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

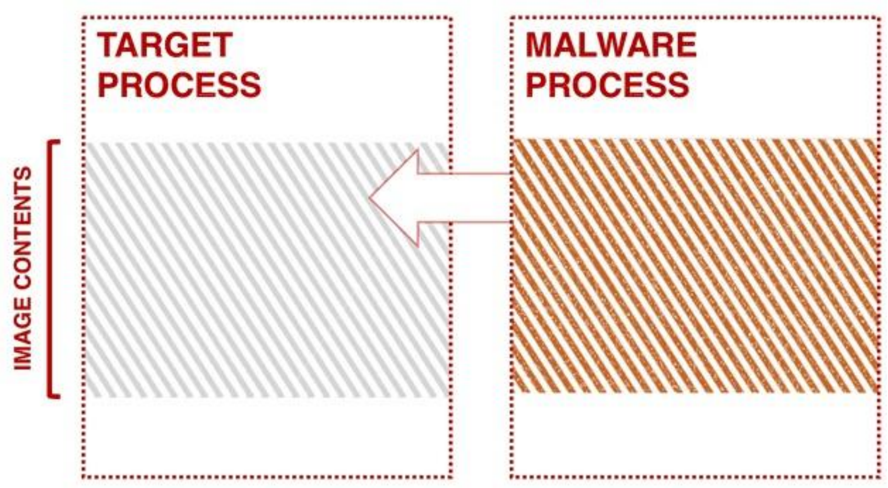
- Reflective DLL injection
- Process hollowing/replacement
- Code/process injection

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?**
    - **...**

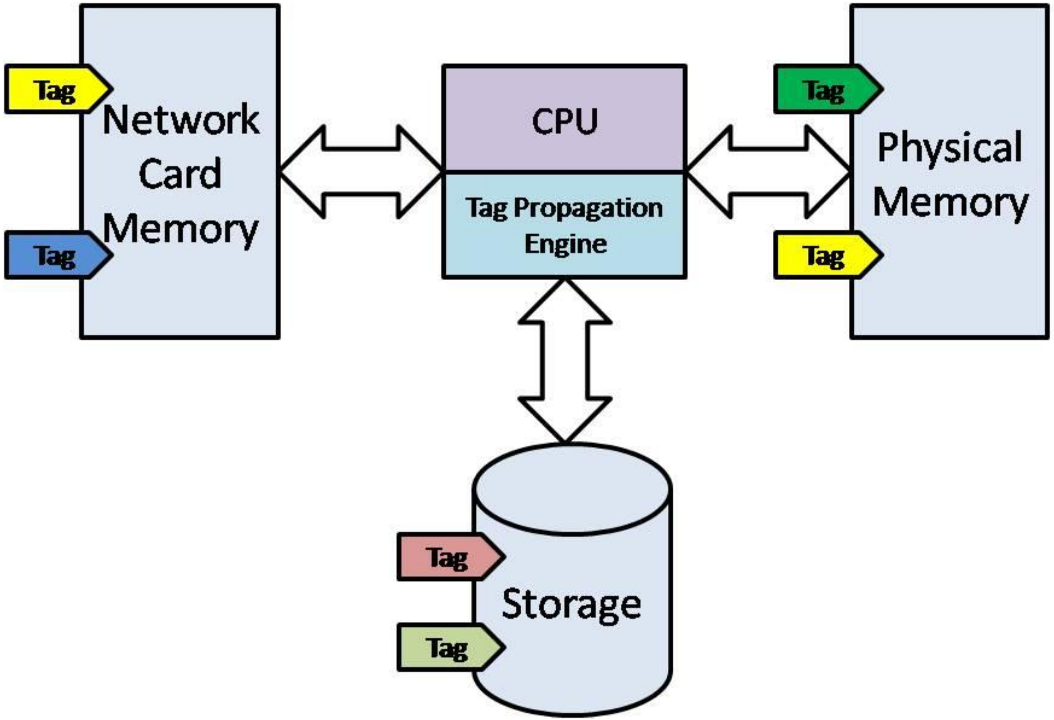
Dynamic Information Flow Tracking (DIFT)

