Northeastern University

International Secure Systems Lab

A Large-Scale, Automated Approach to Detecting Ransomware

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What is a ransomware attack?

1. **Paying the ransom fee**
2. **Receiving the decryption key**

A Typical Ransom Note

Attacks on Hospitals

Healthcare IT News

TOPICS SIGN UP MAIN MENU

Privacy & Security

Ransomware attackers collect ransom from Kansas hospital, don't unlock all the data, then demand more money

Kansas Heart Hospital declined to pay the second ransom, saying that would not be wise. Security experts, meanwhile, are warning that ransomware attacks will only get worse.

By Bill Siwicki | May 23, 2016 | 02:58 PM

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Kansas Heart Hospital in Wichita paid the initial ransom but decided against paying the second request even though some of its data appears to still be locked.

Kansas Heart Hospital was the victim of a ransomware attack and after it paid the first one, attackers boldly demanded a second ransom to decrypt data.

Kansas Heart Hospital president Greg Duick, MD told local media that patient

University Pays $16,000 to Stop Ransomware Attack JUNE 8, 2016

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TECH CHANGING FACE OF SECURITY

University Pays $16,000 to Stop Ransomware Attack

by Jeff John Roberts @jeffjohnroberts JUNE 8, 2016, 1:29 PM EDT

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Police pay ransom after cyberterror attack on network

Story | Comments (1) | Print | Font Size:

Thomas Murphy, Daniel Sawicki and Lt. Scott Keddie

Posted: Saturday, April 4, 2015 10:27 am

By Jayne W. Miller News Editor
Jayne@YourTownCrier.com | 1 comment

Chief: "Paying ransom was the last resort"

TEWKSBURY – Last December Tewksbury Police confronted a new, and growing, frontier in cyberterrorism when the CryptoLocker ransomware virus infected the department's network, encrypting essential department files until the town paid a $500 bitcoin ransom. In total, police systems were down between four and five days as the department worked with the FBI, Homeland Security, Massachusetts State Police, as well as private firms in an effort to restore their data without paying the ransom.

New estimates from the FBI show that the costs from so-called ransomware have reached an all-time high.

"Cyber-criminals collected $209 million in the first three months of 2016 by extorting businesses and institutions to unlock computer servers."

– CNN Interview with FBI, April 2016

How to defend against ransomware attacks?

- Educating end-users
  - Have a reliable *backup* policy
  - Avoid risky online behavior
- Developing *detection* tools to assist defenders
  - Providing insight from *internal* behavior
- Developing *protection* tools to enhance AV capabilities
  - Stopping the attack, and keeping the data consistent

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Threat Model

- Ransomware can employ any techniques to attack
  - Inject code into benign processes
  - Perform encrypted communication
  - Leverage arbitrary cryptosystems
- We assume that OS kernel, and underlying software and hardware stack are free of malicious code.
- Unveil detects ransomware during *dynamic analysis phase,* and *not* at end-user machines.
  - Complements current dynamic analysis systems
  - A cloud-based malware analysis service, sample sharing

But, how can we detect a ransomware sample?

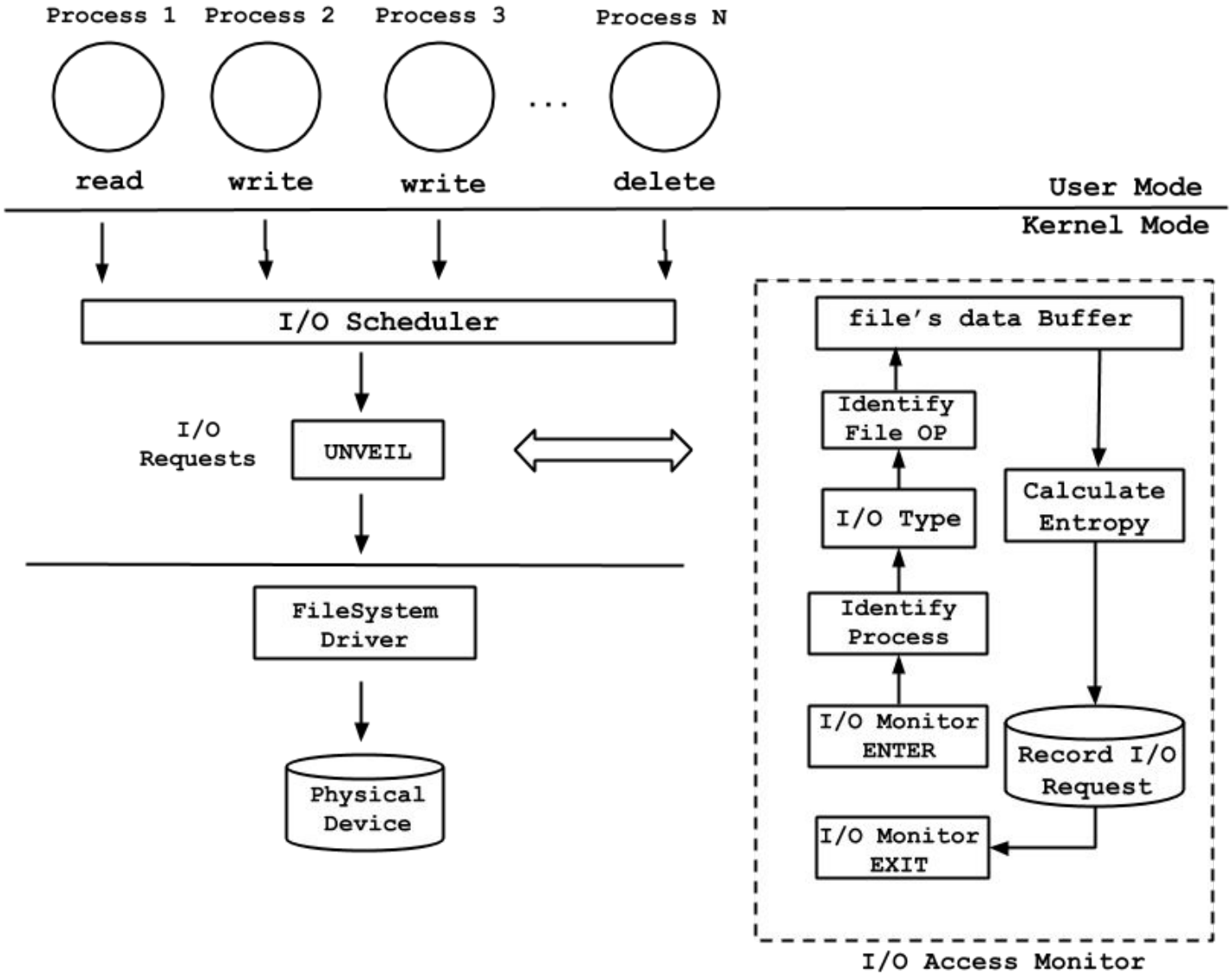
Achilles' Heel of Ransomware

- Ransomware *has to inform* victim that attack has taken place

- Ransomware has certain behaviors that are predictable
  - e.g., entropy changes, modal dialogs and background activity, accessing user files
- A good sandbox that looks for some of these signs helps here…

UNVEIL: An Early Warning Dynamic Detection System for Ransomware

UNVEIL's Architecture



Approach

- Detecting Cryptographic Ransomware:
  - Generating a fake (and attractive) user environment
  - Finding a reliable method for monitoring filesystem activity

Why do we generate fake user environments?

