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Antivirus

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What's an antivirus?

- An antivirus is a piece of software running in background of your computer
- It has mutiple high-level goals:
  - prevent infections by detecting the presence of malicious software
  - remove malicious software from your computer
- It is meant to be a preventions
- Sometimes the malware is able to get in
- In this case the antivirus should be able to
  - disinfect infected programs
  - clean malware from the computer

Main problems AVs face

- Malware tries to self-protect and hide
  - AV evasion techniques
- Malware can use undocumented features of the system
- The attack surface of modern systems is huge
  - applications
  - system services
  - operating systems
  - email
  - network
- A large number of new malicious applications are released on a daily basis
  - the goal has shifted from *intellectual satisfaction* to *money*
  - Also *spying on users* is an important goal (governments, shady organizations, ...)
- Bugs! (AVs are typically implemented in compiled languages.)

quindi, per chi crea AV, è più difficile lavorare senza sapere cosa il malware sfrutta

c e c++, perchè devono esseri veloci!

inoltre AV gira in bg, quindi non può essere pesante. Oltretutto, non sono esenti da bugs.

Current State of AVs

- In the early days, AVs were simple *scanners*
  - command line applications to identify malicious patterns in executable programs
- Modern AVs:
  - scan files in background
  - install firewalls
  - use browser add-ons
- An AV can receive thousands of unique malicious files every day
  - patterns are no longer a suitable way to detect malicious applications
  - *heuristics* have been introduced in most major products

notificato quando viene creato o scritto un nuovo file

browser operano in sandbox, quindi è più facile vederli internamente (con add-ons) che esternamente

patterns non funzionano più, perchè chi crea malware li conosce e può facilmente offuscarli.

Main Components of an AV

- The kernel
- Command-line/GUI scanner
  - can be also *resident* or *real-time*, when they detect file creation/modification
- Daemons or system services (lavorano a livello kernel space)
- File system filter drivers vediamo cosa fa la specifica applicazione, usata molto dagli AV moderni.
- Network filter drivers ispeziona il traffico in/out del sistema. Spesso si cerca di ricreare un grafo delle connessioni in una rete locale.
- Signature database
  - Signatures are the known patterns of malicious files
  - They are consumed by simple pattern-matching techniques
  - Can use CRC (checksums) os MD5 hashes

oggi non patterns, ma plugin: non scarichiamo nuovi pattern, ma nuovi plugin eseguiti dall'antivirus per effettuare specifici check in grado di individuare una certa famiglia di malware. Quindi l'antivirus è un insieme di programmi eseguiti dal core dell'antivirus.

- Unpackers
- File format interpreters (PE, ELF, PNG, JPG, DOCX, PDF, [add your preferred extension here]) alcuni formati sono proprietari (come docx e pdf), e ciò richiede reverse engineering, che spesso si rivela complessa. Ad esempio, in un pdf1, possiamo mettere pdf2, poi ricorsivamente altri pdf dentro.
- Packet filters
- Self-protection mechanisms (avoid kill, ASLR, Data Execution Prevention, ...)
- Emulators E' possibile, per un malware, emulare comportamenti di un SO, quindi un subset delle syscall, per poter lavorare in sandboxes.

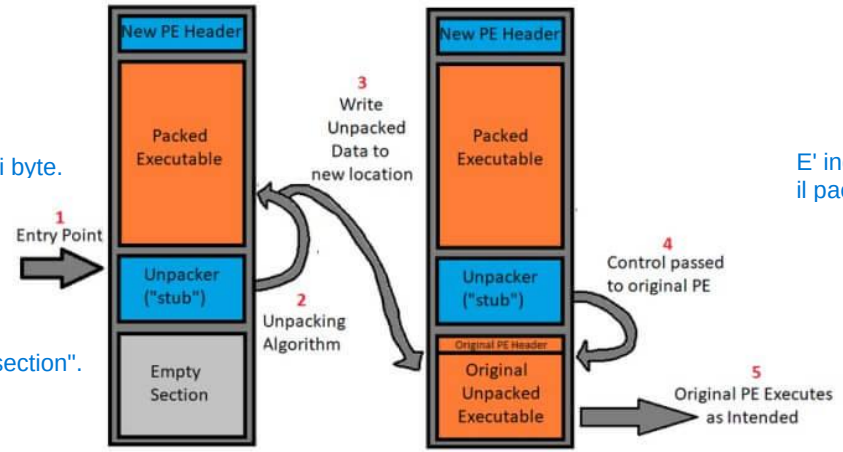
Unpackers

un malware vuole nascondersi dall'antivirus. Abbiamo detto che prima si lavorava su pattern, ma allora basta fare una compressione per alterare la sequenza di byte usata per identificare un malware da ciò che non è.

- Malware is commonly packed with compressors and protectors
  - Sometimes they are just compressed files
  - They can also use encryption
- More advanced techniques transform the code into some bytecode
- This bytecode is coupled with a one or more (randomly-generated) virtual machines to run the original code of the malware

qui c'è l'eseguibile compresso, quindi AV vede solo sequenza di byte.

lo stub/unpacker controlla se malware è eseguibile, facendo il reverse e quindi ottenendo i byte originali, scrivendolo in una "empty section".