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

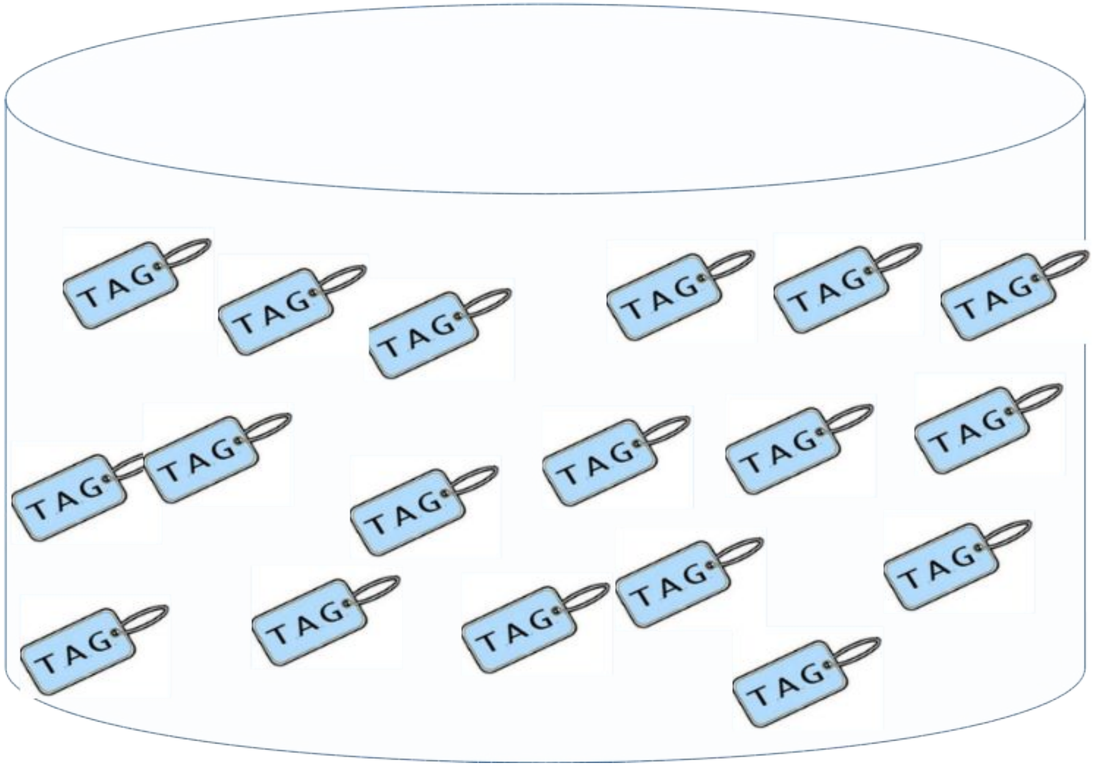
*Suh et al. 2004, Minos (Crandall and Chong 2004), TaintCheck (Newsome and Song 2005), and Vigilante (Costa et al. 2004)

DIFT - How?

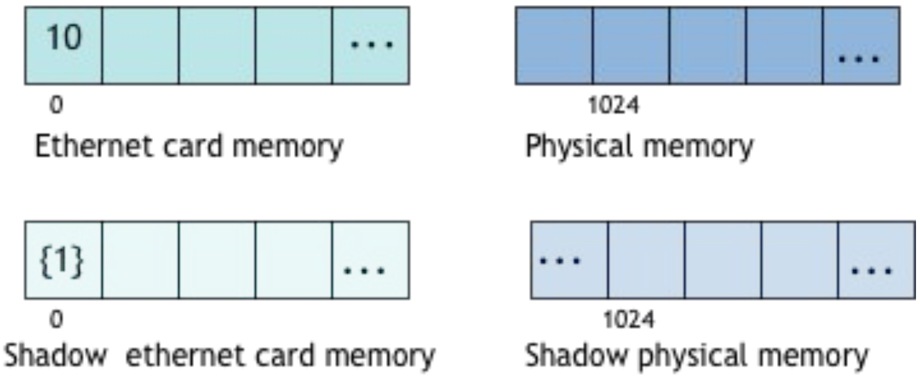
I. Introduce the tags/taints
II. Propagate the tags
III. Check the status of tags



