANSWER SECTION:
thearmynext.info. 600 IN A 213.47.148.82
thearmynext.info. 600 IN A 213.91.251.16
thearmynext.info. 600 IN A 69.183.207.99
thearmynext.info. 600 IN A 91.148.168.92
thearmynext.info. 600 IN A 195.38.60.79
```



Many other C&C possibilities…



Besides $$$

Espionage, intelligence gathering, sabotage, …

- Nation-state level threats

Example: Stuxnet (2008)

- Used multiple Windows 0days
- Infiltrated and physically destroyed Iranian nuclear centrifuges

Other examples

- Duqu: collection of malware modules, related to Stuxnet
- PlugX: RAT targeting government-related institutions/industries
- Regin: found in Belgacom, Belgium's largest telco
- Flame: cyber espionage in Middle Eastern countries
- Gauss: cyber-espionage toolkit based on Flame
- …

Persistence

Startup folder

Registry keys

`HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Run`

Browser helper objects (BHO)

Winlogon Notify

Hook malware DLL as a handler that will be triggered by a given event

System services

Example: DLL injection into svchost.exe (Win32/Conficker)

Malware also often names its process "svchost.exe" to disguise itself

AppInit DLLs

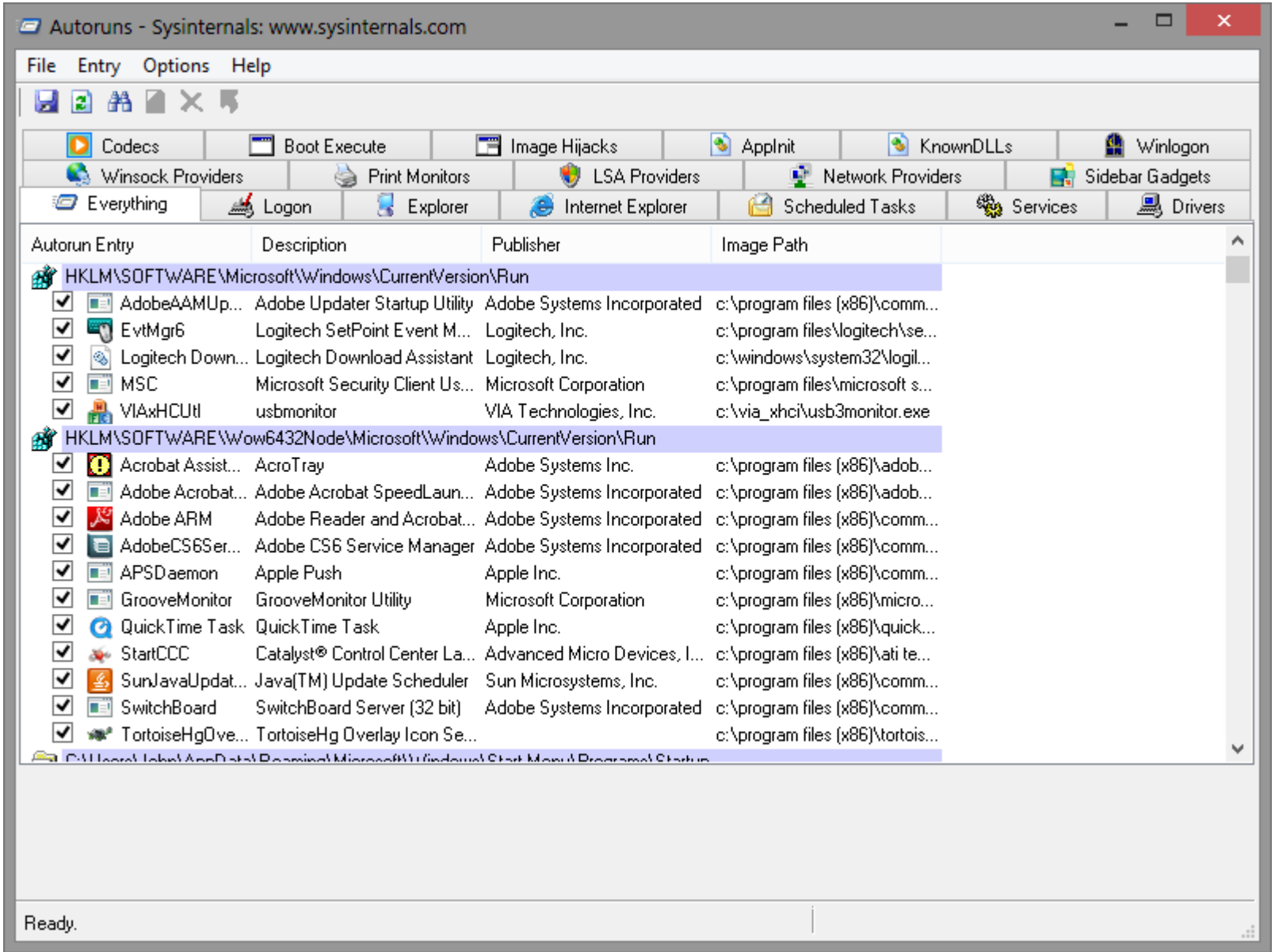
Easy way to hook system APIs by allowing custom DLLs to be loaded into the address space of every interactive application (can be disabled using secure boot)

DLL Load-order (Windows)/LD_PRELOAD (Linux)

Exploit loader's search order to load malicious DLLs

Trojanized binaries, kernel modification, module injection, …

Autoruns


Autoruns - Sysinternals: www.sysinternals.com
File Entry Options Help
Codecs Boot Execute Image Hijacks AppInit KnownDLLs Winlogon
Winsock Providers Print Monitors LSA Providers Network Providers Sidebar Gadgets
Everything Logon Explorer Internet Explorer Scheduled Tasks Services Drivers
Autorun Entry Description Publisher Image Path
HKLM\SOFTWARE\Microsoft\Windows\CurrentVersion\Run
AdobeAAMUp... Adobe Updater Startup Utility Adobe Systems Incorporated c:\program files (x86)\comm...
