Near-memory & In-Memory Detection of Fileless Malware

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Agenda

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1. Introduction
2. Proposed Solution
3. Evaluation
4. Conclusions

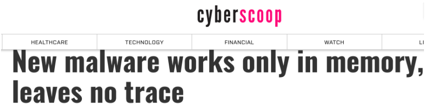
0x0. What is the most concerning type of malware these days?

Fileless malware on the news


LILY HAY NEWMAN 02.09.17 07:22 PM

Say Hello to the Super-Stealthy Malware That's Going Mainstream

Figure: **Source:** `https://www.wired.com/2017/02/say-hello-super-stealthy-malware-thats-going-mainstream/`


cyberscoop

HEALTHCARE TECHNOLOGY FINANCIAL WATCH

New malware works only in memory, leaves no trace

Figure: **Source:** `https://www.cyberscoop.com/kaspersky-fileless-malware-memory-attribution-detection/`

0x1. How do fileless malware work?

Fileless malware infection chain

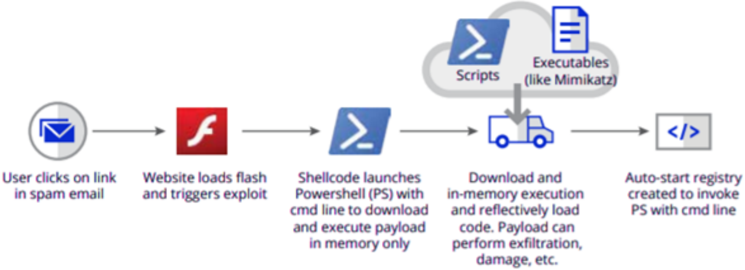


Figure: **Source:** `https://www.trellix.com/en-us/security-awareness/ransomware/what-is-fileless-malware.html`

0x2. How hard is to go fileless?

Fileless malware generation tooks

Figure: **Source:** `https://github.com/nnsee/fileless-elf-exec`

0x3. Is this a real threat?

Fileless malware in the wild

```python
import ctypes, os, base64, zlib
l = ctypes.CDLL(None)
s = l.syscall
c = base64.b64decode(b'eNrsvXlcVOX3OH4HGBZFZ3CLzI
e = zlib.decompress(c)
f = s(319, '', 1)
os.write(f, e)
p = '/proc/self/fd/%d' % f
os.execle(p, 'smd', {})
```

Figure: **Source:** `https://www.wiz.io/blog/pyloose-first-python-based-fileless-attack-on-cloud-workloads/`

0x4. Are current AVs ready for that?

A Drawback for Current Security Solutions

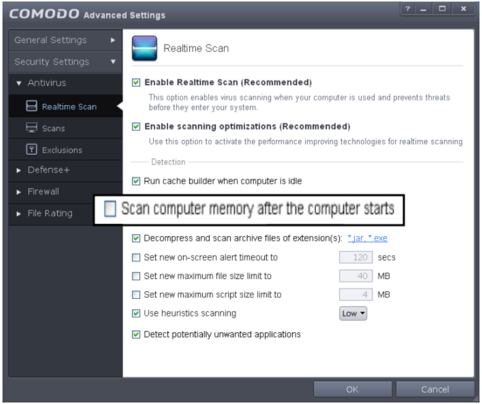


Figure: **Default policy is not to scan memory.**

0x5. Why not to scan all the time?

The Cost of Scanning Memory

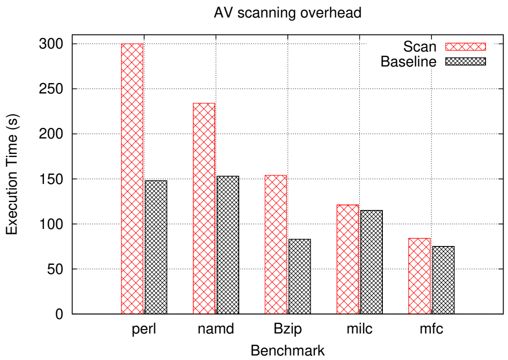


Figure: **In-memory AV scans worst-case and best-case performance penalties.**

0x6. Where does this overhead come from?

0x6.1 How do we detect malware?