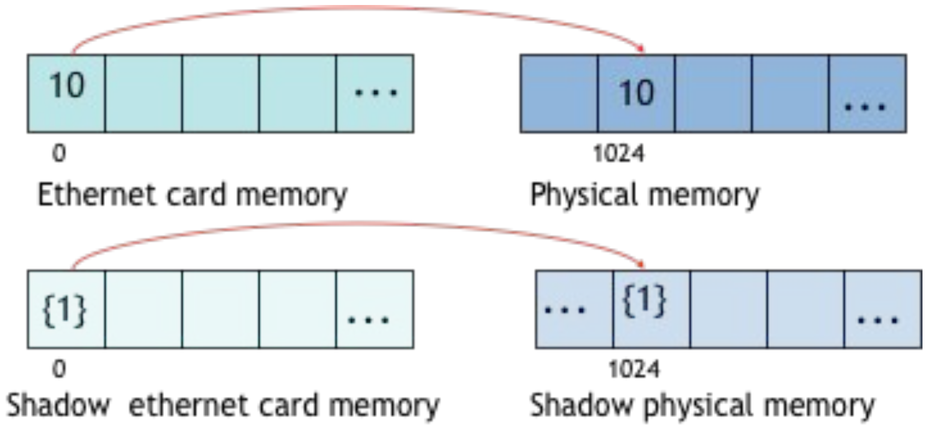
Shadow Memory



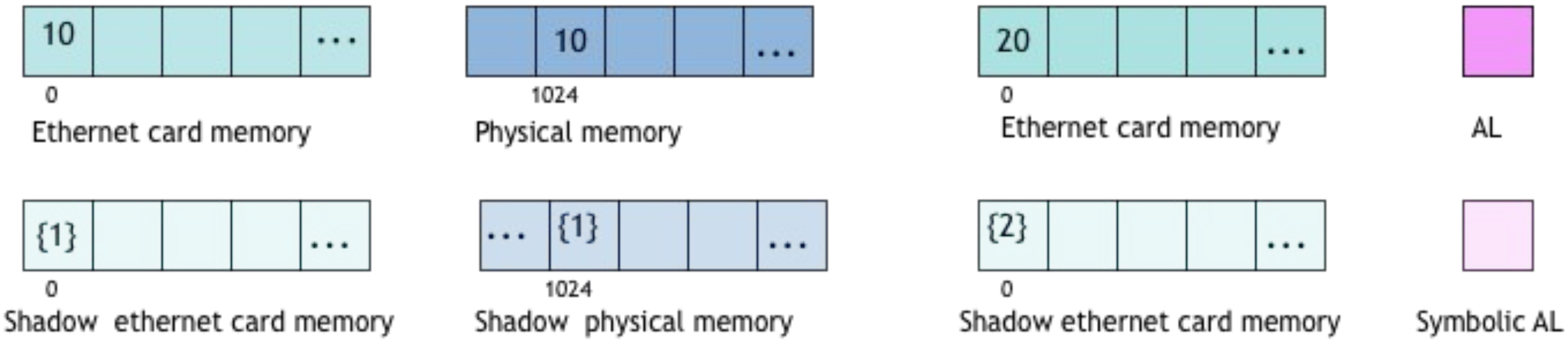
DIFT Example



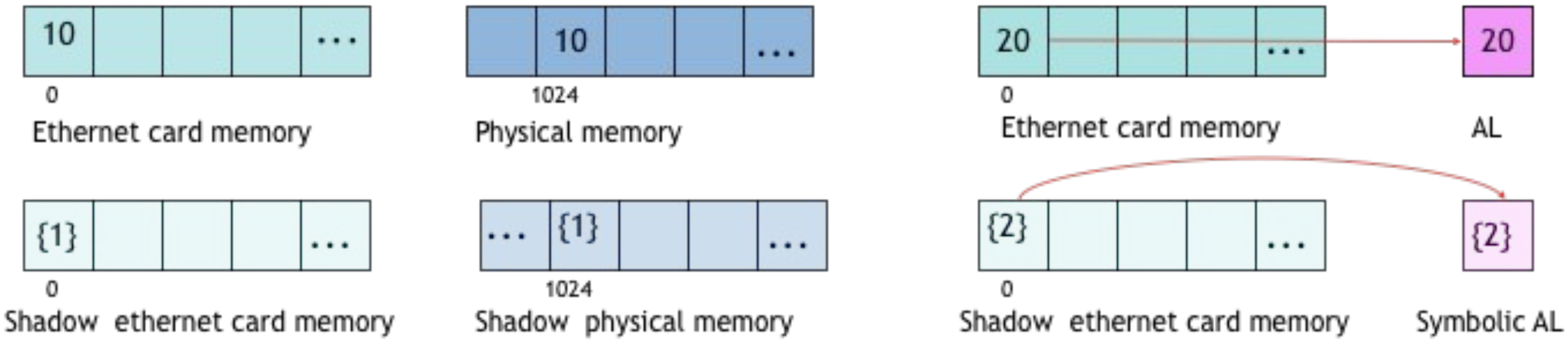
DIFT Example



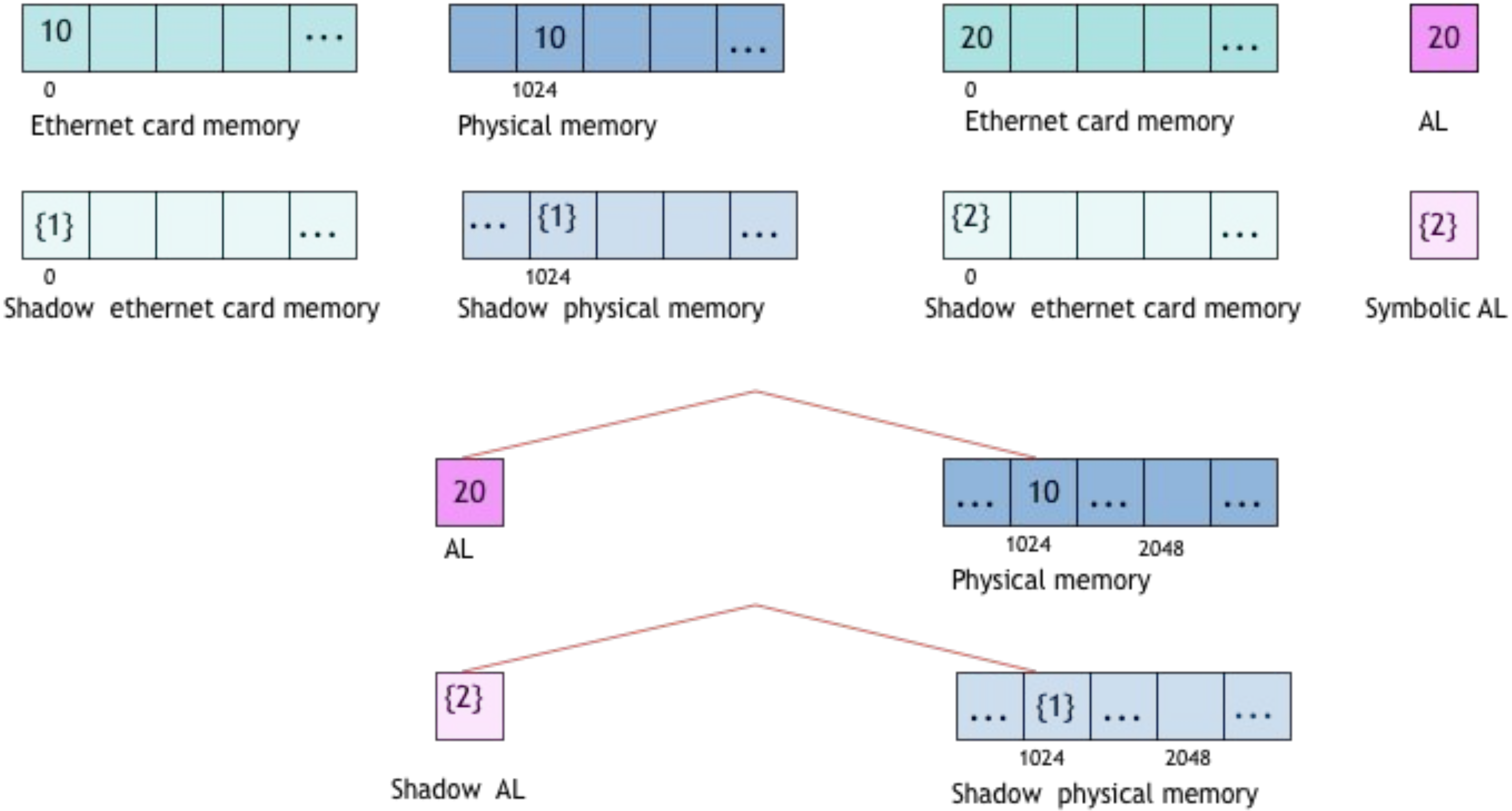