- Making the analysis environment more realistic
- Protecting the analysis system from some user environment fingerprinting
  - A static user environment can be *easily* detected by a malware

Approach

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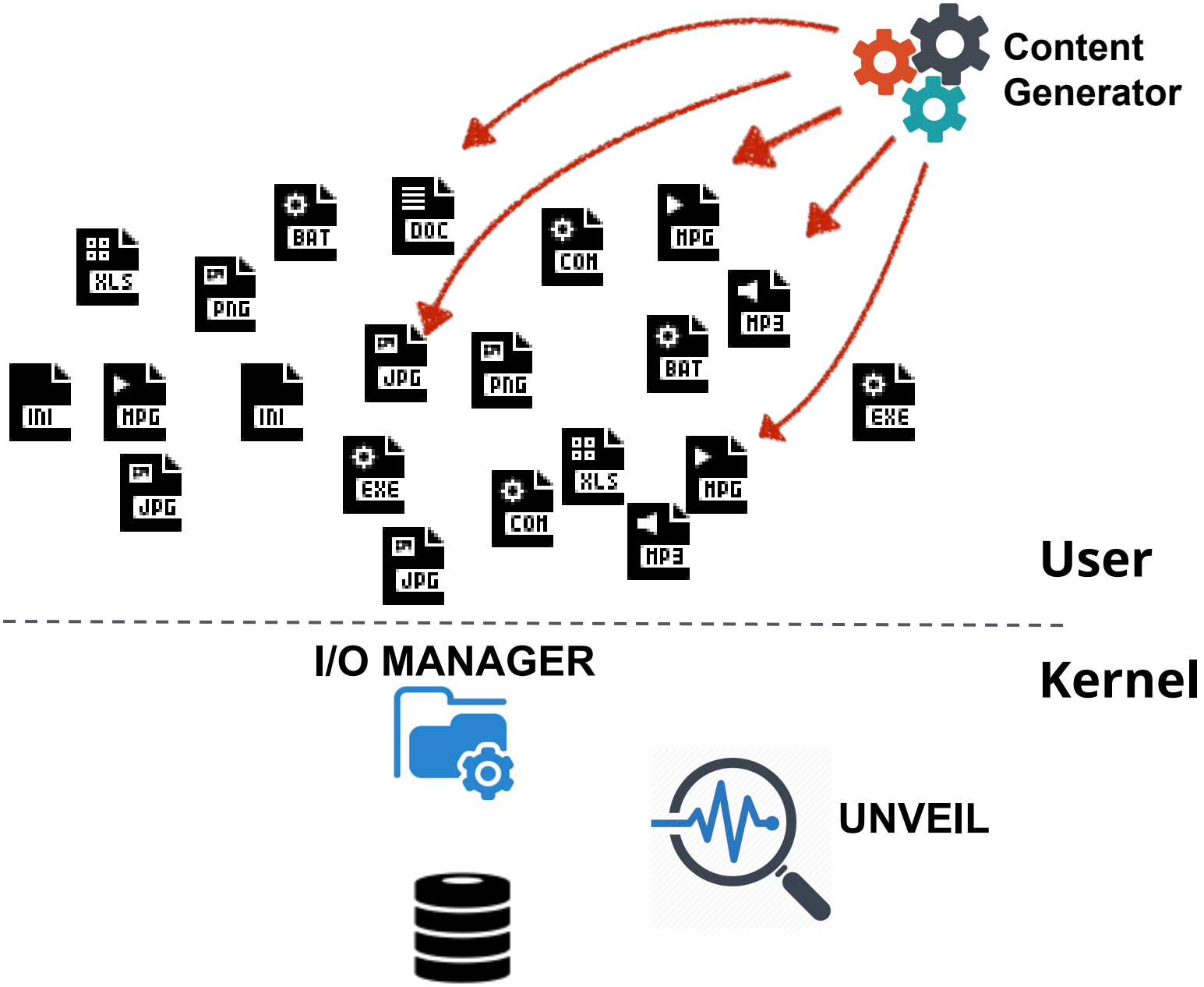
Why do we generate fake user environments?

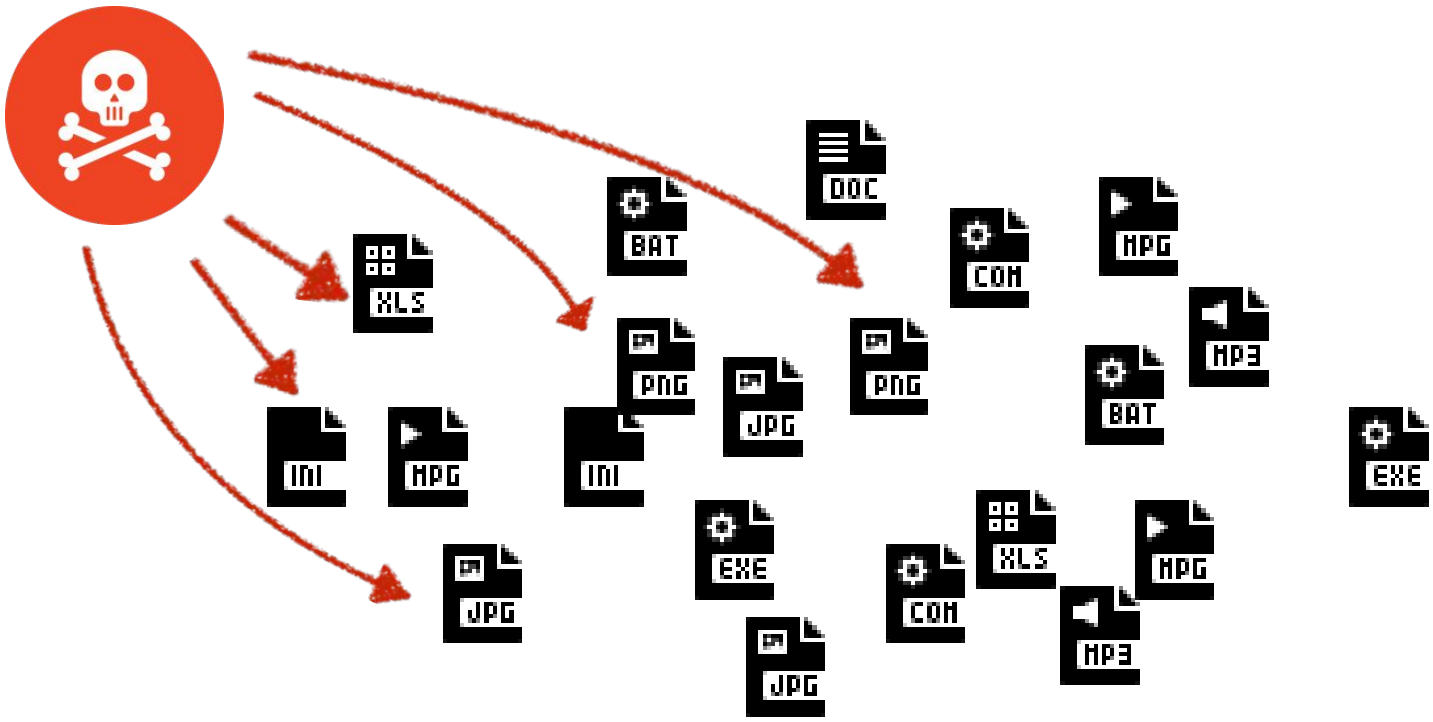
- Making the analysis environment more realistic
- Protecting the analysis system from bare-user environment fingerprinting
  - A static user environment can be *easily* detected by a malware