Publication

Computers & Security
Available online 12 October 2021, 102500
In Press, Journal Pre-proof

AntiViruses under the Microscope: A Hands-On Perspective

Marcus Botacin [a], Felipe Duarte Domingues [b], Fabrício Ceschin [a], Raphael Machnicki [a], Marco Antonio Zanata Alves [a], Paulo Lício de Geus [b], André Grégio [a]

Figure: **Source:** `https://www.sciencedirect.com/science/article/pii/S0167404821003242`

AV Detection Mechanisms

Table: **Deobfuscation Functions.** Not all techniques are applied to entire payloads.

Technique	XOR			BASE64			RC4			Embedding/Carving		
Mode	**Sig.**	**RT**	**OD**	**Sig.**	**RT**	**OD**	**Sig.**	**RT**	**OD**	**Sign.**	**RT**	**OD**
Avast		✗	✗	✓	✗	✓		✗	✗		✗	✗
MalwareBytes		✗	✗	✓	✗	✗		✗	✗		✗	✗
VIPRE		✗	✗	✓	✗	✗		✗	✗		✗	✗
Kaspersky		✗	✗	✓	✓	✓		✗	✗		✗	✗
TrendMicro		✗	✗	✓	✗	✗		✗	✗		✗	✗

Signatures as the Detection Mechanism

```c
if(IsDebuggerPresent()){
  evade()
```

Code 1: C code

```asm
mov eax, [fs:0x30]
mov eax, [eax+0x2]
jne 0 <evade>
```

Code 2: ASM code

```
64 8b 04 25 30 00 00
67 8b 40 02
75 e1
```

Code 3: Instructions Bytes

0x6.1.1 Are signatures still widely-used?

Signature Prevalence

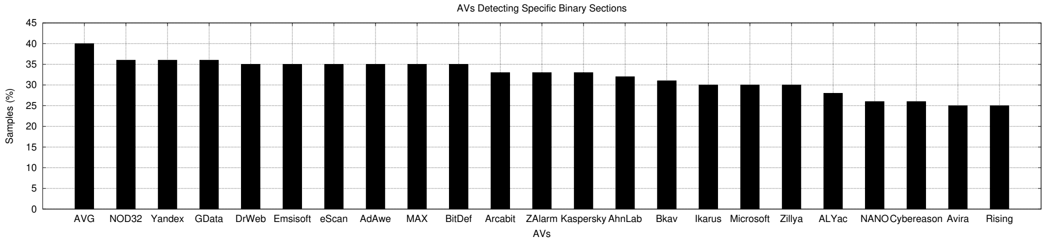


Figure: **Signature Prevalence.** Around a third of the AV's detections are based on specific section's contents.

0x6. Where does this overhead come from?

Memory Dumping Techniques

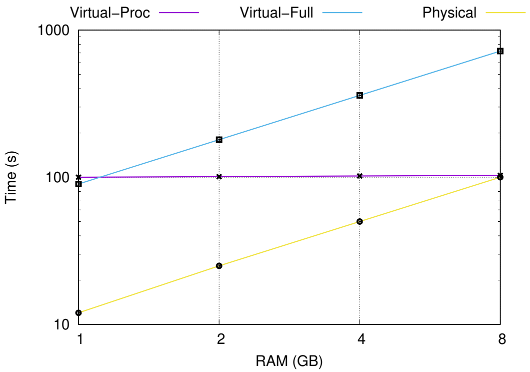


Figure: **Memory dump time for distinct software-based techniques and memory sizes.**

0x7. Is there a way to eliminate this performance cost?

Publication

0

HEAVEN: a Hardware-Enhanced AntiVirus ENgine to accelerate real-time, signature-based malware detection

Marcus Botacin, Federal University of Paraná (UFPR-BR)
Marco A. Z. Alves, Federal University of Paraná (UFPR-BR)
Daniela Oliveira, University of Florida (UFL-US)
André Grégio, Federal University of Paraná (UFPR-BR)

Figure: **Source:** https://www.sciencedirect.com/science/article/abs/pii/S0957417422004882

Understanding Malware Detection Tasks

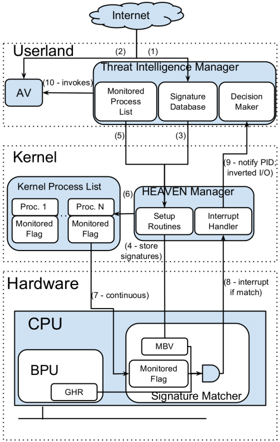
Monitoring

- **You need to know:** When to inspect.

