Black-box analysis of malware

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Black-box analysis of malware – Outline

- Lecture
  1. Incident response
  2. Malware
  3. Black-box principle
  4. Tools
  5. Automatic sandbox analysis
- Hands-on lab
  - Analysis of provided malware samples

Analyzing intrusions

Cyber Incident Response

- Cyber Incident Response
  - “A well-organized effort by which an organization handles a cyberattack, including analysis, containment, remediation and reduction of future risks.”
  - Good incident response results in:
    - Lower costs of ongoing cyber incidents
    - Fewer future incidents
- Cyber Kill Chain
  - Each incident goes through certain phases
  - Each phase can only continue if all previous phases completed successfully
  - Collecting information about each phase helps detect/prevent future incidents

Cyber Kill Chain

Table 4: Intrusion Attempts 1, 2, and 3 Indicators

Phase	Intrusion 1	Intrusion 2	Intrusion 3
Reconnaissance	[Recipient List] Benign PDF	[Recipient List] Benign PDF	[Recipient List] Benign PPT
Weaponization	Trivial encryption algorithm		
	Key 1		Key 2
Delivery	[Email subject] [Email body]	[Email subject] [Email body]	[Email subject] [Email body]
	dn...etto@yahoo.com		ginette.c...@yahoo.com
	60.abc.xyz.215	216.abc.xyz.76	
Exploitation	CVE-2009-0658 [shellcode]		[PPT 0-day] [shellcode]
Installation	C:\...\fssm32.exe C:\...\IEUpd.exe C:\...\IEXPLORE.hlp		
C2	202.abc.xyz.7 [HTTP request]		
Actions on Objectives	N/A	N/A	N/A

M Hutchins, Eric & J Cloppert, Michael & M Amin, Rohan. (2011). Intelligence-Driven Computer Network Defense Informed by Analysis of Adversary Campaigns and Intrusion Kill Chains. Leading Issues in Information Warfare & Security Research.

MITRE ATT&CK Framework

- Globally accessible knowledge base of adversary tactics and techniques based on real-world observations.
  - Good learning point about advanced attackers
- Likely will replace kill chain
- https://attack.mitre.org/

Malware

Malware definition

“Malware, short for malicious software, is an umbrella term used to refer to a variety of forms of hostile or intrusive software, including computer viruses, worms, Trojan horses, ransomware, spyware, adware, scareware, and other intentionally harmful programs. It can take the form of executable code, scripts, active content, and other software. Malware is defined by its malicious intent, acting against the requirements of the computer user — and so does not include software that causes unintentional harm due to some deficiency.”

Malware types

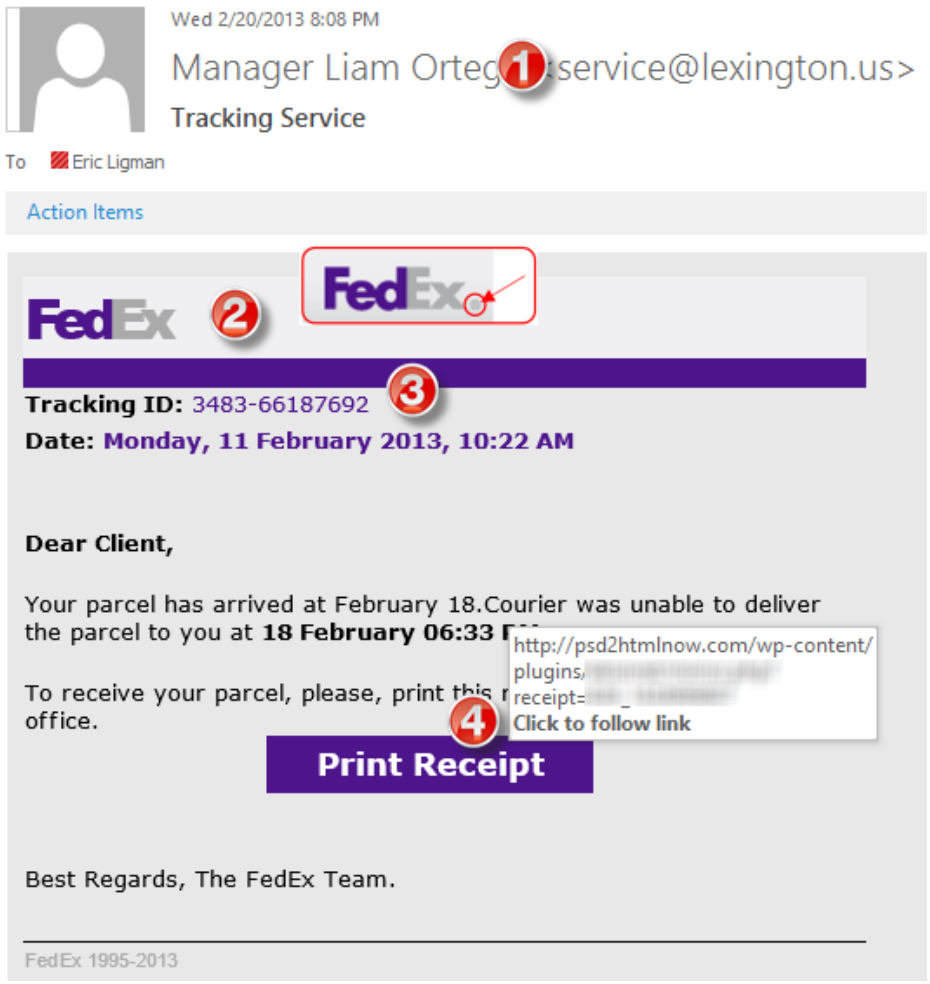
- Trojan
- Fake AV
- Backdoor
- Remote Access Tool (RAT)
- Dropper
- Downloader
- Information stealer
- Keylogger
- Ransomware
- Coinminer
- Sniffer
- Virus
- Worm
- Spyware
- Adware
- Botnet