How do we generate fake user environments?

Generating Fake (Honey) Content

- Real files with valid headers
  - Using standard libraries (e.g., *python- docx, python-pptx, OpenSSL*)
  - Content that appears meaningful
  - File names do not look random, and appear realistic
- File paths
  - User's directory structure is generated randomly, but meaningfully
- File attributes
  - Generate content with different creation, modification, and access times


Content Generator
XLS
PNG
BAT
DOC
COM
MPG
MP3
INI
MPG
INI
JPG
PNG
BAT
EXE
JPG
EXE
COM
XLS
MPG
MP3
JPG
User
I/O MANAGER
Kernel
UNVEIL



User

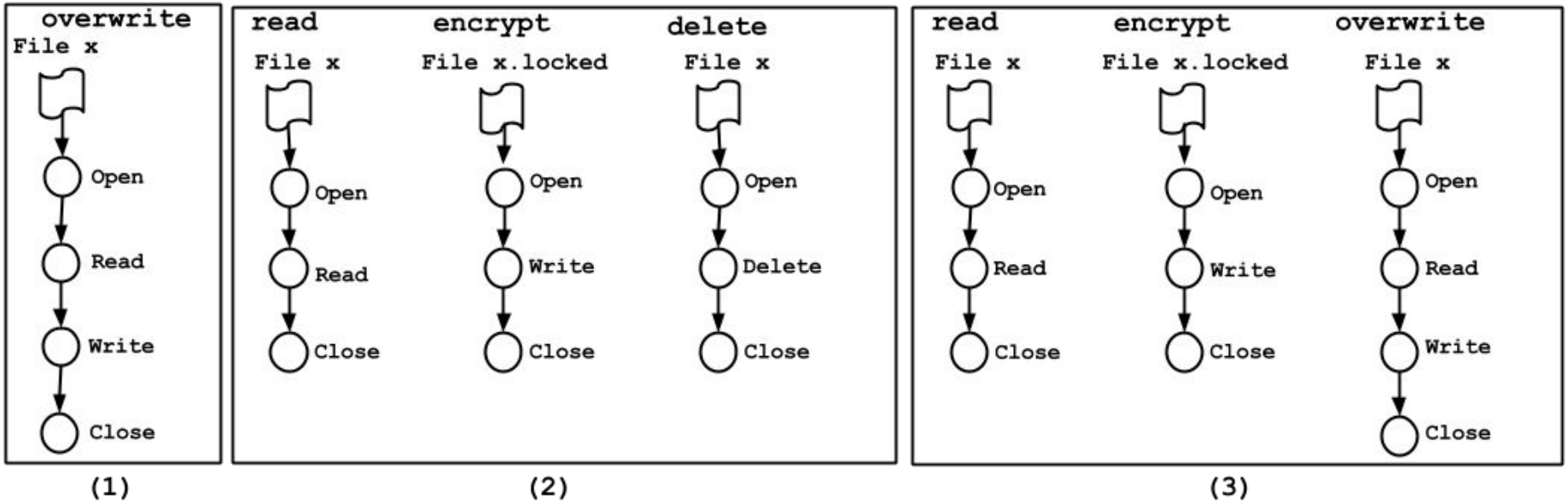
Kernel

I/O MANAGER

UNVEIL

$$R_{fs} = \langle Time, P_{name}, P_{id}, PP_{id}, IRP_{flag}, Arg, Result, Buf_{Entropy} \rangle$$

Extracting I/O Access Sequences



(1) Overwrites the users' file with an encrypted version

(2) reads, encrypts and deletes files without wiping them from storage

(3) reads, creates a new encrypted version, and securely deletes the original files