DIFT Example



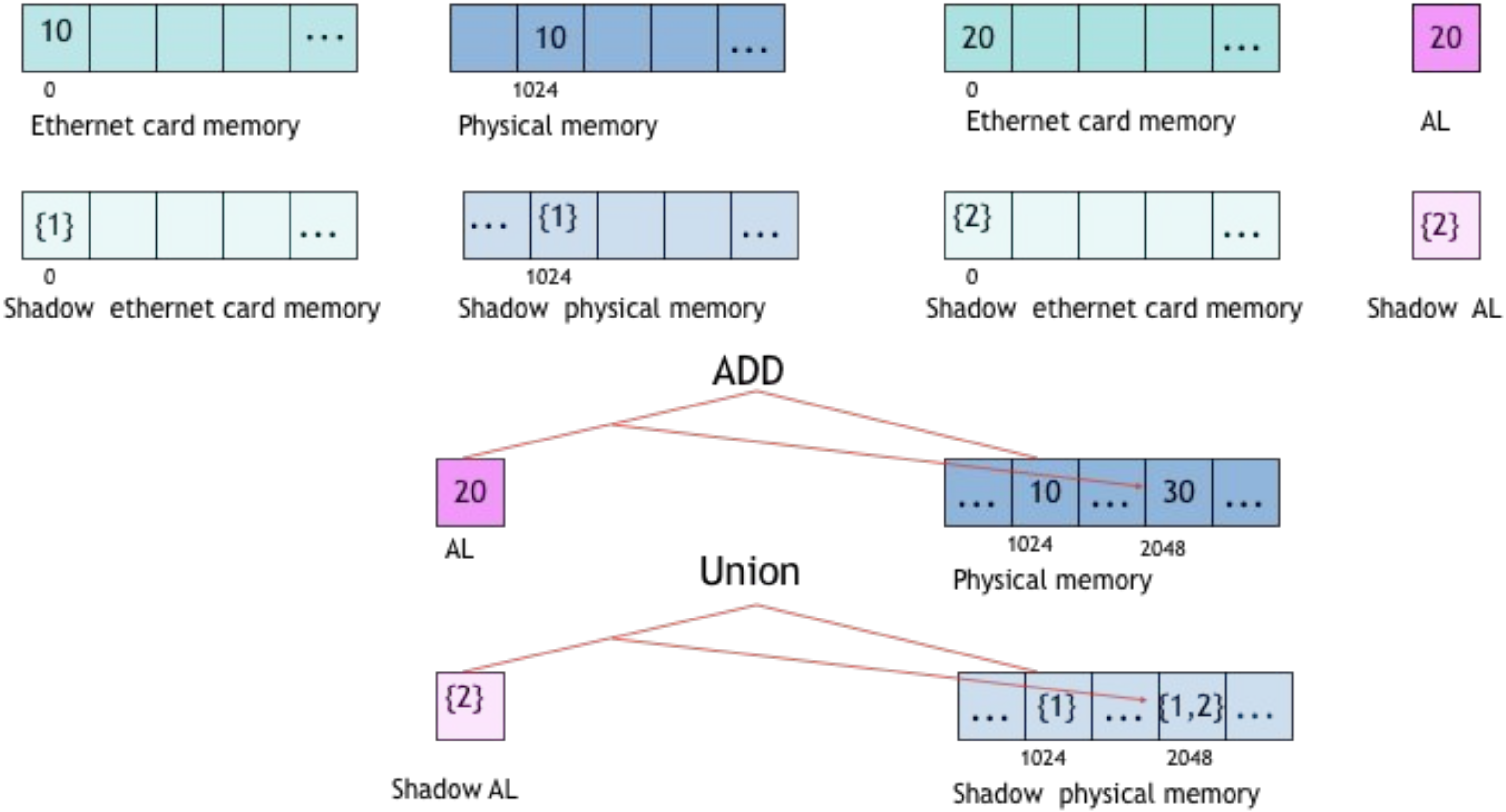
DIFT Example



DIFT Example

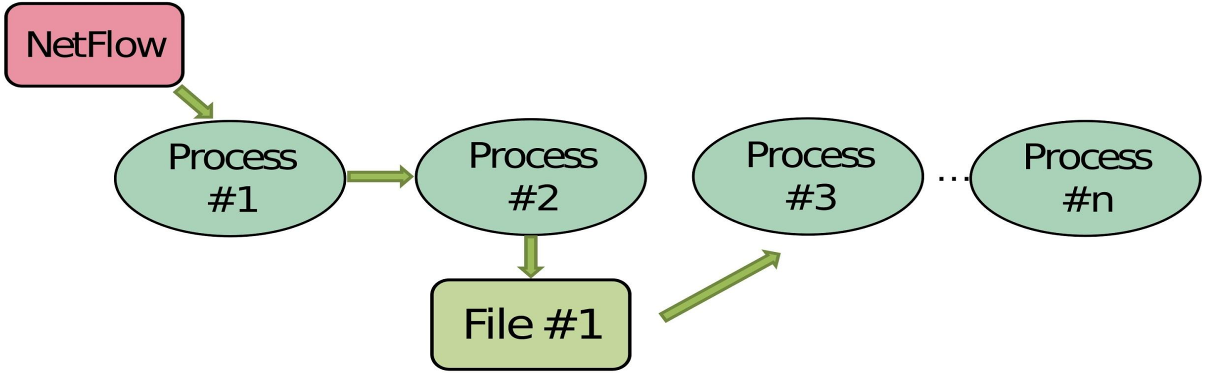


DIFT Example



Provenance List

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



