



Enhancing malware analysis with

Automated Memory Analysis

Why are we here? (one of many reasons)

- A malicious program:
 - Allocates memory in a remote process (and write to it)
 - Executes the code in that memory region
 - Frees the code
- Memory dump taken at the end of execution
 - **No malicious artifacts found in post-mortem analysis**

Why are we here? (one of many reasons)

- Snake/Uroburos rootkit (MD5: 626576e5fof85d77c460a322a92bb267)
- Inline interrupt hooks
- Zeroed image header
 - **This evades file carving**

Setting the Context

- Automated system analyzes a new sample
 - Static Analysis - no significant results
 - Dynamic Analysis - no significant results
 - Memory Analysis – limited results
- Evasion tricks are out of scope
- Focus is on memory analysis enhancement

Static Analysis Challenges

- Time consuming
- 35%~ of malicious samples are packed*
- 90%~ of packed files are protected
- Obfuscation, Cryptors, Encrypted Resources



* https://media.blackhat.com/bh-us-12/Briefings/Branco/BH_US_12_Branco_Scientific_Academic_Slides.pdf

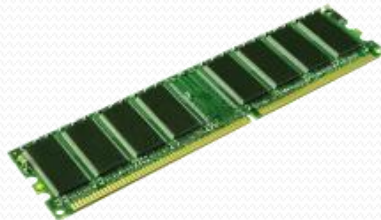
Dynamic Analysis Challenges

- “What you see is what you get”
- Subverting API functions is easy. APIs Lie.
- Calling undocumented/native functions
- Custom WinAPI function implementations
- Reminder: evading dynamic analysis is out of scope



Memory Analysis Advantages

- Discovers system inconsistencies that might indicate a rootkit
- Collects hidden artifacts that cannot be retrieved using OS-provided API
- Advanced malware operates solely in memory
- Identifies system activity and overall machine state



Memory Analysis Disadvantages

- Current solutions require manual inspection (not scalable)
- Interpreting analysis tools output requires in-depth knowledge of OS internals
- Anti-Forensics tools exist* to:
 - Prevent grabbing of memory dumps
 - Plant fake artifacts in memory as decoys
- Artifacts from a single memory dump lack context, since there is no baseline to compare it with
- Taking memory dumps requires accurate timing as memory is volatile

* <http://scudette.blogspot.co.il/2014/02/anti-forensics-and-memory-analysis.html>

Current Automated Approach

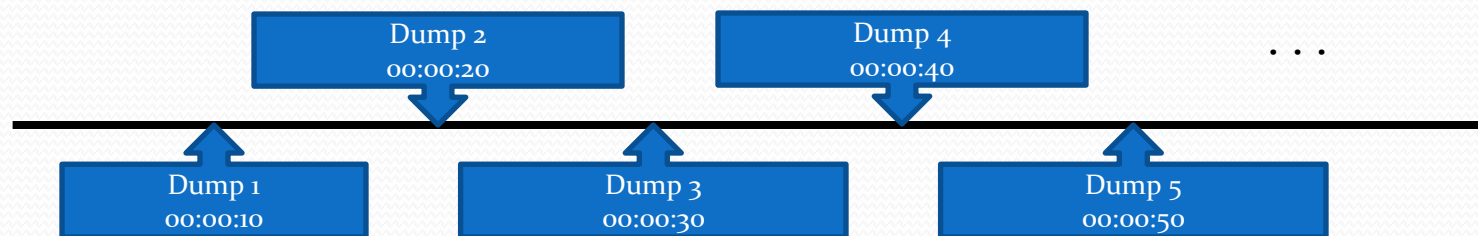
- Execute a sample in a sandbox
- Terminate execution after X minutes
- Grab a memory dump of the machine
- Analyze the memory dump offline
- Detect malicious/suspicious artifacts in-memory
- Revert, Rinse, Repeat

Memory Dump Timing Challenge

- Post-mortem memory dumps (after the program terminates) risks “missing in on the action”
 - Malicious artifacts may appear and disappear intermittently
- Example:
 - Memory region is allocated with RWE permissions
 - Code is written to that region and executed
 - Malware unload itself
 - ➔ Detecting the additionally code at the end will fail