EvtMgr6 Logitech SetPoint Event M... Logitech, Inc. c:\program files\logitech\se...
Logitech Down... Logitech Download Assistant Logitech, Inc. c:\windows\system32\logil...
MSC Microsoft Security Client Us... Microsoft Corporation c:\program files\microsoft s...
VIAxHCUtl usbmonitor VIA Technologies, Inc. c:\via_xhci\usb3monitor.exe
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APSDaemon Apple Push Apple Inc. c:\program files (x86)\comm...
GrooveMonitor GrooveMonitor Utility Microsoft Corporation c:\program files (x86)\micro...
QuickTime Task QuickTime Task Apple Inc. c:\program files (x86)\quick...
StartCCC Catalyst® Control Center La... Advanced Micro Devices, I... c:\program files (x86)\ati te...
SunJavaUpdat... Java(TM) Update Scheduler Sun Microsystems, Inc. c:\program files (x86)\comm...
SwitchBoard SwitchBoard Server (32 bit) Adobe Systems Incorporated c:\program files (x86)\comm...
TortoiseHgOve... TortoiseHg Overlay Icon Se... c:\program files (x86)\tortois...
Ready.

Covert Malware Launching

IAT (Import Address Table) Hooking

Code patching

Just overwrite exiting code with a JMP

DLL Injection

E.g., CreateRemoteThread() + LoadLibrary()

Code injection

More cumbersome: have to dynamically resolve any API dependencies (in the same way as regular shellcode does)

Process replacement

Overwrite whole memory segments of a process

Evasion – *"Stay under the radar"*

Both anomaly and misuse detection systems can be evaded by breaking the detector's assumptions

- Detectors rely on certain features
- Make those features look legitimate or at least non-suspicious

Many techniques

- Packing/mutation/polymorphism/metamorphism
- Fragmentation
- Mimicry
- Rate adjustment (slow and stealthy vs. fast and noisy)
- Distribution and coordination (e.g., DoS vs. DDoS)
- Spoofing, stepping stones, redirection
- …

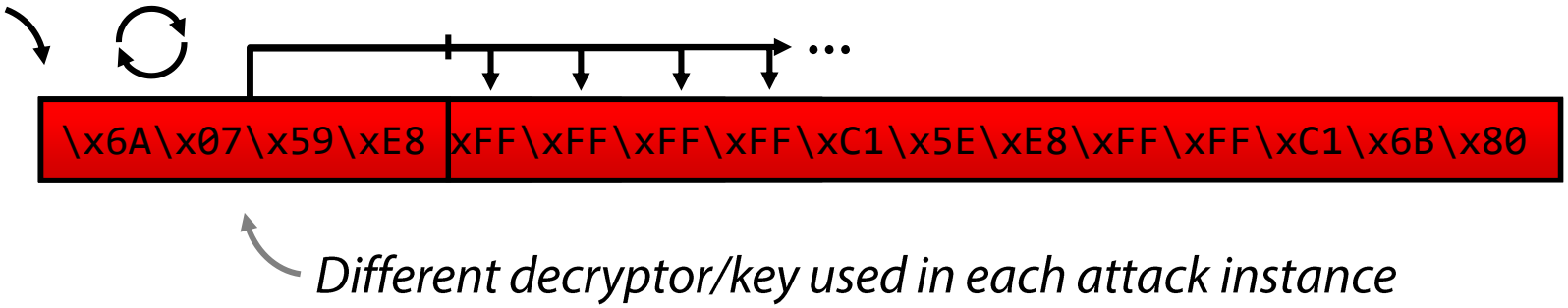
Polymorphism

Used to evade content-based detection (AVs, IDS, …)

Known since the early 90's from the virus scene

Each malware/attack instance is a different mutation of the original ➔ signature matching fails

Might actually make an attack look more suspicious!



