Encrypted and Oligomorphic Viruses

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Encrypted Viruses

- Virus encryption is both
  - an anti-disassembly technique and
  - an obstacle to virus detection using code patterns
- Encryption takes many forms
- The most advanced, difficult-to-defeat viruses use encryption techniques
- We will devote several lectures to understanding, detecting, and disinfecting various encrypted viruses
- This is the first part of Chapter 7 of Szor.

Simple Encryption

- The earliest viruses to use encryption used a very simple decryption algorithm, such as XORing code with its own address
- The point was **not** to use advanced algorithms that were hard to analyze;
  - just to slow down analysis and
  - defeat pattern-based virus detection
- Decrypter code always present in unencrypted form,
  - not much point in choosing complex encryption/decryption methods
- The DOS virus Cascade was the first encrypted virus

Example: Cascade Virus

- The simple decryptor of Cascade, circa 1990:

```
 lea   si,Start   ; start of encrypted code
                  ;       (computed by virus)
 mov   sp,0682h   ; length of encrypted code (1666 bytes)
Decrypt:
 xor   [si],si    ; xor code with its address
 xor   [si],sp    ; xor code with its inverse index
 inc   si         ; increment address pointer
 dec   sp         ; decrement byte counter
 jnz   Decrypt    ; loop if more bytes to decrypt
Start:            ; virus code body
```

Cascade Virus Walkthrough

- Setting up the indices:

```
lea   si,Start
          ; start of encrypted code (computed by virus)
```

- The virus does not have a "Start" label whose address is determined by a compiler
  - Instead, it computes the address at infection time, depending on the location in the file being infected
- Virus uses hex offsets; we show "Start" to make it more readable

Cascade Virus Walkthrough

- Stack pointer used as counter

```
mov  sp,0682h  ; length of encrypted code (1666 bytes)
```

- Virus knows its own length before it infects a new file
- Using the stack pointer is an anti-debugger technique
  - Cascade is therefore an armored virus
- However, this line of code is a distinctive pattern (signature) for this virus

Cascade Virus Walkthrough

- The XOR encryption lines:

```
xor  [si],si   ; xor code with its address
xor  [si],sp   ; xor code with its inverse index
```

- The XOR operation is reversible:

<u>0f237h</u> XOR 0682h = 0f4b5h

0f4b5h XOR 0682h = <u>0f237h</u>

- Very fast to encrypt and decrypt, yet sufficient to prevent detection by patterns
  - IMPORTANT: Even the hex patterns are file-dependent, because they depend on addresses

Cascade Virus Walkthrough

- Increment counters/indices and loop:

```
inc  si        ; increment address pointer
dec  sp        ; decrement byte counter
jnz  Decrypt   ; loop if more bytes to decrypt
```

- With pattern-based detection impeded by encryption, an anti-virus researcher would like to step through the decryptor in a debugger and see the decrypted code
- However, use of stack pointer inhibits most debugger use