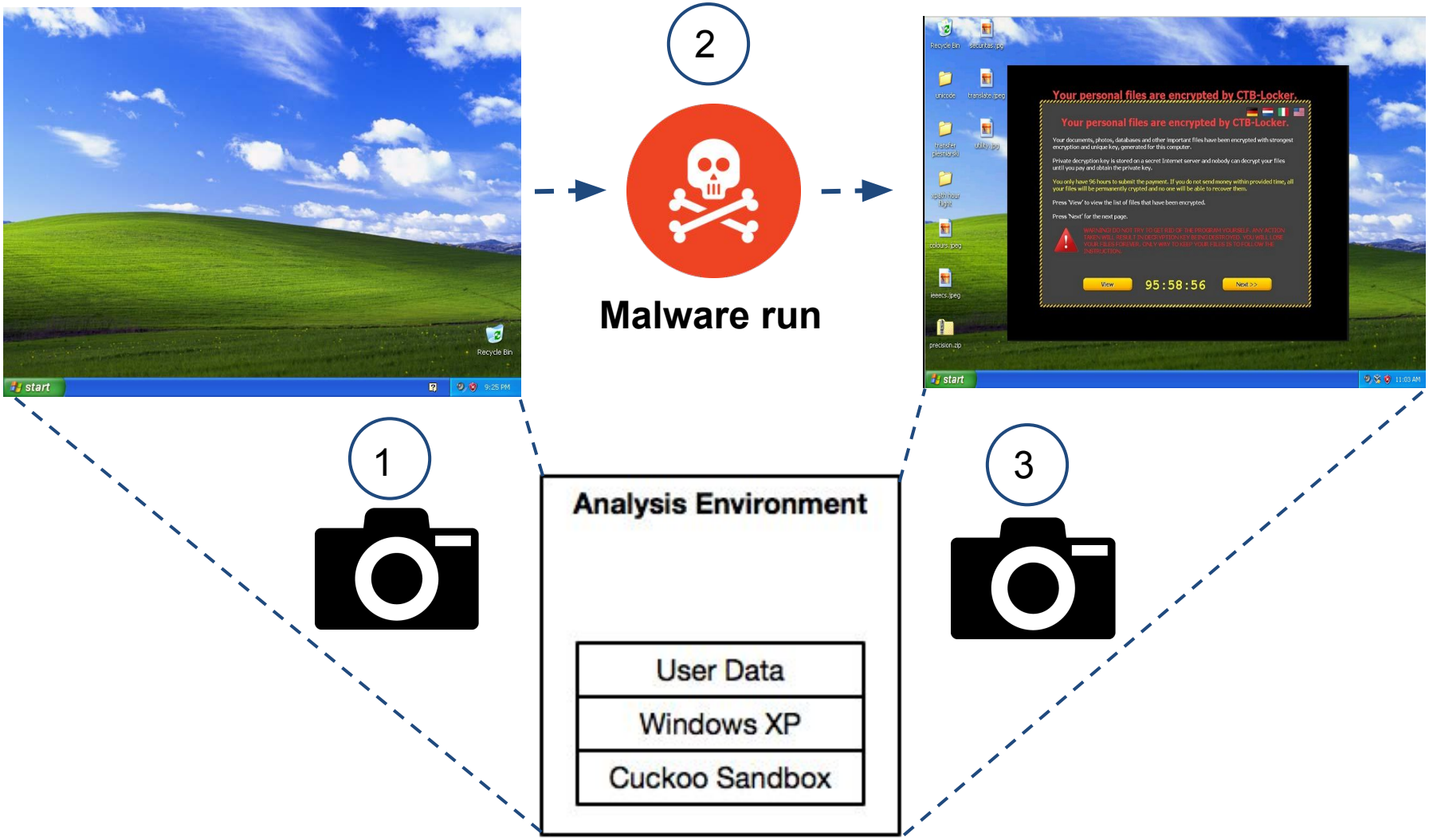
IO Access Sequences in Multiple Ransomware Families

Ransomware Family	IRP Operation	Process	Filename	File Offset	Entropy	Description
CryptoWall	IRP_MJ_CREATE	explorer.exe	honeyfile.doc			Read, write
Read →	IRP_MJ_READ	explorer.exe	honeyfile.doc	[0, 4096)	4.21	
Write →	IRP_MJ_WRITE	explorer.exe	honeyfile.doc	[0, 4096)	7.11	
	...					
	IRP_MJ_CLEANUP	explorer.exe	honeyfile.doc			
	IRP_MJ_CLOSE	explorer.exe	honeyfile.doc			
FileCoder	IRP_MJ_CREATE	svchost.exe	honeyfile.doc			Read
New File →	IRP_MJ_CREATE	svchost.exe	honeyfile.doc.crypt			Read, write
	IRP_MJ_READ	svchost.exe	honeyfile.doc	[0, 4096)	4.21	
Encrypted version →	IRP_MJ_WRITE	svchost.exe	honeyfile.doc.crypt	[0, 4096)	7.02	
	...					
	IRP_MJ_CLEANUP	svchost.exe	honeyfile.doc			
	IRP_MJ_CLOSE	svchost.exe	honeyfile.doc			
Deleting the Original File →	IRP_MJ_CREATE	svchost.exe	honeyfile.doc			Read attributes, delete
	IRP_MJ_SET_INFORMATION	svchost.exe	honeyfile.doc			
	IRP_MJ_CLEANUP	svchost.exe	honeyfile.doc			
	IRP_MJ_CLOSE	svchost.exe	honeyfile.doc			
	IRP_MJ_CLOSE	svchost.exe	honeyfile.doc.crypt			
CrypVault	IRP_MJ_CREATE	explorer.exe	balance.doc			Read
New File →	IRP_MJ_CREATE	explorer.exe	balance.doc.vault			Read, write
	IRP_MJ_READ	explorer.exe	balance.doc	[0, 41014)	4.33	
Encrypted version →	IRP_MJ_WRITE	explorer.exe	balance.doc.vault	[0, 41014)	7.14	
	...					
	IRP_MJ_CLEANUP	explorer.exe	balance.doc			
	IRP_MJ_CLOSE	explorer.exe	balance.doc			
	IRP_MJ_CREATE	explorer.exe	balance.doc			Write
Secure Deletion →	IRP_MJ_WRITE	explorer.exe	balance.doc	[0, 4096)	4.02	
	IRP_MJ_WRITE	explorer.exe	balance.doc	[4096, 8192)	4.02	
	...					
	IRP_MJ_CLOSE	explorer.exe	balance.doc.vault			
	IRP_MJ_SET_CREATE	explorer.exe	balance.doc			Read attributes, delete
	IRP_MJ_SET_INFORMATION	explorer.exe	balance.doc			

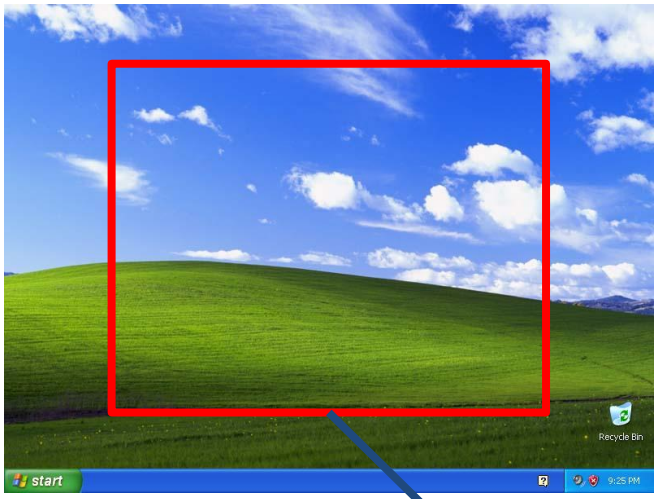
Iteration over files during a CryptoWall attack