Malware infection vectors

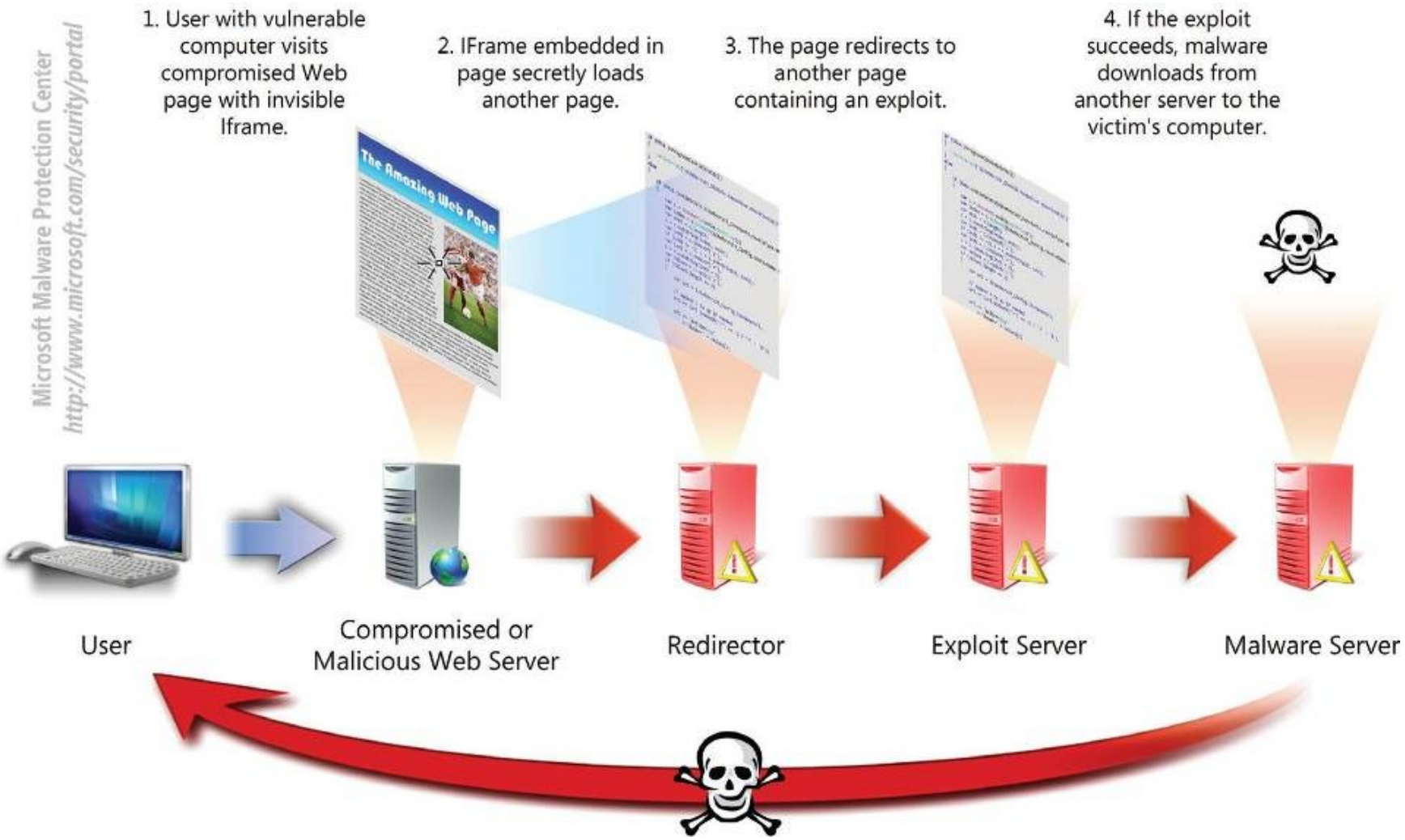
- Email
  - Link
  - Attachment
  - Link + document download
- Malicious website
  - Drive-by download
- USB
- Cracked software
- Worms

Infection vector – Phishing

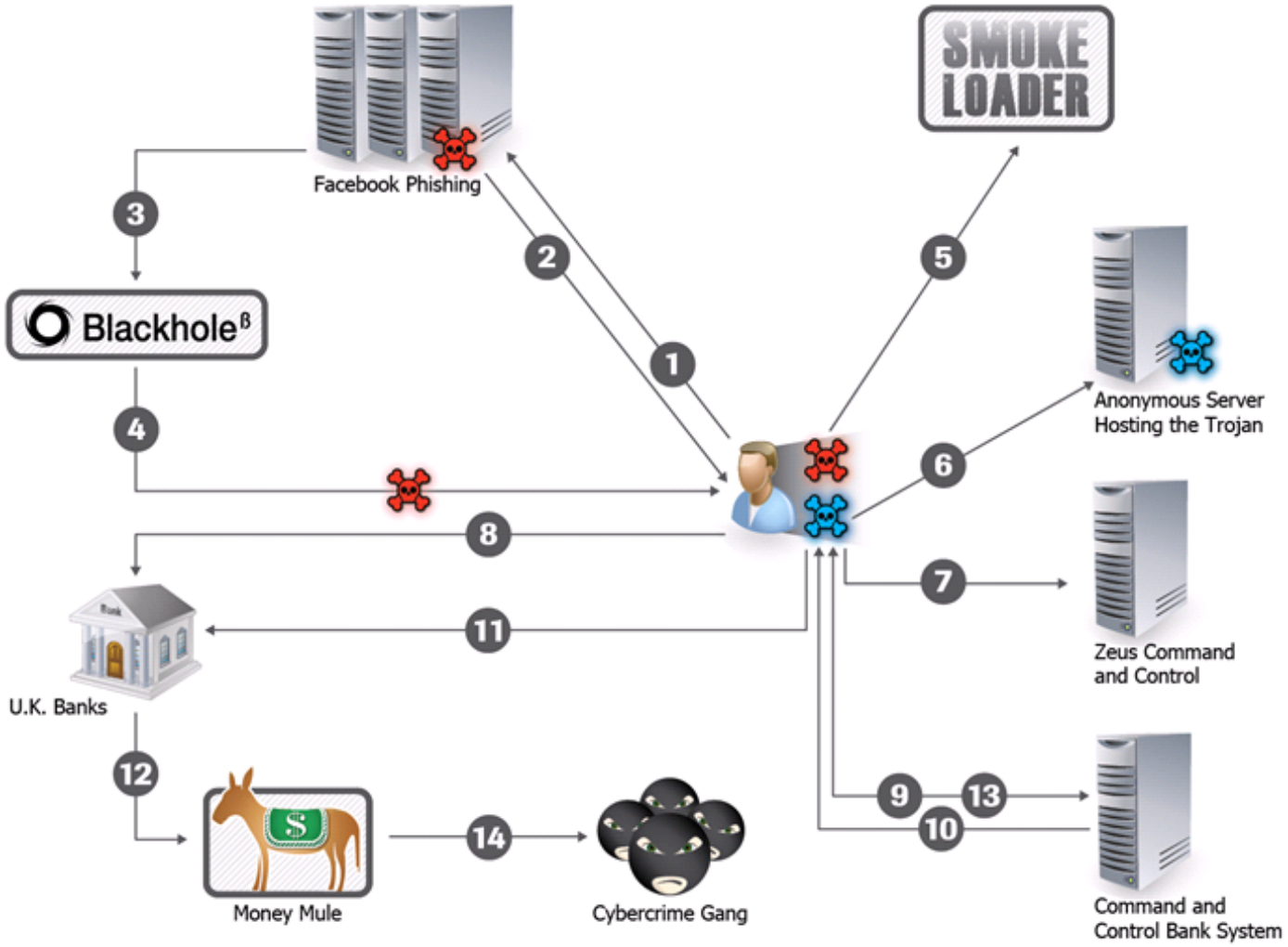
- Subject
  - “Account blocked”
  - “Package to be delivered”
  - “Expiring subscription”
  - “Invoice” / “Receipt” / “Parchment”
- Signs
  - Unexpected sender address (1)
  - Graphic errors (2)
  - Erroneous info (3)
  - Links to unexpected URL (4)
  - Links to same URL
  - Generic salutation
  - Use of threats, sense of urgency