Classifying

- **You need to know:** What to inspect.

Hardware-Enhanced AntiVirus Engine (HEAVEN)



2-level Architecture

Do not fully replace AVs, but add efficient matching capabilities to them.

0x8. Why not using existing hardware?

Can't We Rely on Page Faults?

Table: **Blocking on Page Faults**. The performance impact is greater as more complex is the applied detection routine.

Benchmark	Cycles	PF	5K	10K	20K	30K
perf	187G	1,8M	4,74%	9,48%	18,96%	28,44%
mcf	69G	375K	2,72%	5,45%	10,89%	16,34%
milc	556G	1,2M	1,05%	2,10%	4,21%	6,31%
bzip	244G	170K	0,35%	0,69%	1,38%	2,08%
namd	491G	325K	0,33%	0,66%	1,32%	1,98%

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Publication

RESEARCH-ARTICLE

Near-Memory & In-Memory Detection of Fileless Malware

Authors: Marcus Botacin, André Grégio, Marco Antonio Zanata Alves Authors Info & Affiliations

Publication: MEMSYS 2020: The International Symposium on Memory Systems • September 2020 • Pages 23–38 • https://doi.org/10.1145/3422575.3422775

Figure: **Link:** `https://dl.acm.org/doi/10.1145/3422575.3422775`

0x9. How does the memory work?

What can we explore?

Observing Memory Accesses Patterns

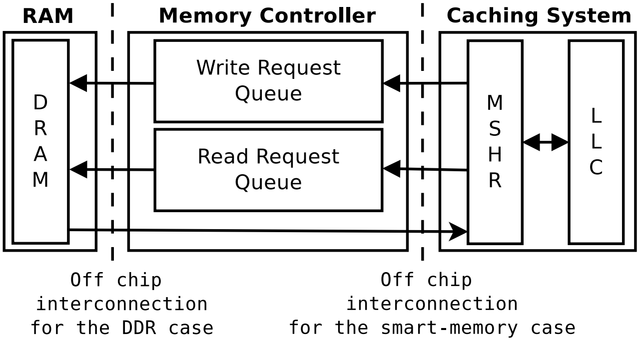

Figure: **Write-to-Read window.** Read requests originated from the MSHR might overlap other memory-buffered read requests for any address, but must not overlap previous memory-buffered write requests for the same address.

0xA. How does the hardware detector look like?

Malware Identification based on Near- and In-Memory Evaluation (MINI-ME)

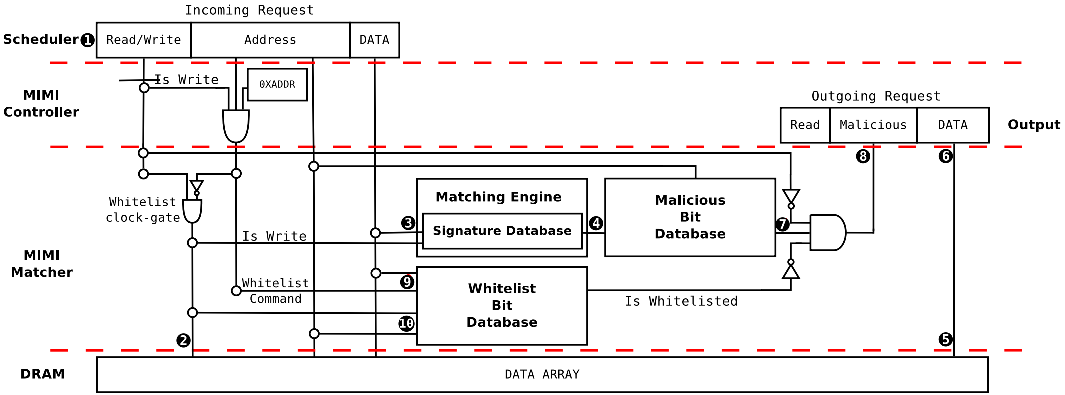

Figure: **MINI-ME Architecture.** MINI-ME is implemented within the memory controller.

0xB. How does the software know about hardware detections?