Analyzing Cascade

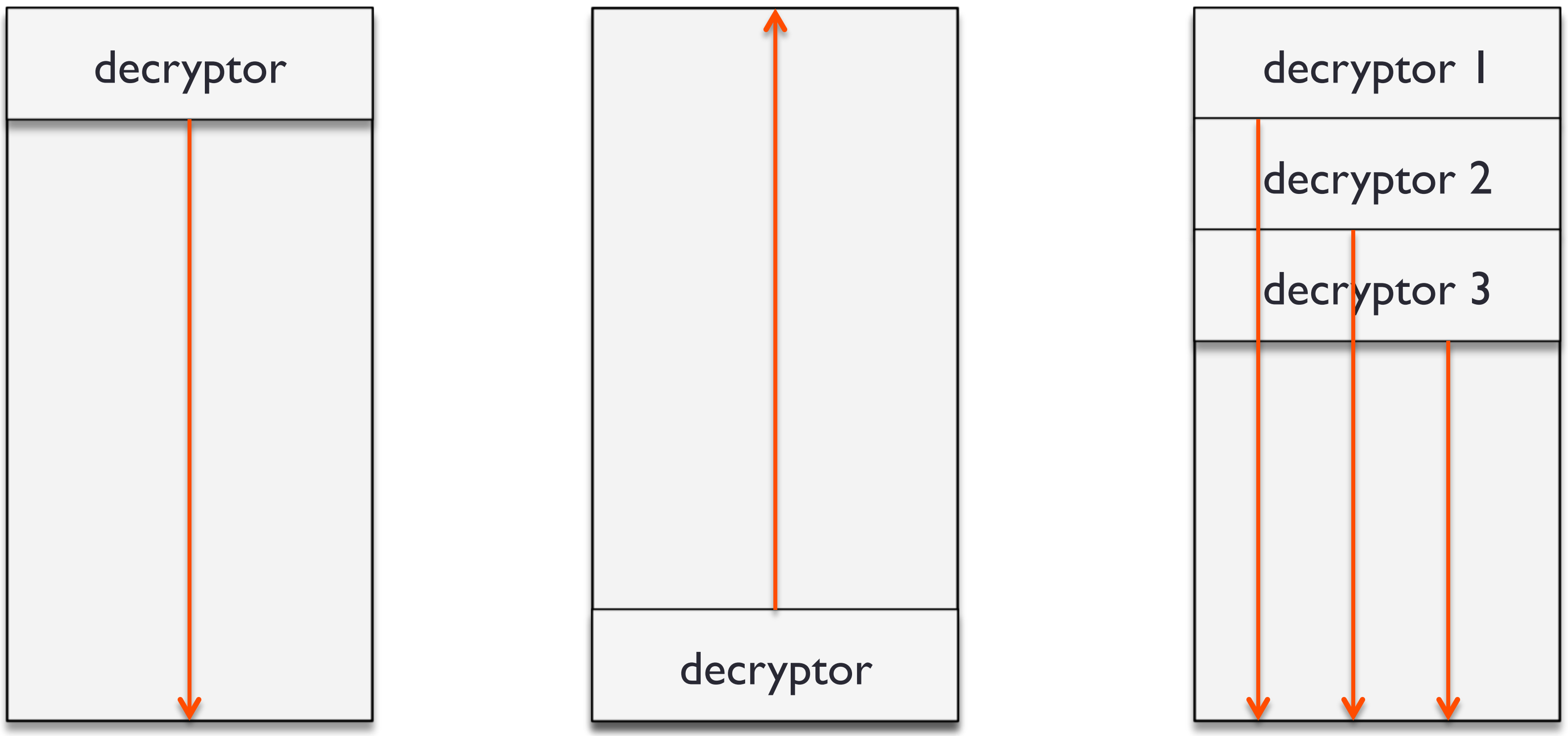
- Prevention in the OS: don't allow writing to the executable code segment
  - Virus writer can work around this by decrypting into a buffer, rather than decrypting code in its place
- The best attack upon a simple encrypted virus is to detect the code patterns of the decryptor, e.g.

```
mov  sp,0682h  ; length of encrypted code (1666 bytes)
```

Difficult Decryptors

- One decryptor loop might traverse the virus body, applying a decryptor function (e.g. XOR or something more complex),
  - then another decryptor loop can traverse the virus code in reverse order applying a different decryption function, etc.
- Unencrypted decryptor code could::
  - decrypt a piece of code that is a more complex decryptor,
  - …which then decrypts another decryptor,
  - …which decrypts the virus
- Static analysis of the patterns of the first decryptor would be irrelevant; that decryptor could be common to many viruses and <u>also</u> to commercial software
  - i.e., first decryptor is legitimate, commonly used decryptor

Decryptor loop examples



Decryptor strategies (cont'd)

- Change decryption direction
- Multiple layers of encryption
- Mixed directions
- One decryptor/Multiple keys
- Obfuscate Decryptor start (EPO) with padding, etc.
- Non-linear decryption

Detecting Decryptors

- The main loop of the decryptor (a tight loop with XORs) looks like it would be a good subject for pattern-based detection
  - But, many different viruses can use the same decryptor algorithm and have totally different payloads and behaviors
- A virus could pad itself out so that it has the same length as other, unrelated viruses – "mimicry"
- **Doh!** Even worse is the fact that some commercial software is obfuscated by an *anti-debug wrapper*, which looks just like the decryptor code for Cascade, in order to prevent reverse engineering of their product
  - Can produce false positives

Detecting Decryptors cont.

- Memory allocation within the decryptor can produce a good code pattern to match
- Decryptor has three locations in which it can decrypt the virus code:
  1. **In place;** OS can disallow this
  2. **In heap;** allocation code is unencrypted and makes pattern-based detection easier
  3. **On the stack;** stealthiest choice --- why?

Detecting Decryptors cont.

- How can an encrypted virus be detected if it uses stack allocation, makes itself look like a commercial anti-debug wrapper, makes itself the same length as unrelated viruses, etc.?
- Emulation and dynamic analysis are common approaches
  - Expensive
  - Proprietary

Virus Code Evolution

- Simile is one example of a virus that *evolves* in order to frustrate pattern-based detection
- Each time it replicates, it generates a different memory allocation code sequence in the decryptor
  - Can be done with simple obfuscations, code re-orderings, etc.
  - No single pattern matches the allocator
- More common is mutating the decryptor code itself and using stack allocation
- We'll have more to say about Simile when we discuss Metamorphism.