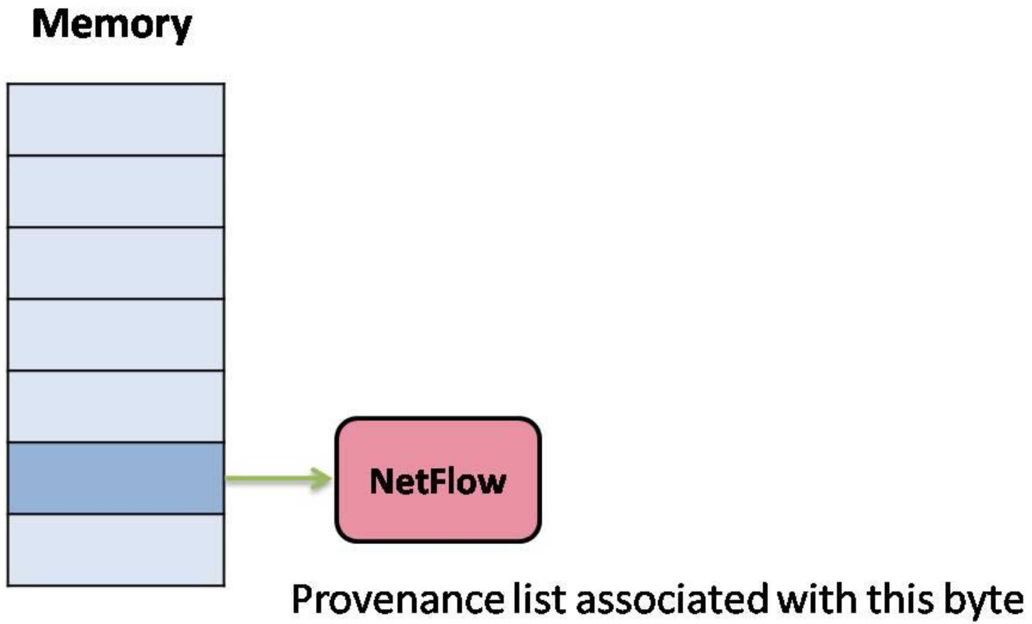
A provenance list for a specific byte

Tag Confluence

- Two or more tags of different types can “come together”.

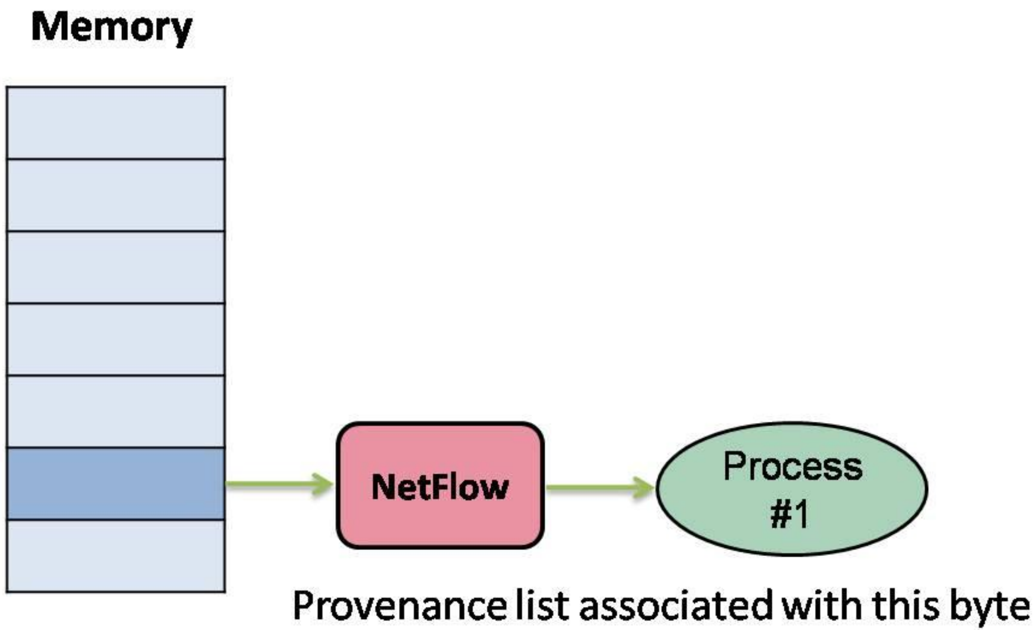