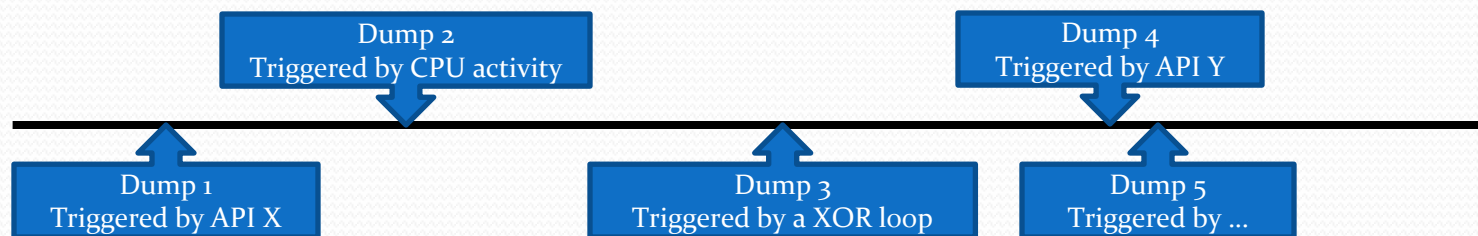
Possible Solution

- **Interval-Based memory dump**
- Grab a memory dump every X seconds
- Analyze each dump - search for malicious artifacts
- Does it solve the problem? **No**
 - Malware can slip between the intervals
 - Many dumps to analyze make it inefficient (Time/Space)



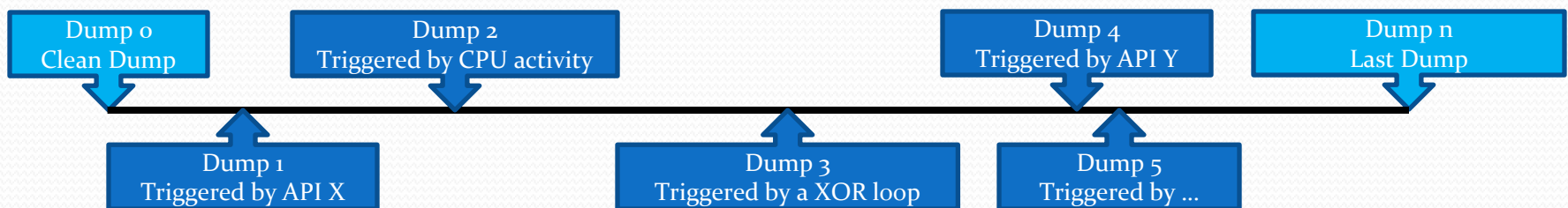
Better Solution

- **Trigger-Based memory dump**
- Dump memory when something “interesting” happens
- “Interesting” points in time:
 - Known malicious API-sequence (behaviors) in user/kernel mode (e.g. Code injection, hollow process)
 - Evidence cleaning attempts (e.g. Process Termination, Un-mapping memory, etc.)
 - “Heavy” mathematical computation (e.g. unpacking in progress)
 - Sampling CPU performance counters for abnormal process activity



Differential Analysis

- Analyze each dump for malicious artifacts
- Diff all dump analysis results from last to clean
 - Clean: Taken before Malware execution
 - Last: Taken when time exceeded
- Produce a list of New/Modified/Deleted artifacts
- Visualize!



Our Approach

- Execute a sample in a controlled environment (CE)
- Trace and monitor execution
- When a trigger is detected
 - Suspend CE -> Dump Memory -> Resume CE
- Before the sample terminates
 - Suspend CE -> Dump Memory -> Terminate CE
- Differential Analysis
 - Clean Dump vs. Dump #1 vs. Dump #2, .. vs. Final Dump
- Generate Report

DEMO #1 - Showcase Malware

- Trigger-Based vs. Interval-Based
- Differential analysis
- Visualization

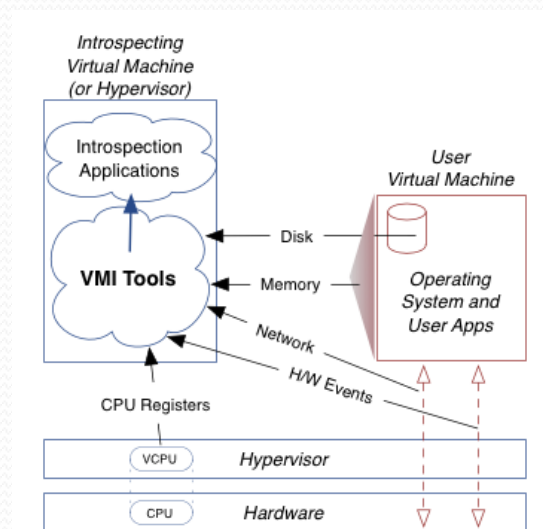


Differential Analysis Plugins

- Process Heap Entropy checker
 - Check for entropy changes over time
- Anti Virus Strings
 - Check for new unpacked strings
- Hybrid Data Extractor
 - Comparing code in-memory (dynamic) against the code on disk (static) to detect unpacked code/data
- Modified PE Header
 - Monitor PE header modification and reconstruct it on-the-fly