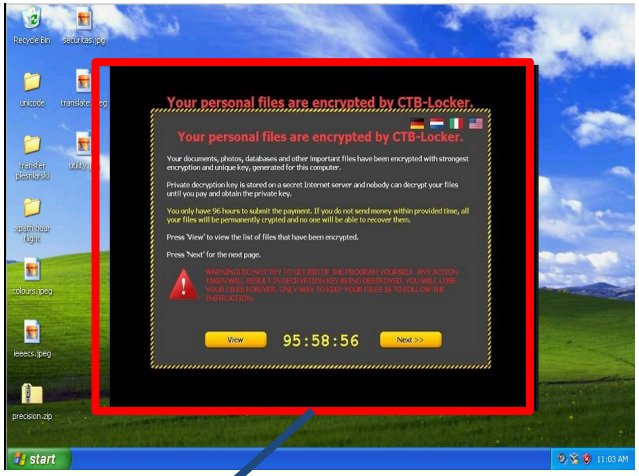
File	Operation	Process	Entropy
midterm_paper.docx	IRP_MJ_CREATE	svchost.exe	—
midterm_paper.docx	IRP_MJ_READ	svchost.exe	4.01
midterm_paper.docx	IRP_MJ_WRITE	svchost.exe	7.28
	...		
midterm_paper.docx	IRP_MJ_CLEANUP	svchost.exe	—
midterm_paper.docx	IRP_MJ_CLOSE	svchost.exe	—
myweddingparty.mpeg	IRP_MJ_CREATE	svchost.exe	—
myweddingparty.mpeg	IRP_MJ_READ	svchost.exe	5.14
myweddingparty.mpeg	IRP_MJ_WRITE	svchost.exe	7.24
	...		
myweddingparty.mpeg	IRP_MJ_CLEANUP	svchost.exe	—
myweddingparty.mpeg	IRP_MJ_CLOSE	svchost.exe	—

Desktop Locker Ransomware



Desktop Locker Ransomware





Dissimilarity Score

Preparing the Analysis Environment

- UNVEIL is deployed on top of Cuckoo Sandbox
  - UNVEIL supports all versions of Windows platforms.
  - Our tool is deployed in Kernel.
  - Bypassing UNVEIL is not technically easy in user-mode.
- Finding active malware is not easy
  - We modified some parts of Cuckoo to make it more resilient to environmentally sensitive samples
    - e.g., fake response to some of the environment checks
  - Other anti-evasion measures to look more realistic
    - e.g., defining multiple NTFS drives, changing IP address range and MAC addresses

Evaluation

1) Detecting known ransomware samples

a) Collecting ~3500 ransomware from public repo, Anubis, two security companies.
b) 149 benign executables including ransomware-like behavior
c) 348 malware samples from 36 malware families

Benign Applications

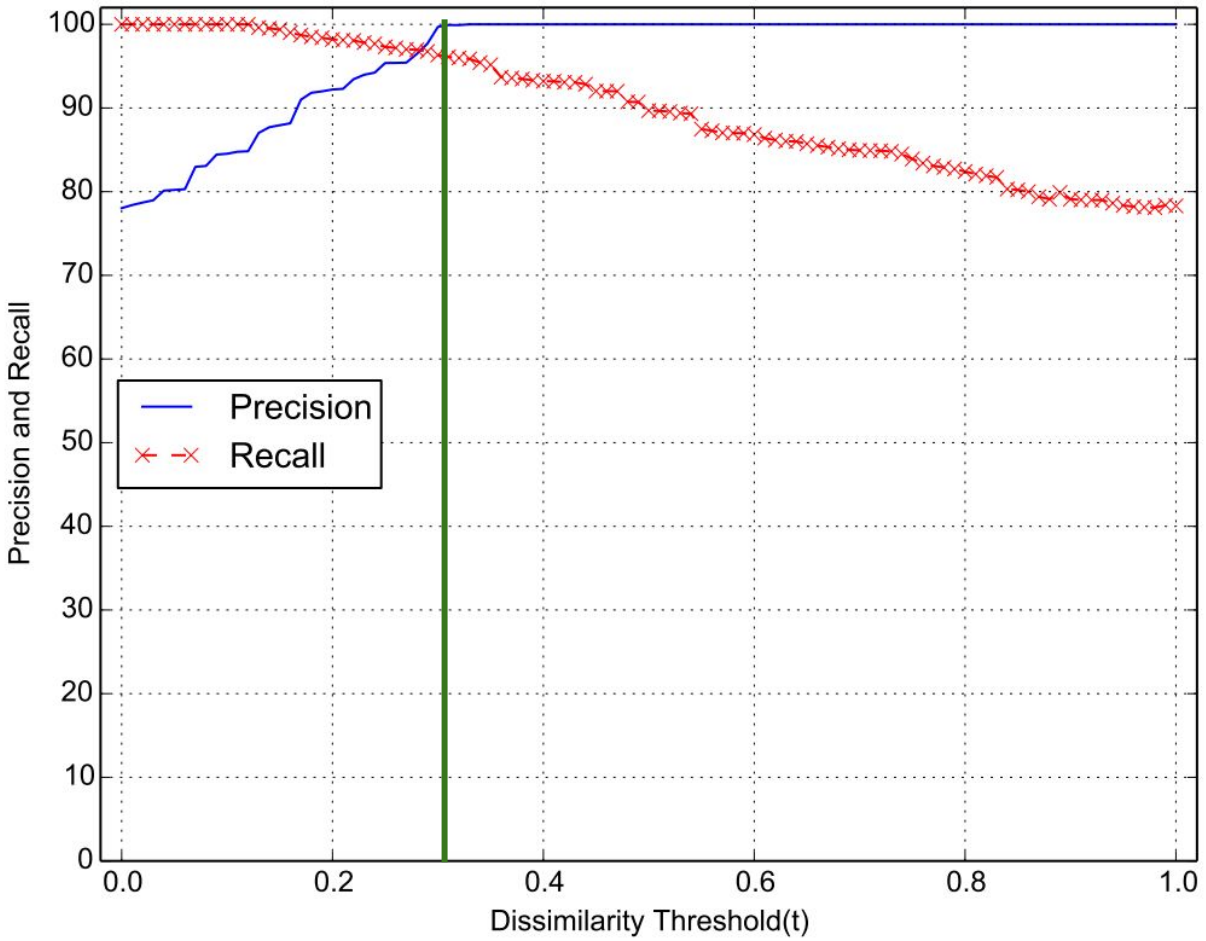
Application	Main Capability	Version
7-zip	Compression	15.06
Winzip	Compression	19.5
WinRAR	Compression	5.21
DiskCryptor	Encryption	1.1.846.118
AESCrypt	Encryption	—
Eraser	Shredder	6.2.0.2969
SDelete	Shredder	1.61