Infection vector – Drive-by download



Example – Zeus infection



Black box malware analysis

Motivation – Ask the right questions

- What is the scope of compromise? What are 2nd stage callbacks?
- Communication between local file server and an unknown IP address in China has been observed. What process is responsible for the communication?
- Malware is creating temporary files. Where are these files located?
- Malware executable is created again after system reboot. How is it possible and what is causing it?
- A new type of malware has been spreading through internal network. How to quickly assess the malware capabilities? What is its purpose? Is it based on any well-known tool?

Black box malware analysis

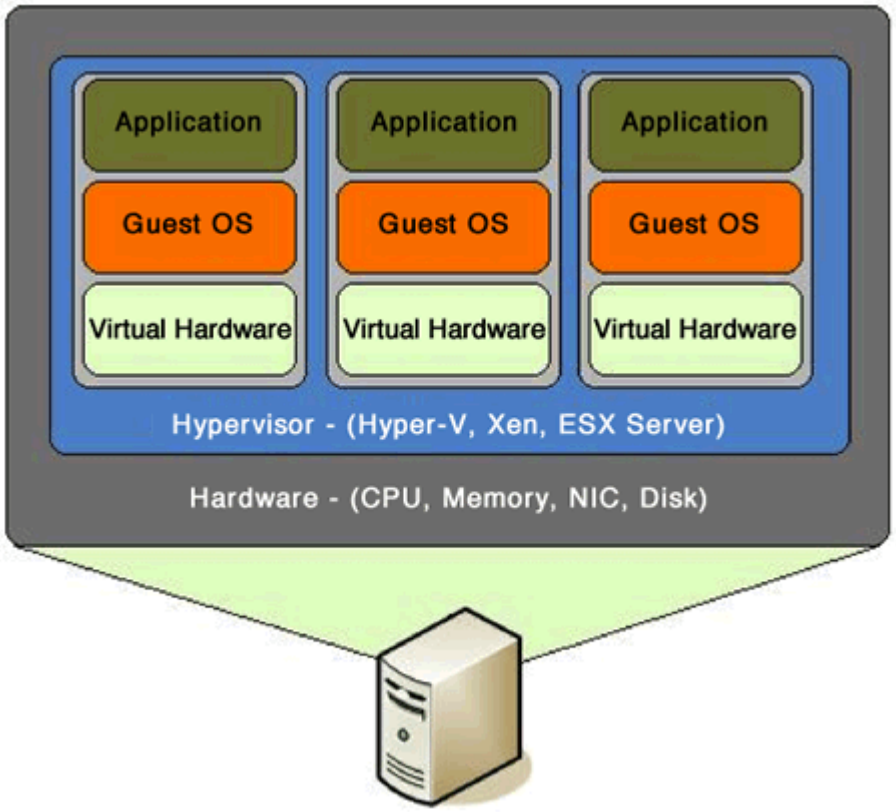
- Dynamic analysis – file is executed
- Analysis without internal knowledge
  - Observable inputs
  - Observable outputs
- Quick, simple
- Common monitoring tools
- Collected indicators about
  - Filenames, process names, process parent/child relationships, temporal relationships, domain names, IP addresses, registry keys, persistence methods, cleanup operations etc.
- Can be highly automated

Black box malware analysis – Principle

1. Prepare analysis environment
2. Create snapshot
3. Run monitoring tools
4. Run malware
5. Collect and observe interactions between malware and VM
6. Restore snapshot
7. Repeat 3-6 as needed

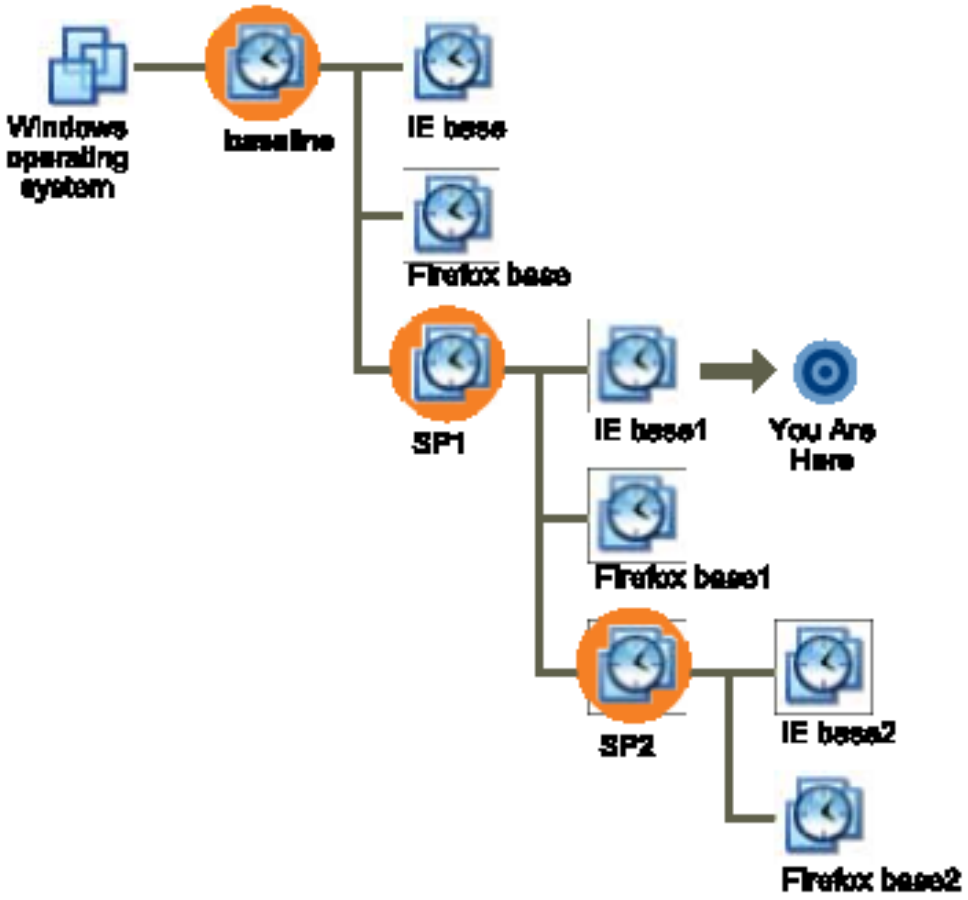
Analysis environment

- Virtual Machine
  - Limited/no connectivity
  - Virtualized services (DNS, HTTP,…)
  - Several VMs for various host types
- Software
  - Monitoring tools
  - Often exploited applications
- Risks
  - VM isolation breach
  - Malware inactivity in VM