Tag Confluence

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



Tag Confluence

- Process #1 accesses that byte.



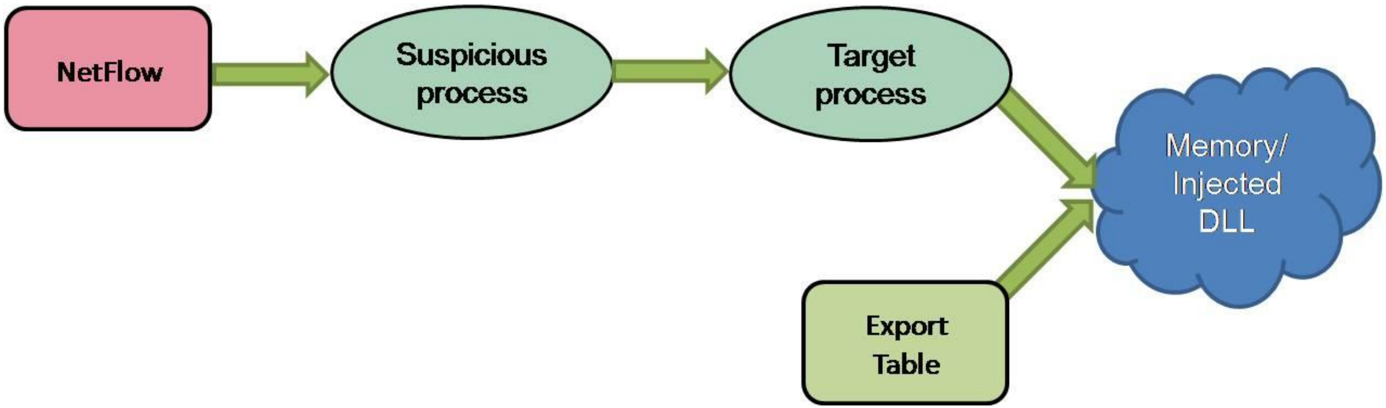
Flagging Policy via Provenance-based DIFT