Ransomware Families

Family	Samples
Cryptolocker	33 (1.7%)
CryptoWall	42 (2.2%)
CTB-Locker	77 (4.0%)
CrypVault	21 (1.1%)
Filecoder	19 (1.0%)
Reveton	501 (26.03%)
Tobfy	357 (18.6%)
Urausy	877 (45.6%)
Total Samples	**1,926**

Dissimilarity score is different from family to family

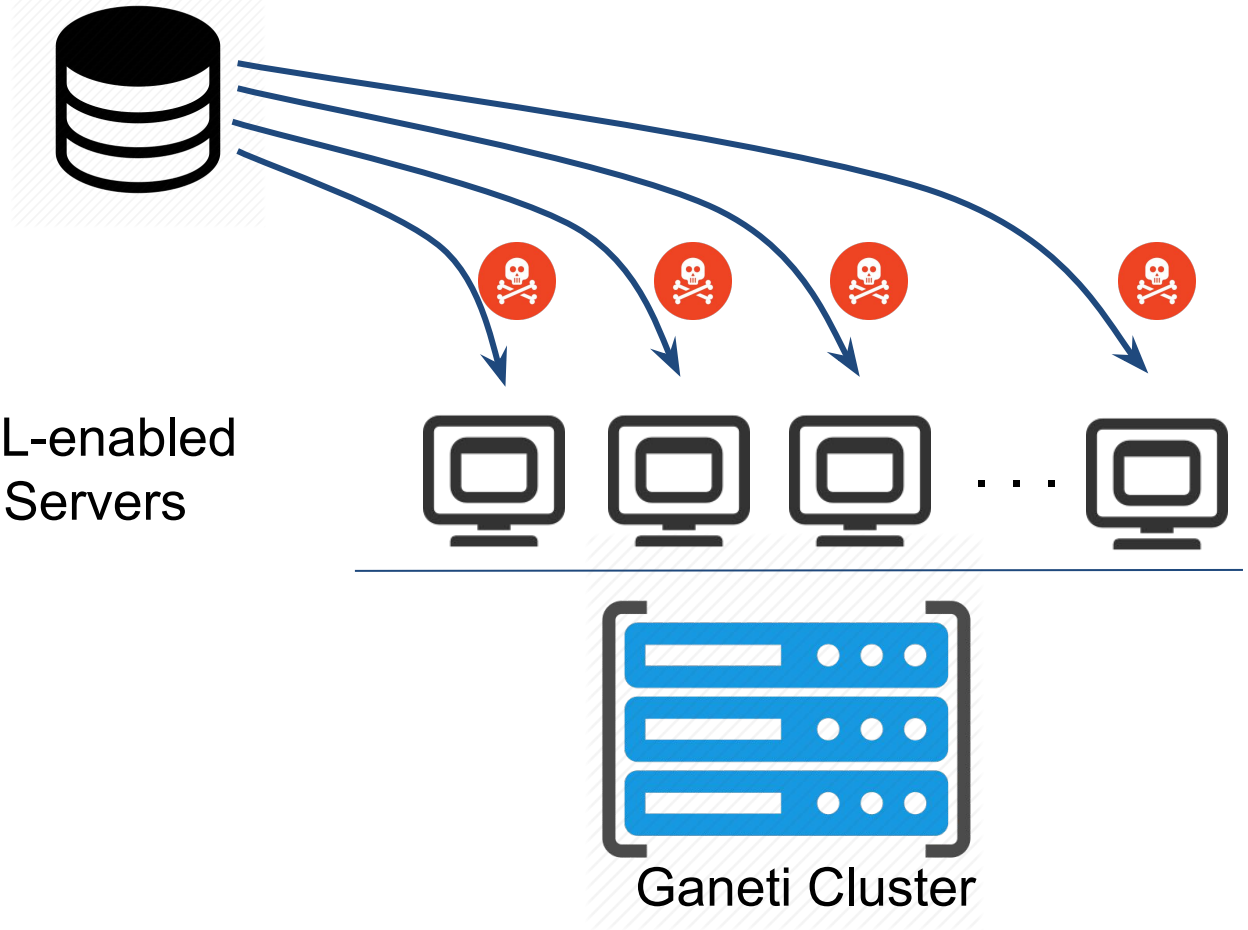
Detecting known ransomware samples



The threshold value t = 0.32 gives the highest recall with 100% precision