Virtual machine snapshot

- Snapshots
  - Saved state of VM
  - Disk state, memory state
- Quick restoration of previous state



Tools

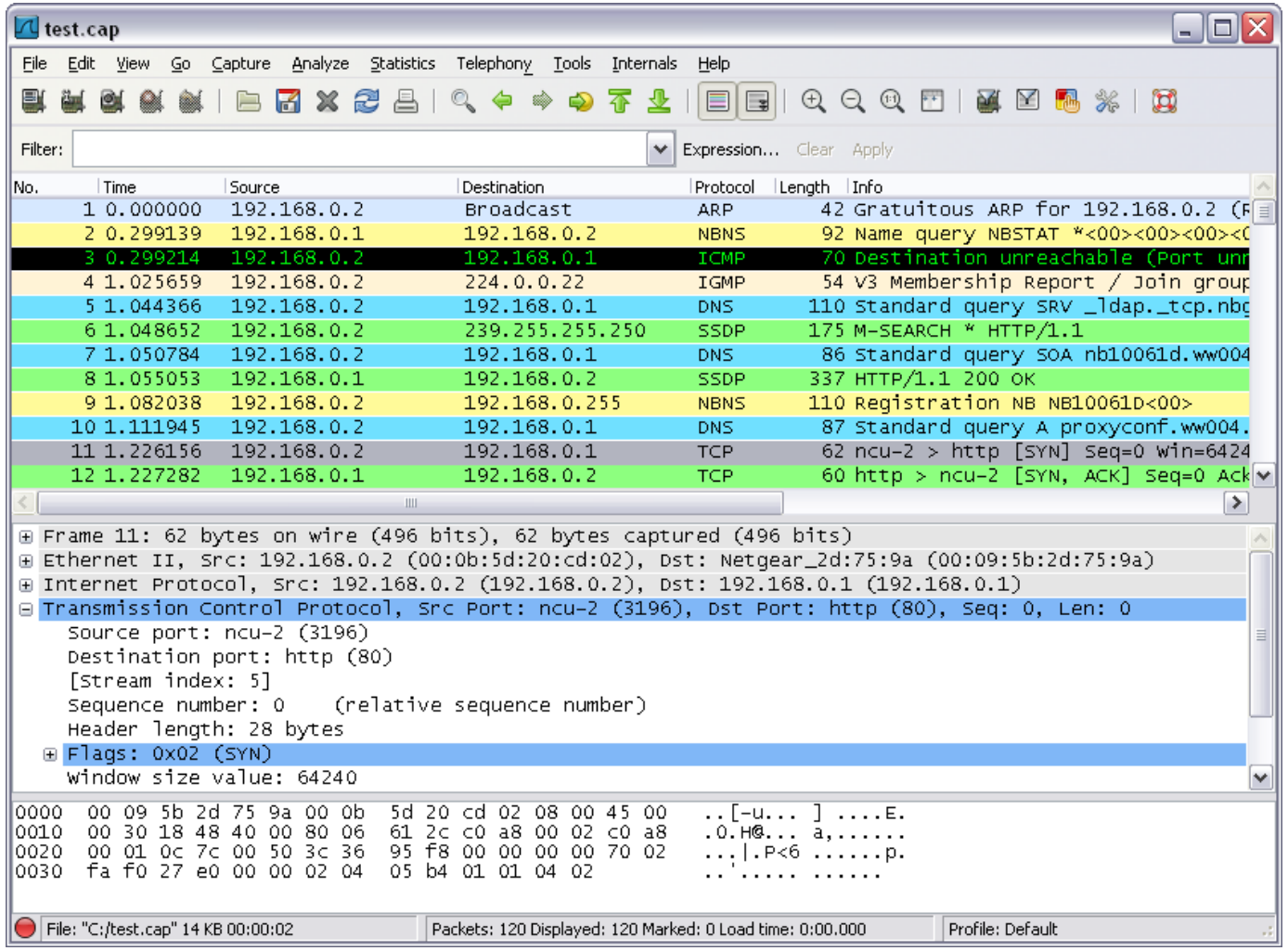
Network analysis

- Capturing sent/received packets
- Protocol dissection
- Promiscuous mode
- Tools
  - Tcpdump, Wireshark, NetworkMiner
- Indicators
  - Domain names, IP addresses, protocols, ports, HTTP parameters
- Q&A
  - Who is this program communicating with? What reputation does the partner have? What data is exchanged? Is it encrypted or obfuscated?

Network analysis – What to look for

- New established connections – HTTP 80/8080
  - Direct calls for domains without DNS lookup
  - Random domain names (e.g., rpxiodffd.biz)
  - Suspicious domain names (e.g., gooogle.org)
  - Similarly looking domain names (e.g., osinstall.biz, swinstall.biz, swinstall.com)
- Outgoing portscans
- Ping/DNS request for well known services
  - Connection availability test
- Be aware of background OS/processes activities!

Example – Wireshark



File system

- Observing file accesses and modifications
- Background file manipulation
- Tools
  - Procmon, Handle
- Indicators
  - File names, folder names, order of actions, compromise spread through local system
- Q&A
  - Where is malware copied after the initial infection? What filenames are used? Where is the collected data stored?

File system – What to look for

- New file names & folders
  - New created files and folders
  - Batch files (.cmd, .bat, .vbs, .ps1)
  - Known favorite malware file names (e.g., 1.exe, test.exe, new.exe)
  - Known file names in uncommon folders (e.g., C:\Temp\svchost.exe)
  - Recycler
- Modifications of system files
- Temporary storage files, encrypted archives

