Automated unpacking

Malware Analysis Seminar

Meeting 5

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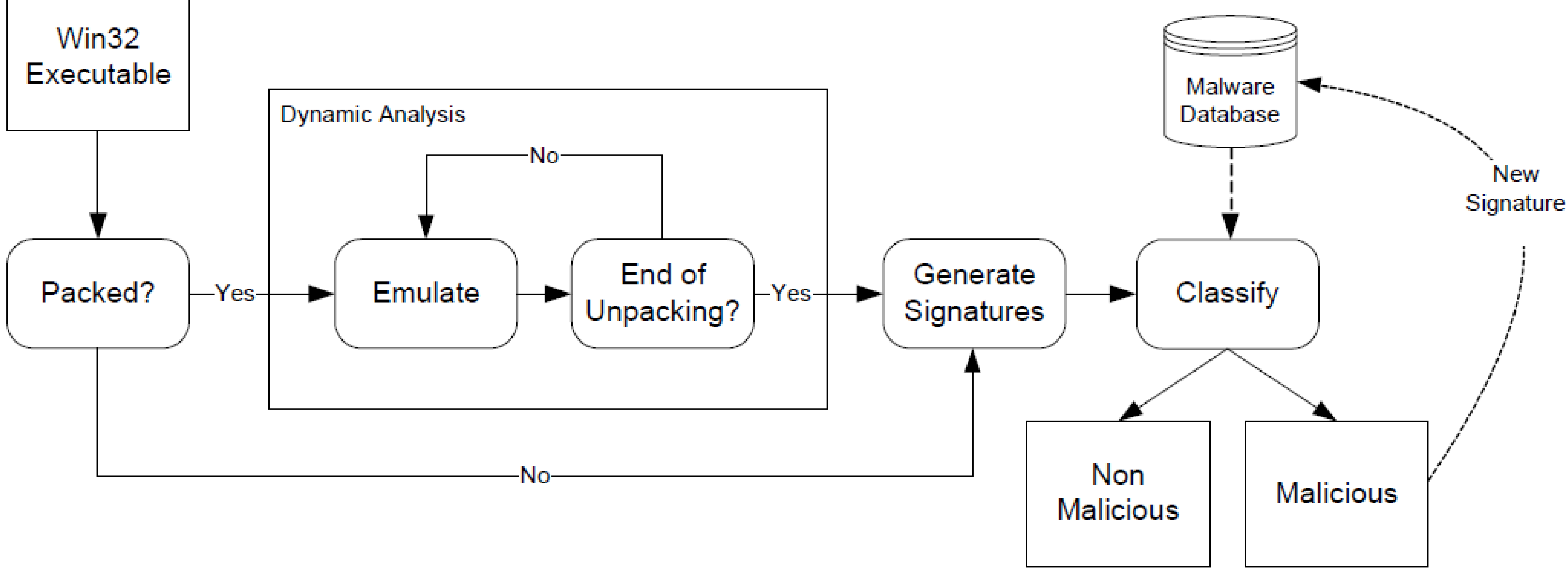
Code packing

Types of packers

- Traditional
- Shifting decode frame
- Code virtualization


Win32
Executable
Dynamic Analysis
No
Packed?
Yes
Emulate
End of
Unpacking?
Yes
Generate
Signatures
Classify
Malware
Database
New
Signature
Non
Malicious
Malicious
No

Taxonomy of polymorphism

Syntactic changes

- Change of code's syntactic structure
  - Semantics remains unchanged
  - Borrows techniques of code obfuscation
- Evade signature based detection of traditional antivirus software

- Dead code insertion

```
push %ebx
pop %ebx
```

- Instruction substitution

```
mov   $0, %eax ->  xor %eax, %eax
```

- Variable renaming & register reassignment

```
mov $0, %eax                mov $0, %ebx
mov $1, %ebx                mov $1, %ecx
add %eax, %ebx              add %ebx, %ecx
push %ebx                   push %ecx
call $0x80403020            call $0x80403020
```

- Code reordering
  - Change syntactic order of the code
  - Semantic execution path remains unchanged

- Branch obfuscation
  - Hide the target of a branch
  - Structured Exception Handling
  - Indirect branching

```
mov   $0x80402030, %eax
jump *%eax
```

  - Branch functions
- Branch inversion

```
jc 0x80403020 -> cmc      #complement curry flag
                 jnc $0x804030
```

- Branch flipping

```
jz 0x80403020 ->     jnz L
                     jmp $0x804030
                 L:
```

- Opaque predicate insertion
  - Always evaluates to the same result
  - However it's hard to know this result statically
    - Used for both control flow, and data values

```
mov   $1, %eax
jnz   $0x80403020
```