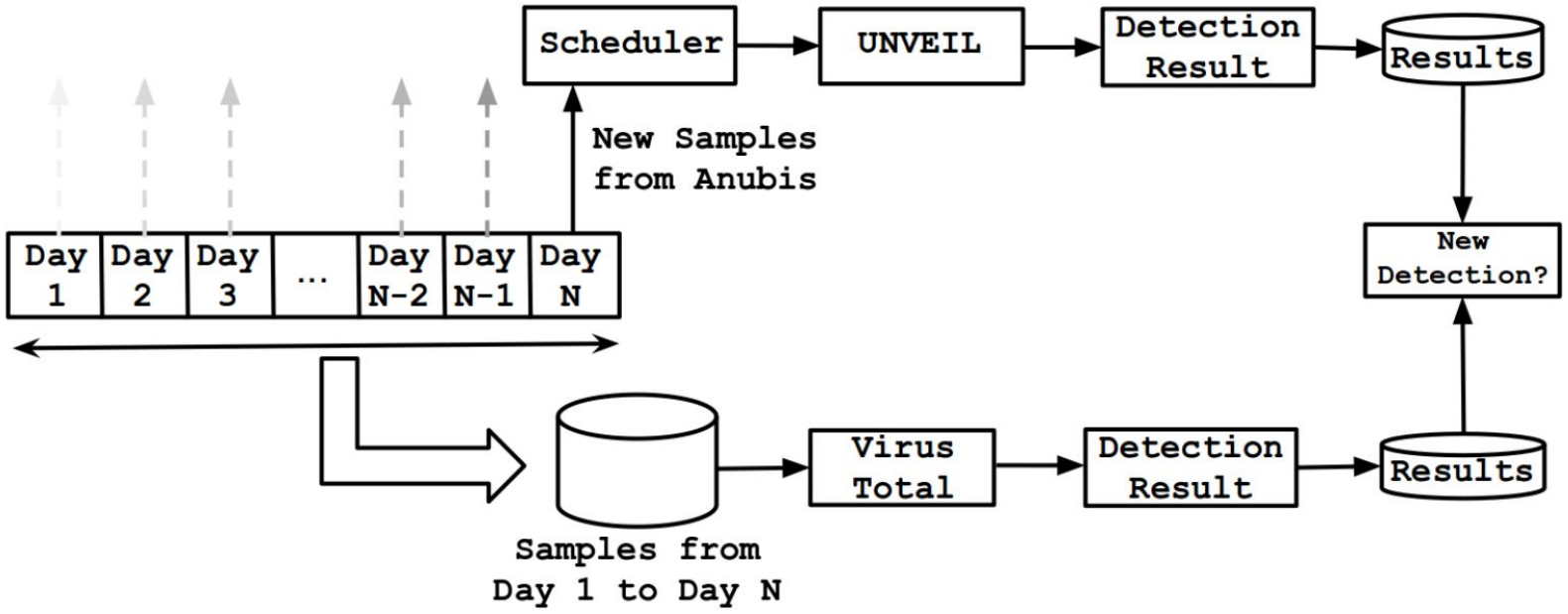
Evaluation UNVEIL with unknown samples

~ 1200 malware samples per day

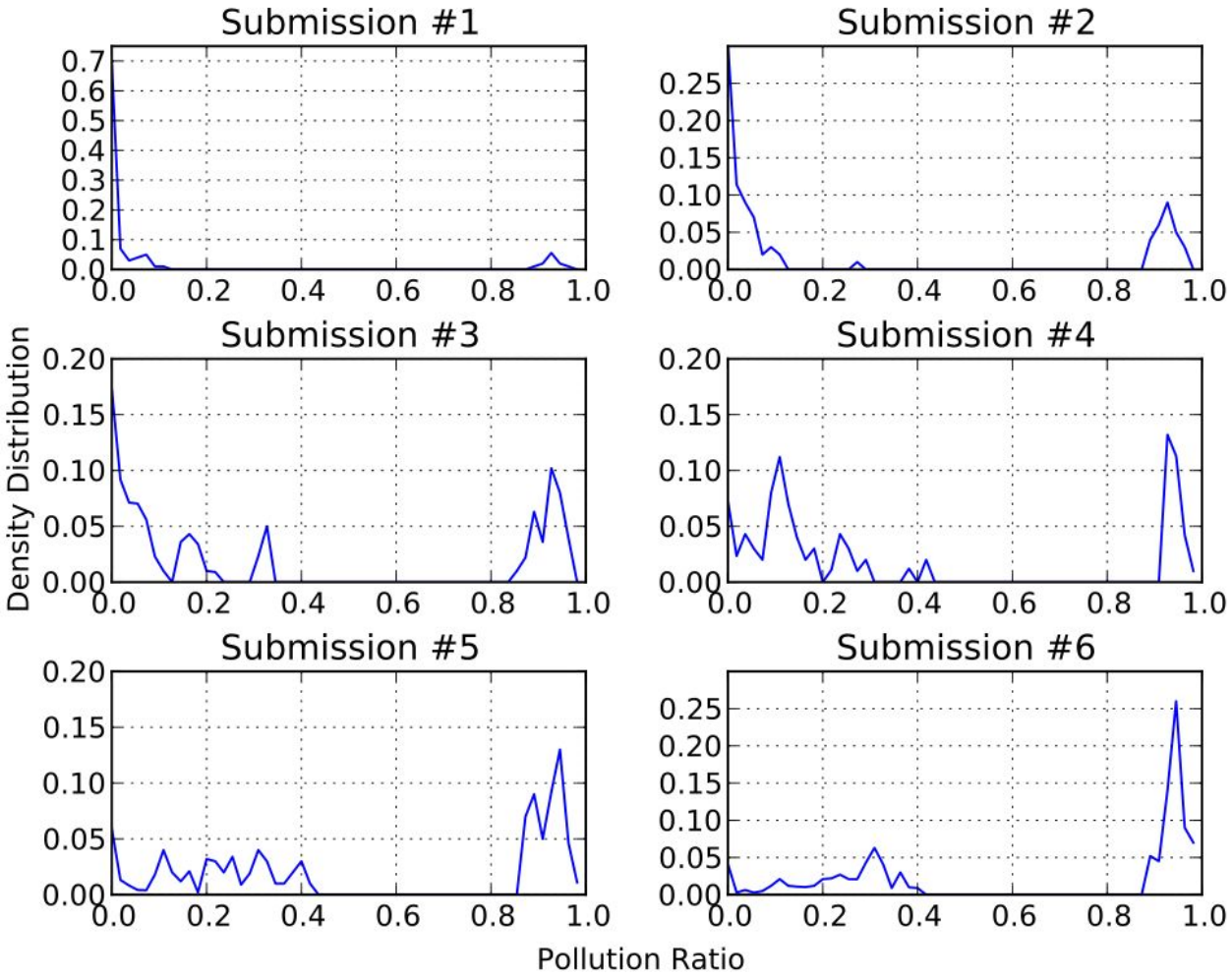


Evaluation UNVEIL with unknown samples

- We used the same similarity threshold (t = 0.32) for the large scale experiment.
- The incoming samples were acquired from the daily malware feed provided by Anubis from March 18 to February 12, 2016.
- The dataset contained 148,223 distinct samples.