Example – Procmon

Process Monitor - Sysinternals: www.sysinternals.com

File Edit Event Filter Tools Options Help

Time ...	Process Name	PID	Operation	Path	Result
14:06:...	setup.exe	2132	Process Start		SUCCESS
14:06:...	setup.exe	2132	Thread Create		SUCCESS
14:06:...	setup.exe	2132	Load Image	D:\setup.exe	SUCCESS
14:06:...	setup.exe	2132	Load Image	C:\Windows\System32\ntdll.dll	SUCCESS
14:06:...	setup.exe	2132	CreateFile	C:\Windows\Prefetch\SETUP.EXE-9F1...	SUCCESS
14:06:...	setup.exe	2132	QueryStandardI...	C:\Windows\Prefetch\SETUP.EXE-9F1...	SUCCESS
14:06:...	setup.exe	2132	ReadFile	C:\Windows\Prefetch\SETUP.EXE-9F1...	SUCCESS
14:06:...	setup.exe	2132	CloseFile	C:\Windows\Prefetch\SETUP.EXE-9F1...	SUCCESS
14:06:...	setup.exe	2132	CreateFile	C:	SUCCESS
14:06:...	setup.exe	2132	QueryInformatio...	C:	SUCCESS
14:06:...	setup.exe	2132	FileSystemControl	C:	SUCCESS
14:06:...	setup.exe	2132	CreateFile	C:\Users	SUCCESS

Showing 2,011 of 99,439 events (2.0%) | Backed by page file

Registry

- Regedit
  - Windows built-in registry editor
- RegRipper
  - Extracts relevant forensic artifacts from registry
- Autoruns
  - Lists all programs set to start after system boot

Registry – What to look for

- Well-known locations
  - Autorun locations
  - Task scheduler
- Changes tracking
- Keywords fulltext search
  - Filenames
  - Processes
  - Domain names

ThreatExpert

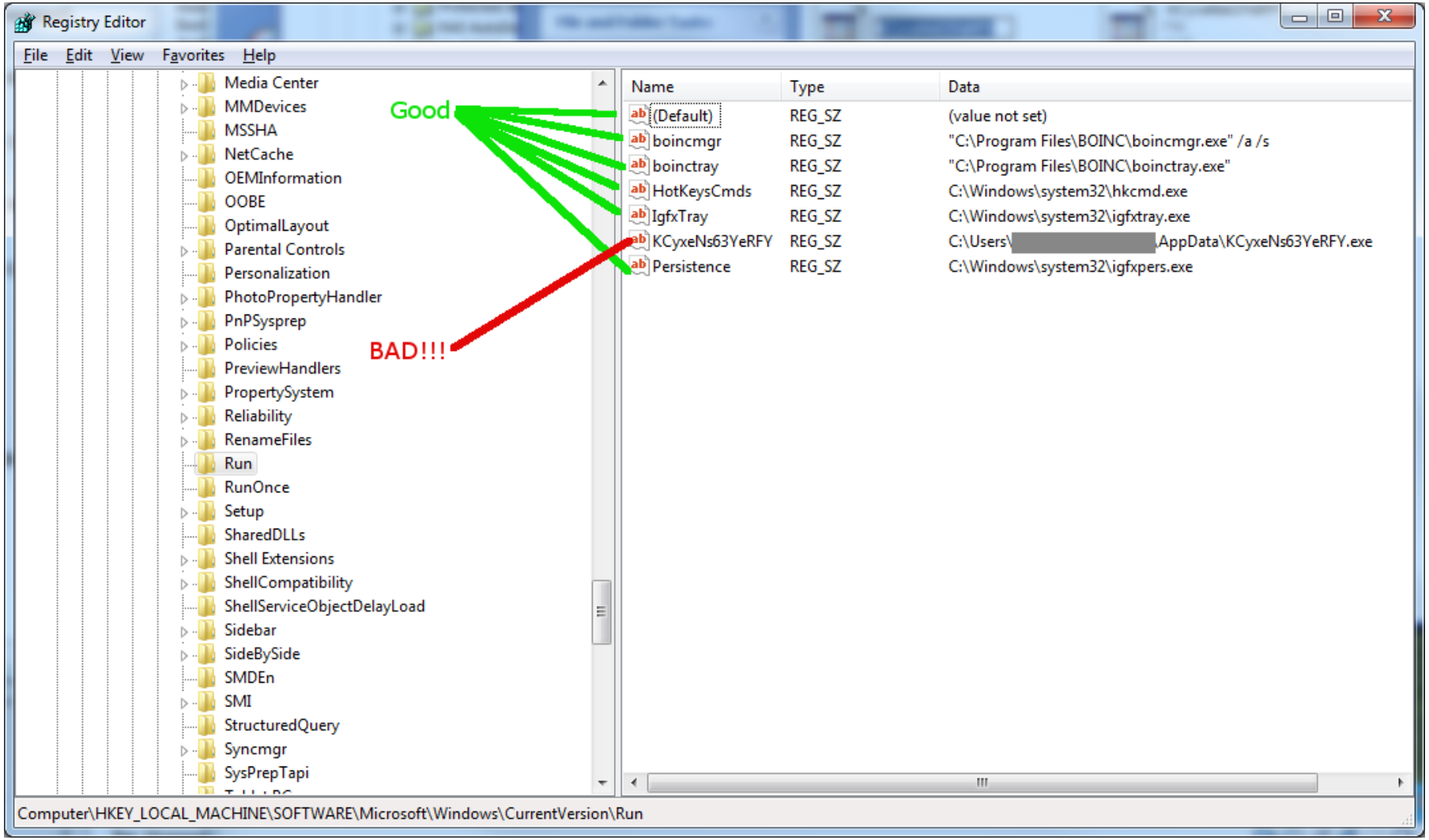
Submission Summary:

The newly created Registry Values are:

- [HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Security Center]
  - UacDisableNotify = 0x00000001
- [HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Security Center\Svc]
  - AntiVirusOverride = 0x00000001
  - AntiVirusDisableNotify = 0x00000001
  - FirewallDisableNotify = 0x00000001
  - FirewallOverride = 0x00000001
  - UpdatesDisableNotify = 0x00000001
  - UacDisableNotify = 0x00000001

to disable notification of firewall, antivirus and/or update status through the Windows Security Center

Registry – Regedit



Processes

- Observing initial system compromise
- Processes parent/child relationships
- Tools
  - Process Explorer, Procmon
- Indicators
  - Process names, order of execution, dropper activity
- Q&A
  - What processes are run after malware binary is executed? Are batch files involved? Are there watcher processes?

