FAROS: Illuminating In-Memory Injection Attacks via Provenance-based Whole System Dynamic Information Flow Tracking

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Problem

- In-memory Injection attacks.
- They are becoming more and more common.
- We built a reverse engineering tool to flag them and give analysts the information they need to reverse engineer such malware.
In-Memory Injection Attack

- Operates only on memory
- Acts very stealthy
- Hard to detect
Threat Model

- Reflective DLL injection
- Process hollowing/replacement
- Code/process injection
Threat Model - Reflective DLL Injection

- **Reflective DLL injection** refers to loading a DLL from **memory** rather than from disk.

- Windows doesn’t have such loading function.

- Write your own load function: Omitting some of the things Windows normally does, e.g. registering the DLL as a loaded module.
Threat Model - Process Hollowing

- Start a process in a suspended state.
- Replace the process image with a malicious one.
- Run the process.
- Easy!
Threat Model - Code Injection

- Write the malicious code directly to the address space of the target process.
- Have the target process run the code.
- Easy!
Motivation

- Current malware analysis solutions, e.g. CuckooBox and memory forensics tools, are no match.
- An analyst needs visibility into memory throughout the execution to flag such attacks.

**Question:**
- How the attack was conducted?
- What is the source of the attack?
- ...

Dynamic Information Flow Tracking (DIFT)

- Makes systems transparent for attack detection, enforcement of security policies and forensics*

*Suh et al. 2004, Minos (Crandall and Chong 2004), TaintCheck (Newsome and Song 2005), and Vigilante (Costa et al. 2004)
DIFT - How?

I. Introduce the tags/taints
II. Propagate the tags
III. Check the status of tags
Shadow Memory
DIFT Example

Ethernet card memory

Physical memory

Shadow ethernet card memory

Shadow physical memory
DIFT Example
DIFT Example
DIFT Example

```
10
0
Ethernet card memory

{1}
0
Shadow ethernet card memory

1024
Physical memory

... {1}
1024
Shadow physical memory

20
0
Ethernet card memory

{2}
0
Shadow ethernet card memory

20
AL

{2}
Shadow AL

ADD

20
AL

Union

{2}
Shadow AL

... 10 ... 30 ...
1024
Physical memory

... {1} ...
1024
Shadow physical memory

... {1,2} ...
2048
Shadow physical memory
```
Provenance List

- Each byte could have a list of tags (provenance list).

A provenance list for a specific byte
Tag Confluence

- Two or more tags of different types can "come together".
Tag Confluence

- A byte comes in from the network and then moves to the physical memory.

Provenance list associated with this byte
Tag Confluence

- Process #1 accesses that byte.

Provenance list associated with this byte
Flagging Policy via Provenance-based DIFT

Data coming in from the network (Netflow tag) SHOULD NOT “come together” with linking/loading data exported by the kernel (export table tag).

That shouldn’t happen under normal circumstances!
Flagging Policy via Provenance-based DIFT

- Tag confluence heuristic:
System Architecture

Windows (guest)

QEMU/PANDA

Linux (host)

Bare metal

FAROS Plugin
(\textasciitilde 1350 LOC)

OSI/Win7 x86intro

Syscall2
(modified \textasciitilde 6450 LOC)
Results - Reflective DLL Injection
Results - Reflective DLL Injection

Source IP: 169.254.26.161
Source port no: 4444
Destination IP: 169.254.57.168
Destination port no: 48186

NetFlow

Susicious.exe
Firefox.exe

Provenance List #1

Export Table

Provenance List #2
Comparison with CuckooBox

- Most popular open-source malware analysis system.

- We tested CuckooBox on in-memory injection attacks.

- CuckooBox (along with *malfind* and *Volatility* plugins) provided limited visibility into these attacks.

- With CuckooBox, we are blind as to how the attack was conducted.
True/False Positive Analysis

- Tested against 6 memory injection attacks and successfully flagged them all.

- Tested against 90 non-injecting malware samples and 14 benign software from various categories.
  - FAROS presented a very low false positive rate of 2%.
Performance Evaluation

- Performance is not a priority for FAROS.

- Focused on providing a low false positive rate.

- FAROS’ slowdown is 56X compared to QEMU.
Conclusions

- Presented FAROS, a DIFT-based reverse engineering tool, which can illuminate in-memory injection attacks.
- Tag confluence as a promising heuristic.
- Very low false positive (2%).
- FAROS
  - can save reverse engineers substantial time and effort in practice.
  - can provide reverse engineers with valuable information about any in-memory injection attacks.
- FAROS is open source:
  - https://github.com/mnavaki/FAROS
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Thank you!

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