Decryptor Mutation

- Viruses that can evolve by mutating as they replicate can be classified in three categories, based on the degree of variety they produce:

1. **Oligomorphic viruses** can produce a few dozen decryptors; they select one at random when replicating
2. **Polymorphic viruses** dynamically generate code rearrangements and randomly insert junk instructions to produce millions of variants
3. **Metamorphic viruses** apply
   1. polymorphic techniques to the entire virus body rather than just to a decryptor, so that
   2. one generation differs greatly from the previous generation;
   3. no encryption is even necessary to be classified as metamorphic

Oligomorphic Viruses

- Detecting encrypted viruses that have distinctive decryptors was too easy (in the opinion of virus writers!)
- Whale was the first oligomorphic virus
- It carried several dozen decryptors in its body as data; when replicating, it
  - selected one at random,
  - encrypted the virus body with it, and
  - deposited the body and the decryptor in the target file

Oligomorphic Viruses cont.

- Carrying the decryptors as data is a burden to the virus, making it larger
- Memorial was a Windows 95 oligomorphic virus that *generated* 96 different decryptors, choosing one at replication time
  - Detecting 96 different patterns is an impractical solution for virus scanners that must deal with thousands of viruses; pattern database size explosion would result
- Memorial inserted junk instructions at various points in the decryptor code

Junk Instructions

- A junk instruction can be a no-op or do-nothing instruction, but it can also be an instruction that uses registers or memory locations that are unused in the decryptor
- Given the following decryptor loop for the Memorial oligomorphic virus:

```
Decrypt:
  xor [esi],al        ; decrypt a byte with key in AL
  inc esi             ; go to next byte
  inc al              ; slide the key up
  dec ecx             ; decrement the byte counter
  jnz Decrypt         ; loop back if more to decrypt
```

Junk Instructions cont.

- Code patterns can be obfuscated with junk instructions:

```
Decrypt:
  add ebx,edx           ; junk
  xor [esi],al          ; decrypt a byte with key in AL
  dec edx               ; junk
  inc esi               ; go to next byte
  mov [whocares],edx ; junk
  inc al                ; slide the key up
  dec ecx               ; decrement the byte counter
  jnz Decrypt           ; loop back if more to decrypt
```

Junk Instructions cont.

- A different variant puts different junk instructions at different offsets:

```
Decrypt:
  add bh,4             ; junk
  xor edx,edx          ; junk
  xor [esi],al         ; decrypt a byte with key in AL
  inc esi              ; go to next byte
  xchg ebx,edx         ; junk
  inc al               ; slide the key up
  cmp ebx,edx          ; junk
  dec ecx              ; decrement the byte counter
  jnz Decrypt          ; loop back if more to decrypt
```

Junk Instructions cont.

- The index increment instructions are order-independent, creating more variants:

```
Decrypt:
  add bh,4            ; junk
  xor edx,edx         ; junk
  xor [esi],al        ; decrypt a byte with key in AL
  inc al              ; slide the key up
  xchg ebx,edx        ; junk
  inc esi             ; go to next byte
  cmp ebx,edx         ; junk
  dec ecx             ; decrement the byte counter
  jnz Decrypt         ; loop back if more to decrypt
```

Junk Instructions cont.

- There is more than one way to increment or decrement counters:

```
Decrypt:
  add bh,4              ; junk
  xor edx,edx           ; junk
  xor [esi],al          ; decrypt a byte with key in AL
  add al,1              ; slide the key up
  xchg ebx,edx          ; junk
  add esi,1             ; go to next byte
  cmp ebx,edx           ; junk
  sub ecx,1             ; decrement the byte counter
  jnz Decrypt           ; loop back if more to decrypt
```

Junk Instructions cont.

- There is more than one way to decrement a counter and loop back if it is not zero:

```
Decrypt:
  add bh,4              ; junk
  xor edx,edx           ; junk
  xor [esi],al          ; decrypt a byte with key in AL
  add al,1              ; slide the key up
  xchg ebx,edx          ; junk
  add esi,1             ; go to next byte
  cmp ebx,edx           ; junk
  loop Decrypt          ; decrement the byte counter and
                        ;   loop back if more to decrypt
```

Detecting Oligomorphic Viruses

- Clearly, it is easy to produce numerous variants of a decryptor
- Filtering out no-ops and do-nothings does not remove the obfuscation
- Emulation, debugging, or proprietary dynamic analyses are needed to produce the decrypted virus for analysis