Cross-checking with VirusTotal

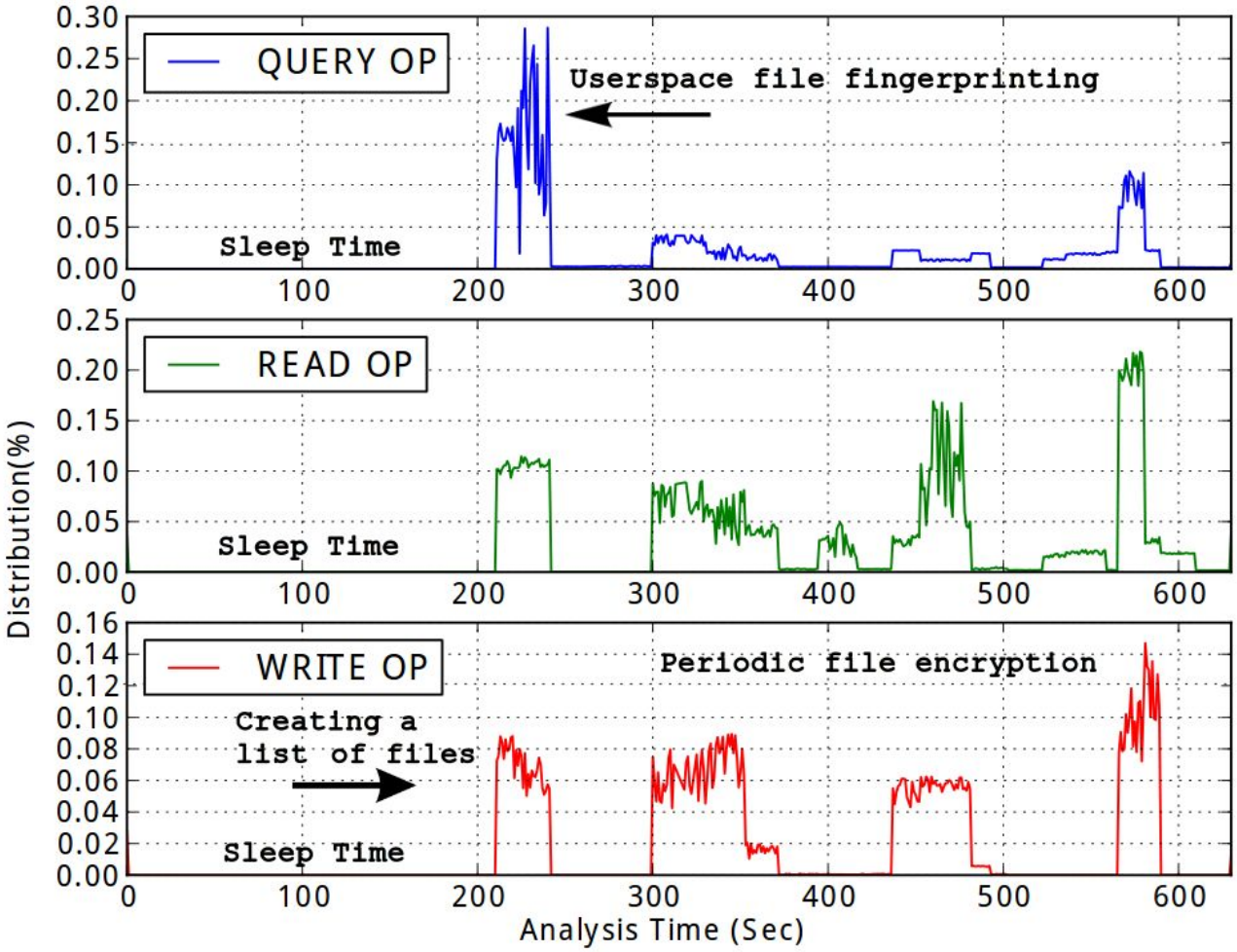


- Pollution ratio is defined as the ratio of the number of scanners that identified the sample to the number of scanners in VirusTotal

Detection Results

Evaluation	Results
Total Samples	148,223
Detected Ransomware	13,637 (9.2%)
Detection Rate	96.3%
False Positives	0.0%
New Detection	9,872 (72.2%)

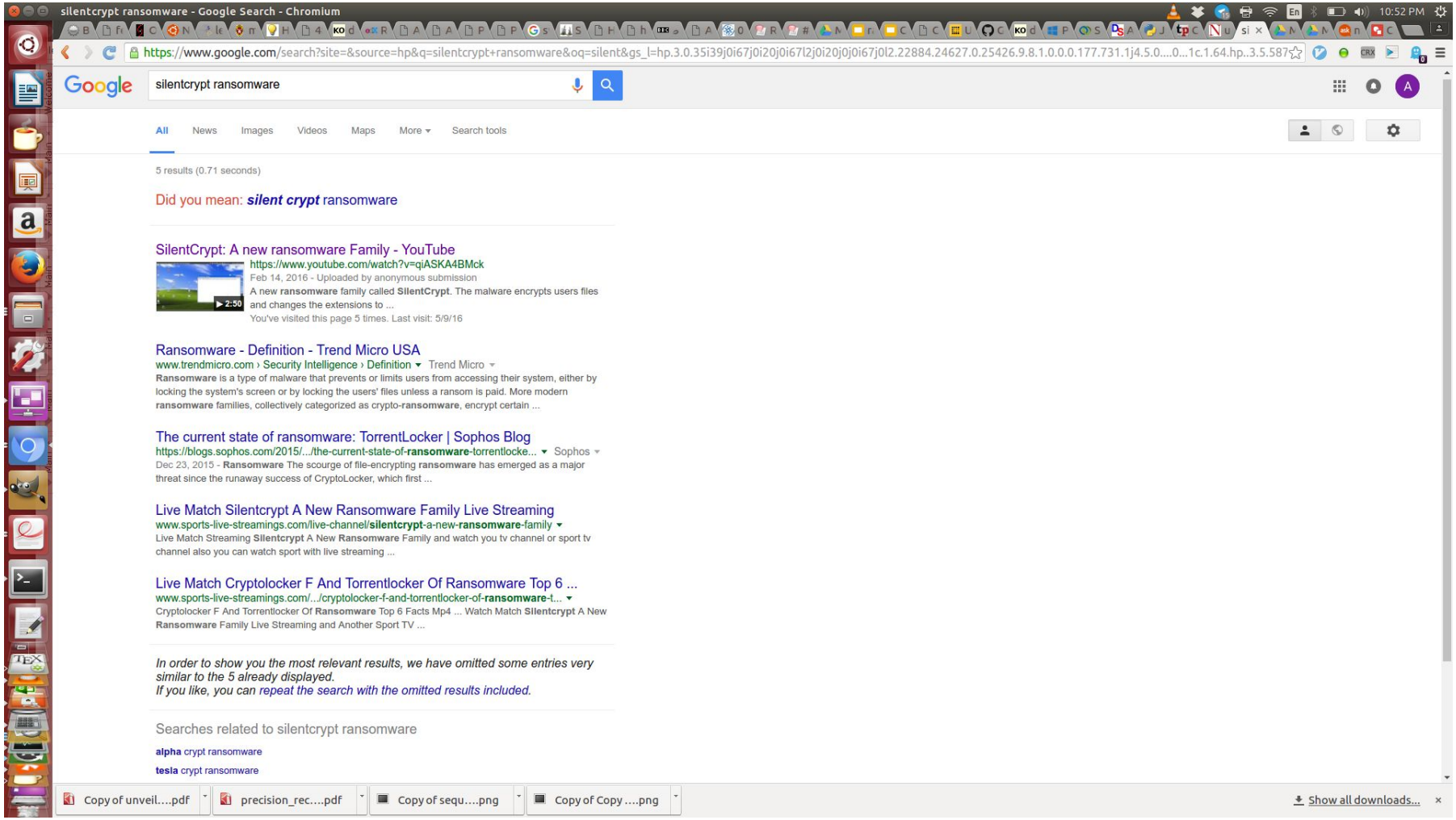
Detection: New Ransomware Family



Detection: New Ransomware Family

- During our experiments, we discovered a new malware family
  - We call it “SilentCrypt”
  - After we reported it, others started detecting it as well
  - We were not able to find any information about this family online
  - The ransomware first checks for private files of a user, contacts the C&C server, and starts the attack based on the answer

Detection: New Ransomware Family



Conclusion

- Ransomware is a serious threat
- UNVEIL introduces concrete models to detect Ransomware
- Detecting an unknown family shows that the solutions are useful in practice
- We continue to improve functionality tuned towards detecting ransomware

Thank You