Processes – What to look for

- Order of executables
  - Initial malware
  - Dropper/downloader
  - Persistence executable
  - Final malware
- Command line interpreters
  - cmd.exe
  - **Powershell**
  - Cscript, wscript

Example – Process Explorer

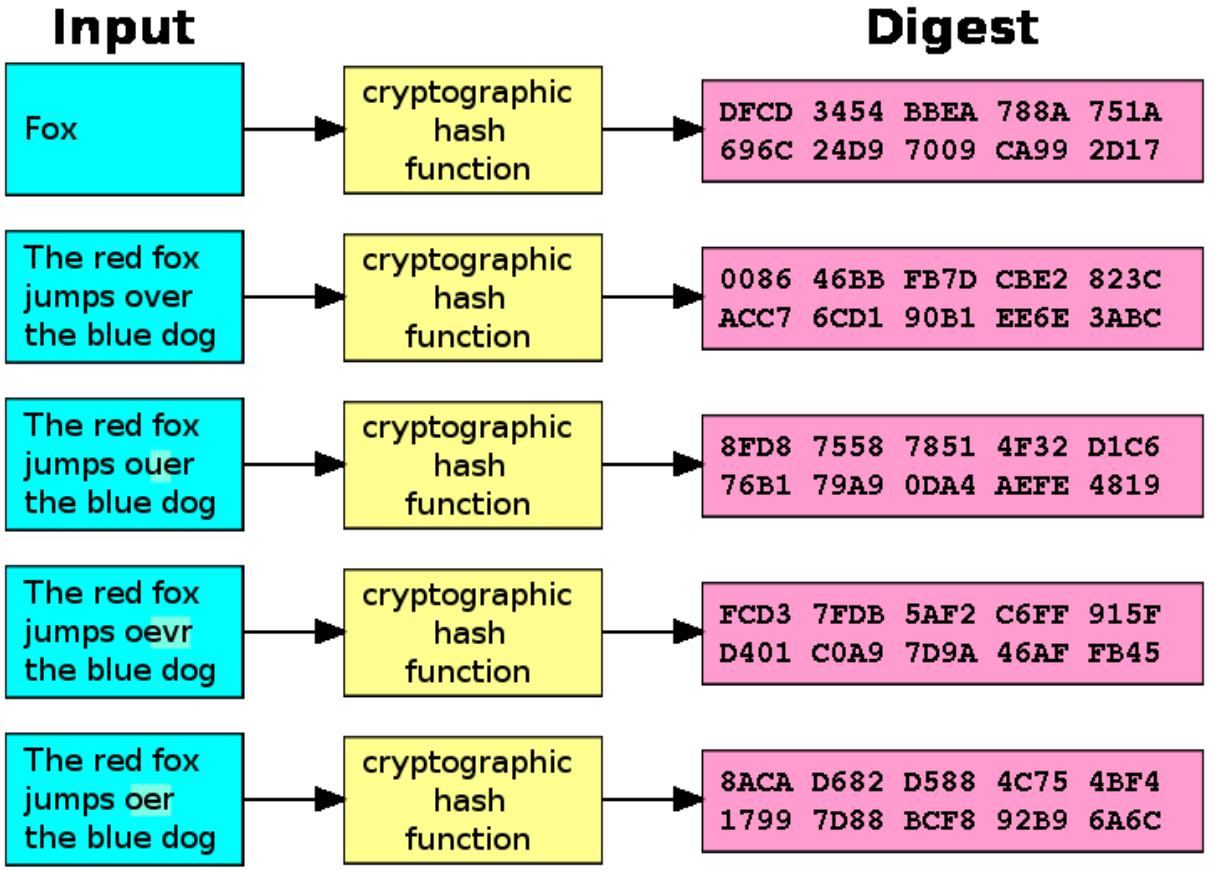
Process Explorer - Sysinternals: www.sysinternals.com

File Options View Process Find Users Help

Process	CPU	Working Set	Private Bytes	PID	Description	Company Name	VirusTotal
System Idle Process	97.65	24 K	0 K	0			
System	0.12	1 904 K	48 K	4			
Interrupts	0.48	0 K	0 K	n/a	Hardware Interrupts and DPCs		
smss.exe		876 K	316 K	328			The system canno...
csrss.exe	< 0.01	3 980 K	1 680 K	540			The system canno...
csrss.exe	0.02	15 620 K	2 248 K	608			The system canno...
wininit.exe		3 672 K	1 172 K	616			The system canno...
services.exe		8 816 K	5 716 K	664			The system canno...
svchost.exe		8 448 K	3 940 K	836	Host Process for Windows S...	Microsoft Corporation	0/55
WmiPrvSE.exe		6 020 K	2 472 K	3792			The system canno...
WmiPrvSE.exe		5 204 K	2 124 K	2456			The system canno...
nvvsvc.exe		6 340 K	2 436 K	900	NVIDIA Driver Helper Servic...	NVIDIA Corporation	0/53
NvXDSync.exe		15 328 K	6 028 K	1632			The system canno...
nvvsvc.exe	< 0.01	10 628 K	4 344 K	1660			The system canno...
svchost.exe		7 228 K	4 012 K	940	Host Process for Windows S...	Microsoft Corporation	0/55
svchost.exe		21 848 K	22 828 K	1036	Host Process for Windows S...	Microsoft Corporation	0/55
audiodg.exe		14 836 K	15 696 K	4832			The system canno...
svchost.exe	< 0.01	13 940 K	7 048 K	1072	Host Process for Windows S...	Microsoft Corporation	0/55
dwm.exe	0.18	34 232 K	31 748 K	2352	Desktop Window Manager	Microsoft Corporation	0/55
svchost.exe		11 328 K	6 320 K	1100	Host Process for Windows S...	Microsoft Corporation	0/55
svchost.exe	< 0.01	35 972 K	22 256 K	1144	Host Process for Windows S...	Microsoft Corporation	0/55

Executable file analysis

- Cryptographic hash
  - Hash function which is considered practically impossible to invert
  - Unique identification of file
  - Counter: Polymorphism
  - MD5, SHA1
- Fuzzy hash
  - Context triggered piecewise hash
  - Families of files
  - ssdeep
- Strings



Example – Strings

```
server.exe
AppData
4bcce4de98bcdb4d29f66c0fe1ffe002
hackerhani.no-ip.biz
Software\Microsoft\Windows\CurrentVersion\Run
Software\
yy-MM-dd
??-??-??
Microsoft
Windows
SystemDrive
netsh firewall delete allowedprogram "
Software
cmd.exe /c ping 0 -n 2 & del "
SEE_MASK_NOZONECHECKS
netsh firewall add allowedprogram "
```

Domain name

Persistence registry key

Commands to be executed

MD5: 5d347384ea978a96bc842ad9f29e95f2

Analysis

Black box analysis – indicator interpretation

- Network analysis – domain & IP verification, processes communicating
- Hash comparison
  - Collisions, same-hash files
- Behavior analysis
  - System processes, created processes, persistence
- File manipulation