Packers and Unpacking

Goals

- AV evasion
- Payload compression
- Hinder analysis/reverse engineering

Typical steps

- Decrypt packed code (compression, encryption, …)
- Load code into memory (disk, same or section, heap, …)
- Resolve imports of original executable (automated or manual)
- Transfer control to original entry point

Virtualizers

- Turn x86 code into code of a random ISA that runs on an embedded VM

Many free and commercial packer/crypters/protectors

- UPX, PECompact, ASPack, Petite, WinUpack, Themida, …

Code Obfuscation (Metamorphism)

NOP interspersion

```
inc ecx
dec ecx
```

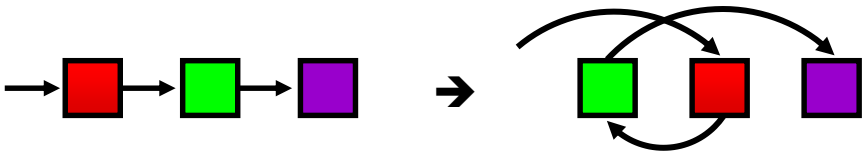
Instruction substitution

```
mov eax,0xF3
```

➔

```
push 0xF3
pop eax
```

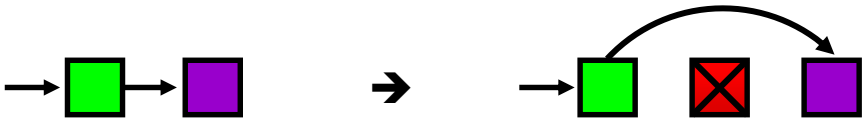
Block transposition



Register reassignment

```
sed -i 's/eax/ebx/g'
```

Dead code insertion



Many more

Opaque predicates, jump in the middle of instructions, stack frame manipulation, exception handling, …

Anti-debugging/Reverse Engineering

Make the life of malware analysts and automated malware analysis systems hard…

Obfuscate everything

- Obscure strings, IAT, function calls, code, …
- Erase headers from memory (anti-dumping)

Debugger detection

- Windows APIs (e.g., `IsDebuggerPresent()`)
- Read TEB debugging flag
- Generate exceptions
- On-the-fly checksums of the code image (detect breakpoints)
- Timing checks (debuggers are slow)
- Many other techniques…

VM Detection and Environment-aware Malware

Evade automated malware analysis sandboxes

VMware artifacts

- VMware Tools, MAC address, BIOS vendor, …

Instruction inconsistencies: different behavior on bare metal vs. emulator/virtualized system

- `cpuid, sidt, sgdt, sldt, smsw, …`

Detect existing hooks/instrumentation

Detect user activity

Kernel-level Rootkits

Typically implemented as kernel modules/drivers

Modern OSes use signed drivers

- Install an existing signed driver with an exploitable vulnerability
- Sign malware with acquired/stolen certificate
- Exploit a kernel vulnerability

Hooking

- Interrupt Descriptor Table (IDT), System Descriptor Table Hooking (SSDT), IRP handlers, …
- Easy to detect

Code patching

- Detectable using checksumming

Direct Kernel Object Manipulation (DKOM)

Hide malware footprints from the object manager, event scheduler, logs, …

- Also, add privileges/groups to tokens
- Processes, drivers, files, network connections, …
- Checksumming not effective: kernel structures that are frequently updated during normal system operation
- More stealthy (but more complex) technique

EPROCESS Object manipulation

- Doubly linked list of structures that represent processes
- Can be modify to hide a malicious process

DRIVER_SECTION manipulation

- Similar technique for drivers

Covert Channels

Transfer information without being noticed

- Myriad ways to achieve this…

Hide in commonly used traffic

- HTTP, DNS, ICMP, …
- Protocol tunneling, packet field manipulation, size, timing, …

Contact only non-suspicious destinations

- Host C&C on Google, Amazon, …
- Use forums, twitter, comments, etc. for communication

Steganography

- Hide communication or exfiltrated data within images or other files

Many other mediums

- Radio/electrical signals, sounds, vibrations, temperature, …

Indicators of Compromise (IoCs)

Artifacts observed on a host or network that with high confidence indicate a computer intrusion

Host level

- Hashes of malware executables/modules/files
- Strings in malware binary
- System-wide changes/behaviors

Network level

- Resolved domains
- Accessed IP addresses
- URLs
- Network request/packet content