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

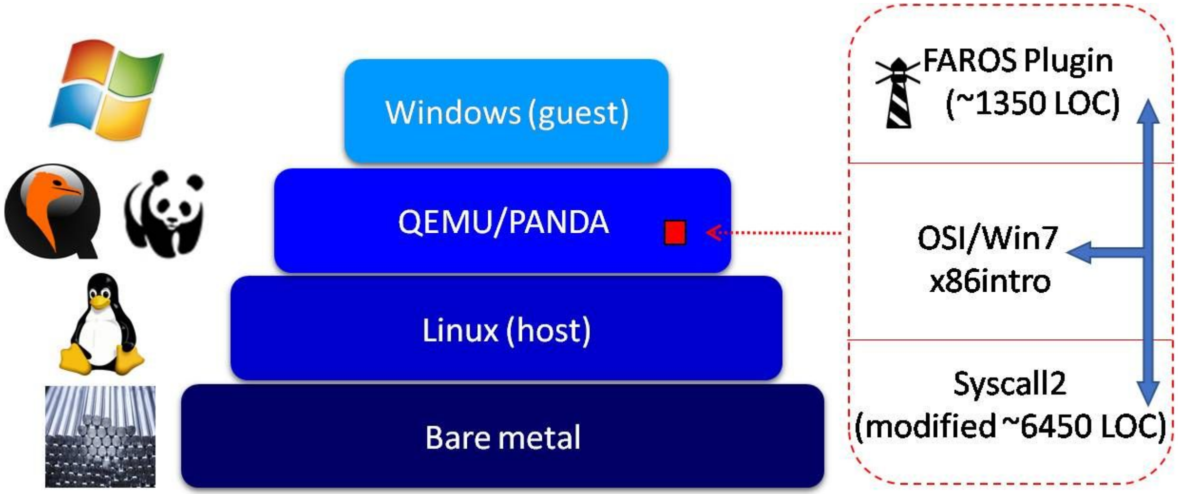
That shouldn't happen under normal circumstances!