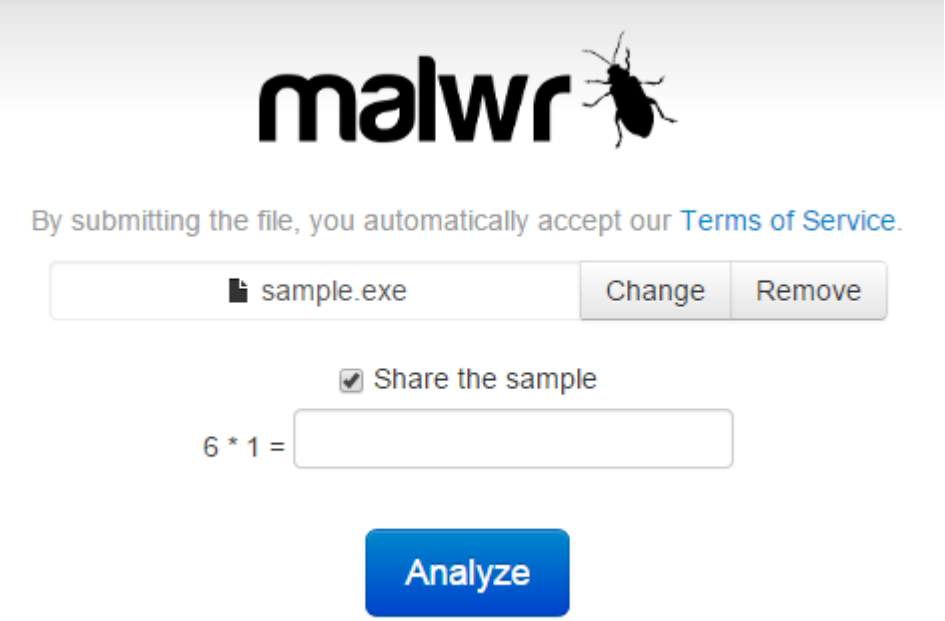
Document analysis – Quick insight

- EXIF information
- File metadata
- Document sandboxing
- Document interpretation ambiguity
- Practical examples
  - Double extensions, different content in different viewers, code block obfuscation & hiding

Automated sandbox analysis

Automated sandboxing

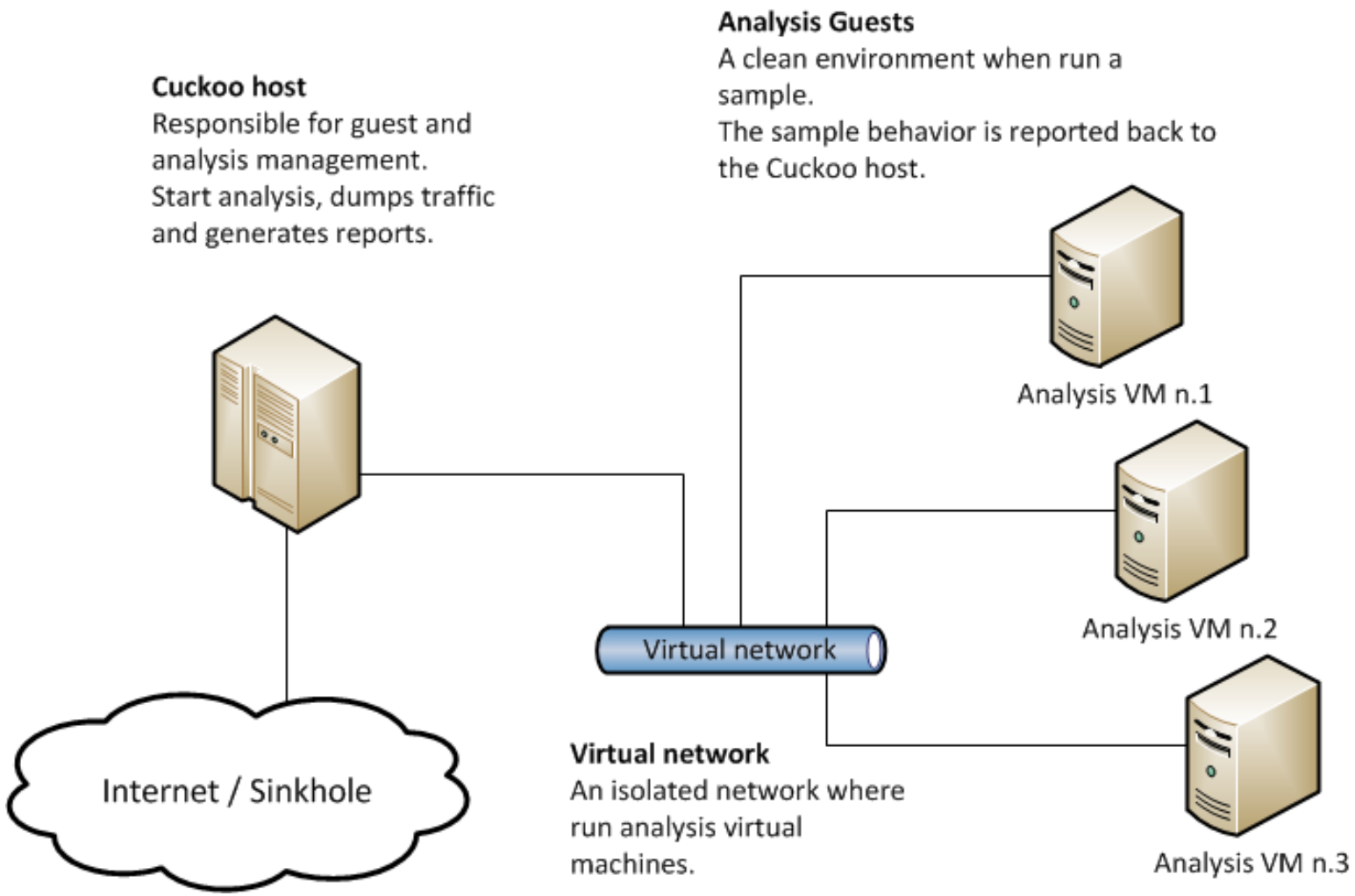
- Automated
  1. Execute malware in sandbox
  2. Wait a few seconds
  3. Receive summary report
  4. Investigate report
- Non-interactive
- Known tools
  - Cuckoo, Norman, Anubis etc.



