UNIVERSITY OF MARYLAND

When malware changed its mind: An Empirical Study of Variable Program Behaviors in the Real World

Erin Avllazagaj *Ziyun Zhu* *Leyla Bilge* *Davide Balzarotti* *Tudor Dumitraş*

EURECOM

albocode@umd.edu
@albocoder

Intro: Malware behavior variability

Example: Ramnit worm
Exploits CVE-2013-3660
Only on vulnerable Windows 7, not running in admin mode

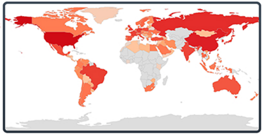
Makes ~100 mutexes creation calls

Dataset

Passive recording of:
26K suspicious programs

7.6M execution traces
5.6M real users' machines
113 countries

All the year of **2018**



Action type	File name	File path	...	Sample Hash	Execution id	Machine id
File Create	setup.exe	CSIDL_PROFILE	...	AAA	1	abc
Mutex Create	mtxlasjkf	-	...	ABC	5243523	abd
--	--	--	--	--	--	--

(Split the data by sample hash)

Action type	File name	File path	...	Sample Hash	Exec.id	Mach.id
File Create	setup.exe	CSIDL_PROFILE	...	AAA	1	abc
--	--	--	--	AAA	--	abc
--	--	---	--	AAA	--	cde

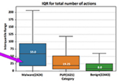
Action type	File name	File path	...	sample Hash	Execution id	Machine id
Mtx. Create	mtxlasjkf	-	...	ABC	5243523	abd
--	--	--	--	ABC	5243523	abd
--	--	--	--	ABC	23	efg

Classify the 26K suspicious programs using VirusTotal labels and AVClass:
- 22K benign samples ~6M executions
- 2.4K malware samples ~900K executions
- 1.6K PUP samples ~700K executions

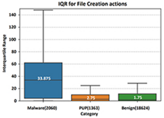
Measuring cross-machine variability

Action type	File name	File path	...	Sample Hash	Exec.id	Mach.id
File Create	setup.exe	CSIDL_PROFILE	...	AAA	1	abc
--	--	--	--	AAA	--	abc
--	--	---	--	AAA	--	cde

Counting	10 exec / 2 exec	5 exec / 3 exec	1 exec / 1 exec	6 exec / 1 exec	1 exec / 0
Total actions:	26	30	25	90	=> IQR = 4
File Creations:	10	10	6	25	=> IQR = 0
Mutex Creations:	3	1	3	4	=> IQR = 0
...	...	...	...	...	



>**50%** of the **malware** have **59** missing/additional actions across all the machines in the first week of their appearance



File Creation is the **major source** of machine-induced variability.

>**50%** of the malware have **33** missing/additional file creations

		Median			75^th^ percentile		
		Mal	PUP	Ben	Mal	PUP	Ben
File	Path	4	1	-	10	3	2
	Name	25	2	1	49	8	8
	Ext.	3	1	-	5	2	1

Variability is in the **number of unique file names** not paths.
Malware write in the same number of unique file paths.

Case study: Glupteba

	Jaccard index	IQR
File name	0	0
Mutex name	0.2	2

Mutex values appeared in:
h48yorbq6rm87zot — all the machines
ZonesCacheCounterMutex — in ~50%
ZoneAttributeCacheCounterMutex — in ~50%
2 random values appear in only 1 machine

$$\text{Jaccard} = \frac{\text{number of values appearing in all machines}}{\text{number of all unique values}} = \frac{1}{5} = \mathbf{0.2}$$

IQR = {num. unique mtx. names in 75 percentile} - {those in 25 percentile} = 3-1 = **2**

Mutex name is a better candidate for building signatures for this specific malware sample

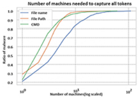
Invariant behavior analysis

```
logsource:
    category: process_creation
    product: windows
detection:
    selection:
        CommandLine: '*-noni -ep bypass $*'
    condition: selection
```
https://github.com/SigmaHQ/sigma

Measure prevalence of tokens in parameter values for 3 most used parameters.

Q1: How to capture all malware tokens?

File name tokens are more challenging to capture than the file path and CMD tokens.

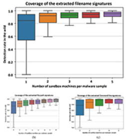


Q2: How to maximize detection with minimum number of sandboxes?

File name tokens from 3 machines reach high detection, more machines provide diminishing ret.

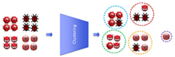
File path tokens need to be extracted from at least 7 machines

CMD line also requires 3 to 4 machines at most



Variability VS malware solutions

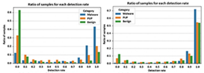
Clustering



Intuition: All sample's executions will be in the same cluster.

From all malware samples
- **67%** fall in 1 cluster
- **27%** fall in 2 clusters
- **5%** fall in 3 clusters
- **1%** fall in 4 different clusters

Anomaly detection



Using all benign executions we get lower FP but also lower detection.

- When employing malware analysis methods:
  - Use multiple executions of the same malware samples
  - Use multiple executions of the benign samples