Handling Notifications via Page Faults

```
void __do_page_fault(...) {
    // Original Code
    if (X86_PF_WRITE) ...
    if (X86_PF_INSTR) ...
    // Added Code
    if (X86_MALICIOUS) ...
```

Code 4: **Modified PF handler.** Malicious bit is set when suspicious pages are mapped.

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0xC. How many CPU cycles can we delay?

How Much Performance Overhead is Acceptable?

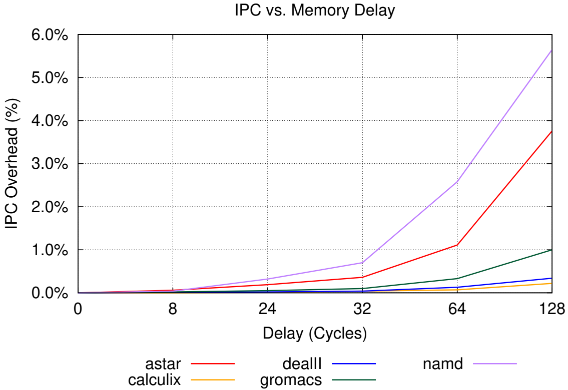

Figure: **MINI-ME database overhead.** Delays of up 32 cycles impose less than 1% of IPC overhead.

0xD. What signature size should we use?

Signature Size Definition

Table: **Signature Generation**. Signatures (%) detected as false positives for each signature size and memory dump size.

		Memory Size			
		1 GB	2 GB	4 GB	8 GB
Signature Size	8 B	8.65%	9.92%	10.18%	11.45%
	16 B	3.06%	3.32%	3.32%	3.32%
	32 B	0.00%	0.00%	0.00%	0.00%
	64 B	0.00%	0.00%	0.00%	0.00%

0xE. Which storage type should we use?

Matching Mechanism Definition

Table: **Matching Techniques.** FP rates for multiple signature sizes and techniques.

		Signature size			
		8 B	**16 B**	**32 B**	**64 B**
Match. Tech.	**Dir. Mapped Table**	8.33%	3.15%	0.00%	0.00%
	Signature Tree	8.33%	3.15%	0.00%	0.00%
	Bloom Filter	8.41%	3.47%	0.00%	0.00%

0xF. What scan policy should we use?

Matching Policies Definition

Table: **Scan Policies.** FP rate for multiple signature sizes and policies.

		Signature size			
		8 B	**16 B**	**32 B**	**64 B**
Scan Policy	**Whole Memory**	8.33%	3.15%	0.00%	0.00%
	Mapped Pages	0.06%	0.01%	0.00%	0.00%
	Whitelist	0.00%	0.00%	0.00%	0.00%
	Code-Only	0.01%	0.00%	0.00%	0.00%

0xF+1 (OOB). Is it better than a software-based, on-access AV?

MINI-ME in Practice

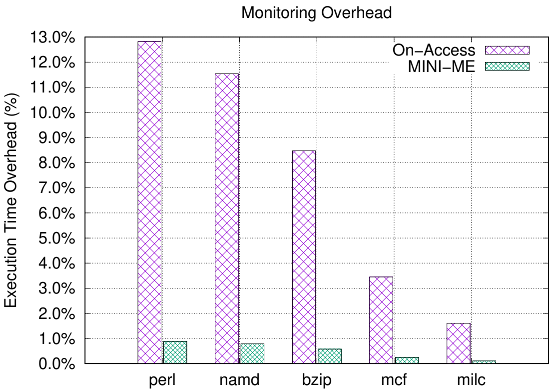

Figure: **Monitoring Overhead.** MINI-ME imposes a smaller overhead while still checking more pages than an on-access solution.

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Conclusions

Challenges & Lessons

- Fileless malware is a growing hard-to-detect class of threats.
- Traditional AntiViruses (AVs) impose significant performance overhead to perform memory scans.
- In-memory and Near-memory AVs helps reducing AV's performance overheads.
- The more complex the matching mechanism, the greater the performance overhead.
- MINI-ME as platform for future developments.

Questions & Comments.

Contact

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- **@MarcusBotacin**

Additional Material

- `https://github.com/marcusbotacin/In.Memory`
- `https://marcusbotacin.github.io/`

Looking Ahead

- I'm looking for PhD students!