Cuckoo sandbox

- Open source malware analysis system
- Can analyze
  - Windows executables, DLLs, PDF documents, URLs, HTML files, PHP scripts, Visual Basic scripts, ZIP archives, Python files, etc.
- Modular, scriptable
- Full memory dump (for Volatility Framework)
- Django web interface
- Mongo (NoSQL) database

Cuckoo – Architecture



Cuckoo – GUI

Info File Signatures Screenshots Static Dropped Network Behavior

Category	Started On	Completed On	Duration	Cuckoo Version
FILE	2013-05-09 20:47:13	2013-05-09 20:49:56	163 seconds	0.5

File Details file indicators

File name	7351eaee39eb672c00c1dbe1e525a9e0
File size	303104 bytes
File type	PE32 executable (GUI) Intel 80386 Mono/.Net assembly, for MS Windows
CRC32	D45DD4BC
MD5	7351eaee39eb672c00c1dbe1e525a9e0
SHA1	f5f06f53f270f1fd044da1da9eea5b59794bc346
SHA256	078ae46df0b431c7d423568495ee01caaf9d024aaf880061c739cfeb4dbf4490
SHA512	950a5e85b4f161578660179eb2afe95798edaebf1b2998702c1250fea613c3b95b9143e643994ebad67e08702ddab47a6accb4b25c9f2d7a3d19fa3ca1b8cbf7
Ssdeep	None
PEiD Signatures	None matched
Yara Signatures	
Antivirus Results	25/46 (collapse)

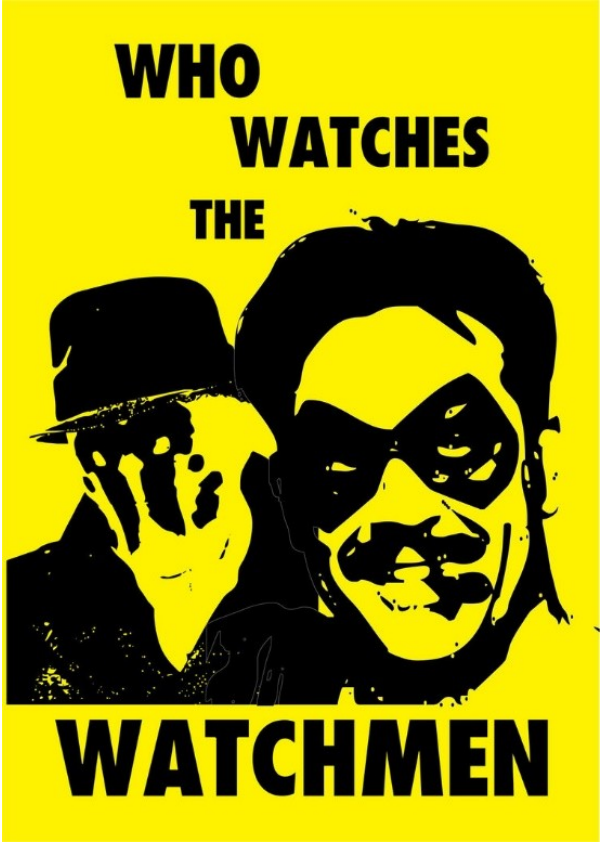
Internet sandbox services

- Public service
  - OpSEC issues
- Huge comparison database
- Exact match by hash
- Similarity search by keywords

- Malwr.com (public Cuckoo sandbox)
- VirusTotal.com
- ThreatExpert.com
- Hybrid-Analysis.com

Operational security (OpSec)

- Advanced attackers monitor victim's actions
  - Unique indicators visible on Google?
  - Attacker host monitoring for incoming traffic
  - Keywords search in mails, PDFs…
- Basics of OpSec
  - "Think before you act" mentality
  - Limited information sharing
  - Trace removal
- PassiveTotal.org



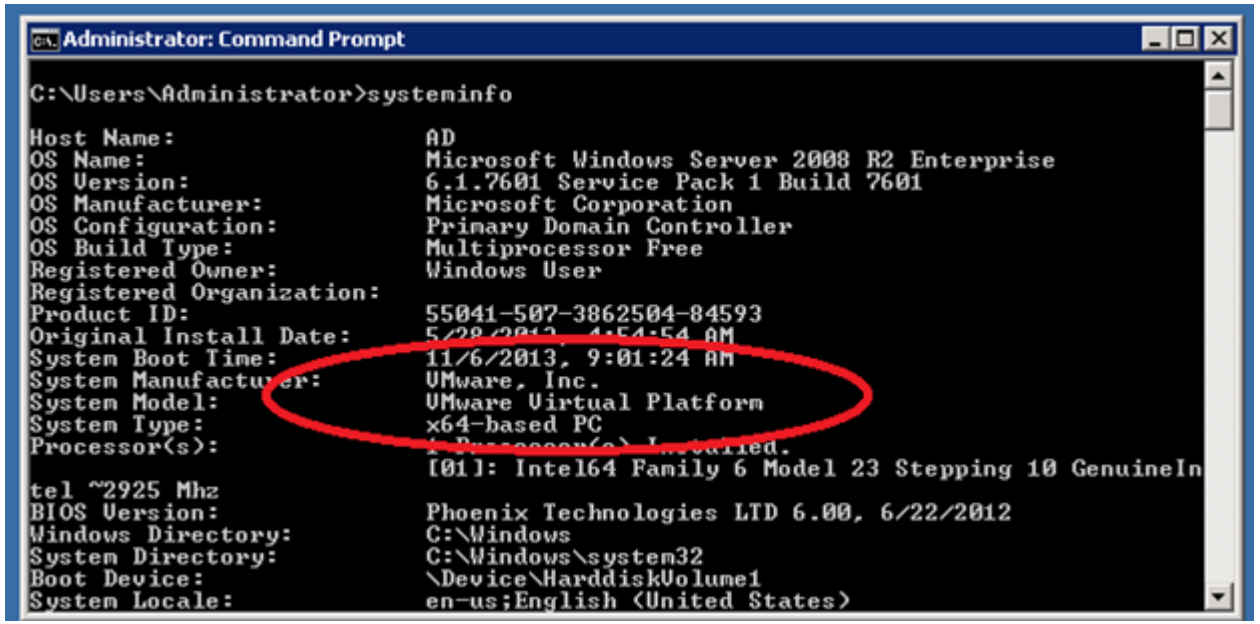
OpSec – Basic rules

- No ping
- No DNS lookup
- No accessing to suspicious domains
- No premature remediation steps (reboot, antivirus scan, OS reinstall)
- No upload of samples
- No indicator validation on external sources

- NOT EVEN through 3rd parties

Anti-sandbox techniques

- Continuous development – sandbox vs. anti-sandbox
- Malware inactive in analysis environment
- Tools presence detection (Wireshark, etc.)
- Virtualization detection
  - Registry (key existence, key value)
  - File system (file existence, drivers)
  - Processes (syscall response)
- Human presence detection
  - Mouse movement
  - Keyboard activity
  - File artefacts



Lab

Lab – Overview

- Hands-on experience of manual black-box analysis
- Guided analysis of selected malware samples
- Tools
  - Wireshark – Network activity
  - Process Monitor – File system activity, process creation
  - Autoruns – Persistence
  - Regshot – Registry changes
  - Process explorer – Process map

Lab – Samples

- 2-3 samples from different malware families
  - Commodity malware – Zeus, ZeroAccess, Generic Trojans,…
- Students will execute samples in virtual environment
  - Provided simple analysis virtual machine (Windows)
  - Indicators collected – network, files, persistence
  - Discussion about interpretation of facts
- Homework
  - 2 samples for analysis independently
  - Write a cohesive report and present key information to the reader