Flagging Policy via Provenance-based DIFT

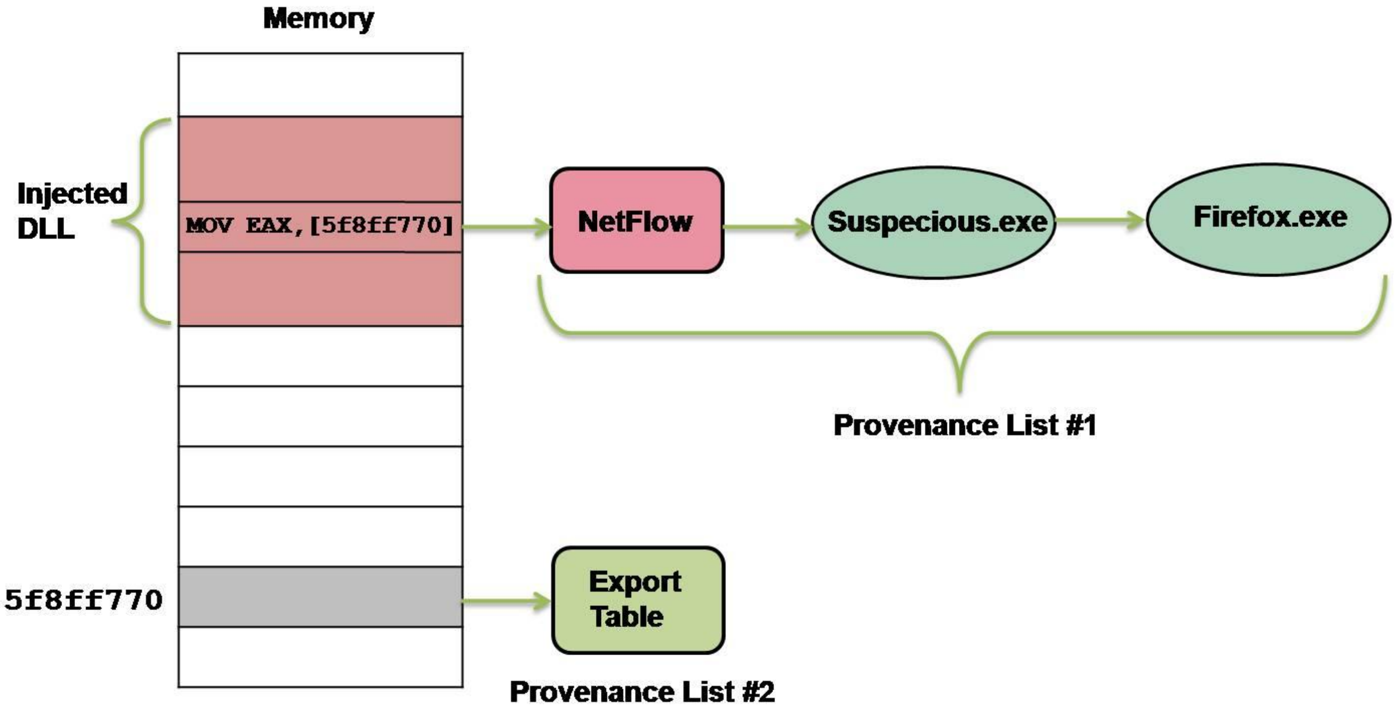
- **Tag confluence heuristic:**



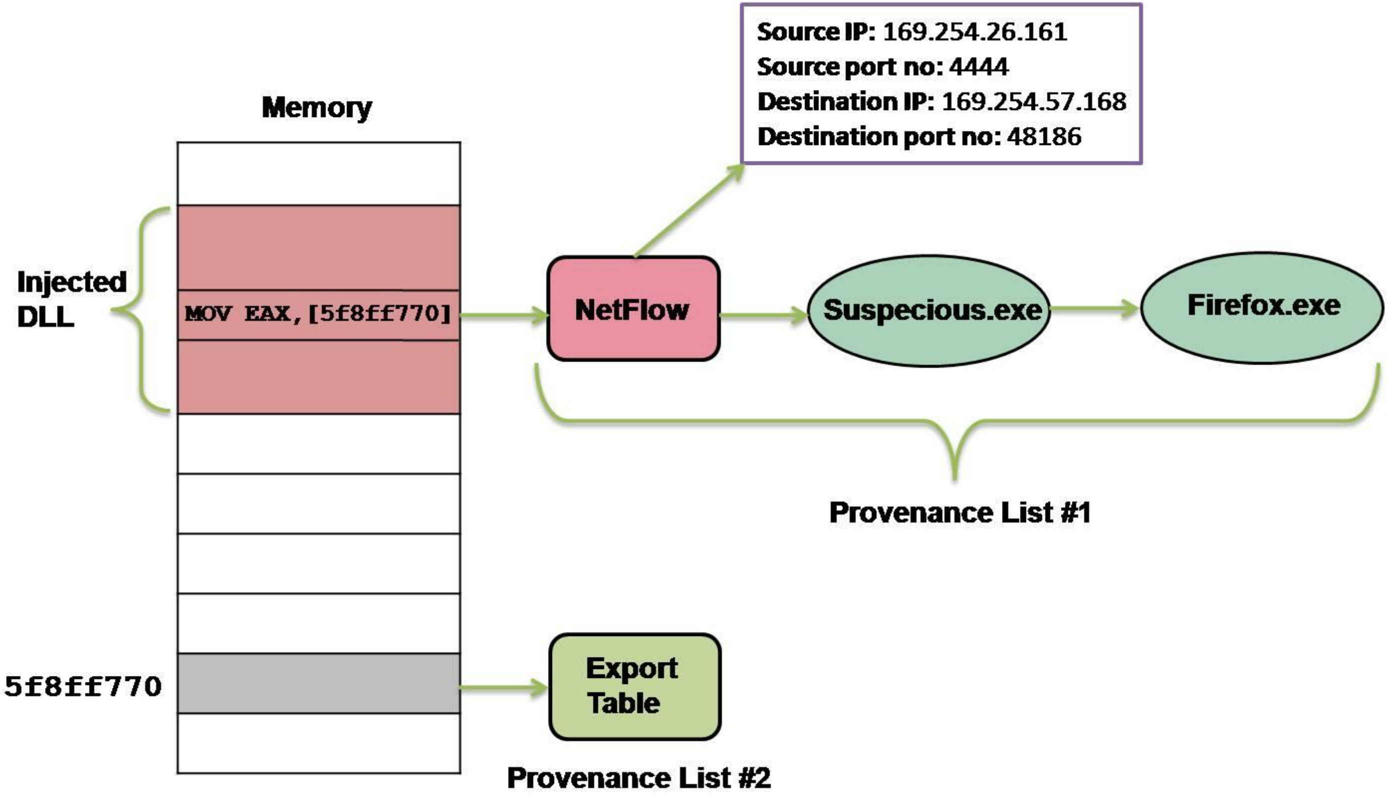
System Architecture



Results - Reflective DLL Injection



Results - Reflective DLL Injection



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

Acknowledgments

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Thank you!

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