Automated unpacking: detecting packed code

Detection

- Signature-based detection
  - PEiD
- Entropy analysis [Bintropy]
  - Statistical measure of the amount of information in a block of data
  - Packed and encrypted code has high entropy
  - Limitations
    - Packers can lower the entropy intentionally
    - Entropy analysis can miss simple obfuscation

Detection

- Behavior based
  - Monitor execution
  - Detect if previously modified memory is executed
  - Limitations
    - Can't distinguish self-modified and packed code

Program feature classification

- Program features
  - Number of standard and non-standard sections
  - Number of executable sections
  - Number of readable/writeable/executable sections
  - Number of entries in the import table
- Some static program features remain invariant
  - Byte and instruction level features perform poorly
  - But don't require undecidable disassembly
  - Code normalization might help
    - But it's not sound

Automated unpacking: static approaches

Code normalization

- The goal is to undo obfuscation
- Code reordering
  - Reliable for unconditional jumps
  - *“In a normalized CFG, each CFG node with at least one unconditional-jump immediate predecessor also has exactly one incoming fall-through edge”*
- Semantic nops
  - Abstract interpretation

Control flow and call graphs

- More invariant
  - Fail to reconstruct precise CFG in face of...
- Opaque predicates (misleading branch targets)
  - Detect opaque predicates
    - Remove them with abstract interpretation
- Pointers and indirection
- Some models ignore indirect branches all together
    - Accept a less accurate representation
  - Alias analysis (Value-Set analysis)
    - Tries to detect all possible values for the pointers
  -

Feature classification

- Data-flow and dependence analysis
  - Hard in the presence of pointers
- API calls
  - Fail in face of stolen bytes which obscure API calls

Automated unpacking: dynamic approaches

PolyUnpack

- Generate static code view
- Identify generated instructions
  - Compare at run-time if instruction is in the static view, if not, it was dynamically generated

```
// Step 1: Static Analysis

// Disassemble P to identify code and data. Partition
// blocks of code separated by non-instruction data into
// sequences of instructions i0, ..., in. These sequences
// form the set I (the static code view). I will be
// repeatedly queried in the dynamic analysis step to
// detect if P is executing unpacked code.

// Step 2: Dynamic Analysis

// Execute P one instruction at a time. Pause execution
// after each instruction and acquire the current
// instruction sequence by performing in-memory
// disassembly starting at the current value of the pc
// until non-instruction data is found. Compare the
// current instruction sequence with each instruction
// sequence in the set I. If the current instruction
// sequence is not a subsequence of any member of I,
// then it did not exist in the static code view of P
// (i.e., it is unpacked code being executed).
```

PolyUnpack: implementation

- Command-line windows tool
  - Software and hardware breakpoints to implement single-stepping
  - www.ollydbg.de/srcdescr.htm library for disassembling
  - OllyDump for dumping
- Careful handling of DLL code
  - Also linked dynamically

Renovo

- Part of BitBlaze
  - Implemented on top of TEMU, extension of QEMU
- Shadow memory
  - Tracks clean (unmodified), and dirty (modified) memory
  - After a block in a dirty memory is executed, Renovo dumps dirty memory, and marks it as clean again
- Tracks processes with CR3

Saffron

- Same idea but uses binary instrumentation to control the program
  - Pin
- Later implementation relies on the Windows page-fault handler modification
  - Tracks memory modifications

Criticism

- Simplistic models
- Heavyweight
- A typical AV solution uses a combination of
  - x86 emulator
  - application level OS emulation

Automated unpacking: dealing with code virtualization

Code virtualization

- Themida
  - Translates x86 code into another language
    - RISC-64, RISC-128, CISC, CISC-2
  - Randomizes instruction encoding
  - Interprets new language
- VMProtect
  - Stack based RISC

Static approach

- Compiler front-end which takes a v-code language
- Recompile in x86
- Observations
  - v-code language is derived from a family of templates
  - High similarity

People do that

- Reverse engineer the VM
  - With the help of dynamic tools
- Implement a disassembler
  - IDA Pro plugin 5K LOC of C++
- Disassemble byte code and convert into IR
- Apply compiler optimizations
- Generate x86 code

Rotalume

- QEMU based dynamic analyzer
  - Record a trace of execution
  - Identify the virtual program counter (VPC)
    - Abstract variable binding
    - Associate each memory fetch with an index variable
    - Deal with x86
  - Identify v-code regions
  - Identify syntax and semantics of v-code operations
    - CFG and taint analysis

Acknowledgements

- Survey of Unpacking Malware. Silvio Cesare.
- Fast Automated Unpacking and Classification of Malware. Silvio Cesare. MS Thesis. 2010.
- Rotalume: A Tool for Automatic Reverse Engineering of Malware Emulators. Monirul Sharif, Andrea Lanzi, Jonathon Giffin, Wenke Lee.
- Unpacking virtualization obfuscators. Rolf Rolles. In WOOT'09.