Taking a (memory) Dump

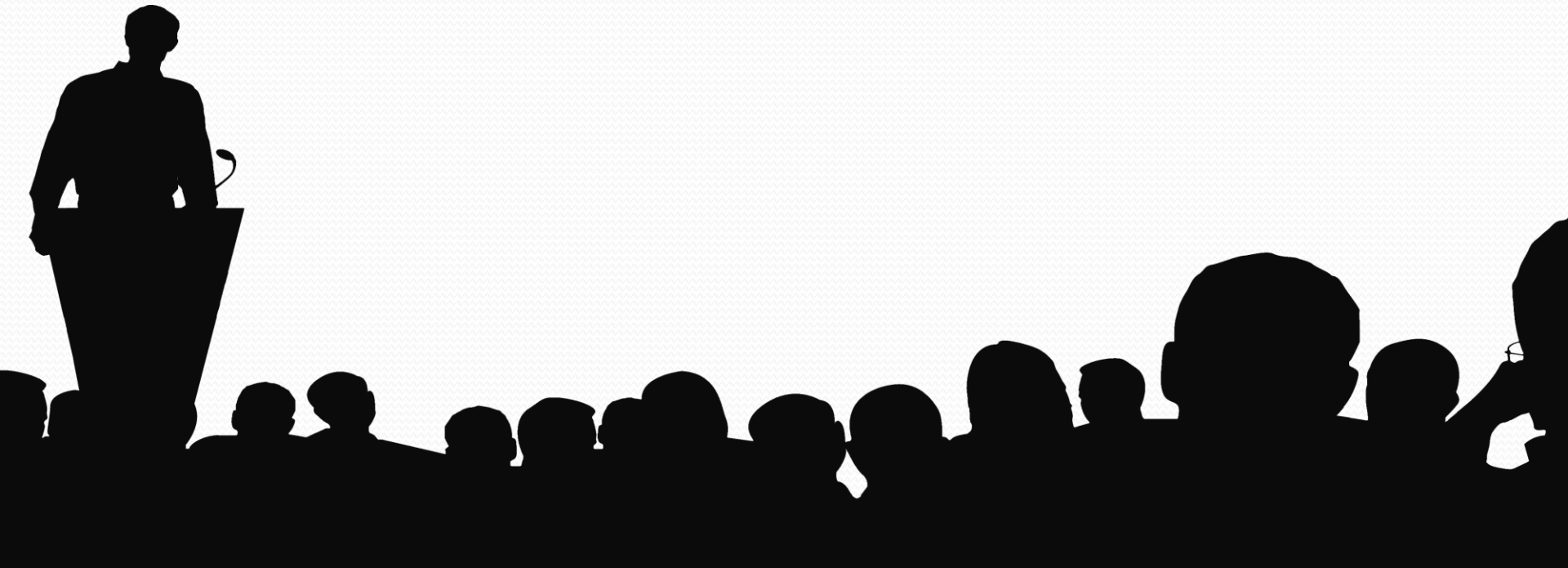
- Live Memory Introspection (*libVMI/pyVMI*)
 - Suspend CE
 - Query memory directly
 - Resume CE
- Offline Memory Dump (*libvirt*)
 - Suspend CE
 - Dump memory to disk
 - Resume CE



<https://code.google.com/p/vmitools/>

DEMO #2 - Advanced Features

- Trigger-based analysis with VMI
- Hybrid Analysis (Dynamic + Memory)
- Artifact dumper



DEMO #3 – SNAKE/Uroburos Rootkit

- Kernel Triggers
- PE header reconstruction
- Artifact dumper



Implementation

- Modified Cuckoo Sandbox v1.1
 - Modified Cuckoo/CuckooMon components
 - New hooks in User/Kernel Mode
 - New static analysis scripts
 - IDA integration (e.g. calculate MD5/ssdeep per function/section)
 - PinTool integration for DBI
- New Volatility plugins for differential analysis

The techniques are generic and can be applied to any sandbox - Read the WP

<https://github.com/djteller/MemoryAnalysis>

Future Work

- Brainstorming & Implementing new triggers
- Automatic verdict (malicious/benign)
- Plug-in framework
- Optimization (e.g. grabbing mini-dumps)
- Extend (non-intrusive) VMI capabilities
- Define new operations for misbehavior analysis
- Port solution to other automated malware systems

Thank You

- Slides
- White Paper
- Code

<https://github.com/djteller/MemoryAnalysis>

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