E' indipendente da come ho effettuato il packaging.

Indications of a Packed Executable

ci dice le librerie che sono state usate

- Lack of Imports in Import Address Table (IAT)
  - On Windows, often also lacking kernel32.dll and user32.dll
- Non-standard Section Names

senza: no user input, no interazioni, quindi la loro mancanza è strana.

- Sections with a small raw size but a large virtual size

empty section presente, misura 0 sul disco, mentre in memory sarà diversa da 0. Quindi vuole "espandersi"

- Low number of discernible strings

è indice di poca interazione con l'utente.

- Sections with RWX privileges
- jmp or call Instructions to registers/strange memory addresses
  - Many conventional packers store the address where to unpack in registers

Esistono mutable applications, che modificano il path di esecuzione a seconda di ciò che sta succedendo.
Se vediamo la slide precedente, l'unpacker dovrà ridare il controllo al codice originale.

Signatures

se trovassimo signature di unpacker, possiamo individuare qualsiasi malware che sfrutta tale unpacker.

- Signatures are patterns (or pieces of code) that try to match some file against some know malware/exploit
  - In some cases, they are used to check the presence of strings or sequences of bytes in a file
    invece di ispezionare tutto lo spazio del malware, i plugin si concentrano su specifiche sezioni
- In many cases, they are actual programs that are run to parse one specific file
- These programs try to be small and quick, and focus on the results of security engineers
- They try to be as general as possible, but the complexity of the file formats can make it quite simple to evade signature-based scanning
  - A typical example is that of PDF files

Evasion Techniques: Ineffective Code Sequences

- A form of *polymorphic code*

I malware mutano se stessi durante l'esecuzione. Quindi, non si copiano esattamente, ma alterano alcune cose.

1a creazione

```
00401005   8BF0              MOV ESI,EAX
00401007   3E:8A00           MOV AL,BYTE PTR DS:[EAX]
0040100A   84C0              TEST AL,AL
0040100C   74 46             JE SHORT Test.00401054
0040100E   53                PUSH EBX
0040100F   3E:8F05 74F940(   POP DWORD PTR DS:[40F974]
00401016   D3DB              RCR EBX,CL
00401018   0FCB              BSWAP EBX
0040101A   68 56104000       PUSH Test.00401056
0040101F   5B                POP EBX
00401020   3E:8903           MOV DWORD PTR DS:[EBX],EAX
00401023   43                INC EBX
00401024   0FBDC2            BSR EAX,EDX
00401027   A9 46A978DC       TEST EAX,DC78A946
0040102C   8BC2              MOV EAX,EDX
0040102E   52                PUSH EDX
0040102F   B6 86             MOV DH,86
00401031   B3 27             MOV BL,27
00401033   B8 7CFAA17F       MOV EAX,7FA1FA7C
00401038   EB 01             JMP SHORT Test.0040103B
0040103A   90                NOP
0040103B   0FBCC2            BSF EAX,EDX
0040103E   3E:C705 FC8841(   MOV DWORD PTR DS:[4188FC],0
00401049   2D 210DE8B9       SUB EAX,B9E80D21
0040104E   69DA E577D49D     IMUL EBX,EDX,9DD477E5
```

2a creazione

```
00401005   8BF0              MOV ESI,EAX
00401007   3E:8A00           MOV AL,BYTE PTR DS:[EAX]
0040100A   84C0              TEST AL,AL
0040100C   74 4D             JE SHORT Test.0040105B
0040100E   53                PUSH EBX
0040100F   3E:8F05 74F940(   POP DWORD PTR DS:[40F974]
00401016   D3DB              RCR EBX,CL
00401018   0FCB              BSWAP EBX
0040101A   68 5D104000       PUSH Test.0040105D
0040101F   5B                POP EBX
00401020   3E:8903           MOV DWORD PTR DS:[EBX],EAX
00401023   43                INC EBX
00401024   0FBDC2            BSR EAX,EDX
00401027   A9 46A978DC       TEST EAX,DC78A946
0040102C   8BC2              MOV EAX,EDX
0040102E   90                NOP
0040102F   90                NOP
00401030   42                INC EDX
00401031   52                PUSH EDX
00401032   FE0C24            DEC BYTE PTR SS:[ESP]
00401035   4A                DEC EDX
00401036   B6 86             MOV DH,86
00401038   B3 27             MOV BL,27
0040103A   B8 7CFAA17F       MOV EAX,7FA1FA7C
0040103F   EB 01             JMP SHORT Test.00401042
00401041   90                NOP
00401042   0FBCC2            BSF EAX,EDX
00401045   3E:C705 FC8841(   MOV DWORD PTR DS:[4188FC],0
00401050   2D 210DE8B9       SUB EAX,B9E80D21
00401055   69DA E577D49D     IMUL EBX,EDX,9DD477E5
```

due nop, aumentiamo edx, diminuiamo edx, ... quindi non stiamo facendo nulla di che, però in un confronto 1-1 tra le due creazione, non avremo un matching esatto riga-per-riga.

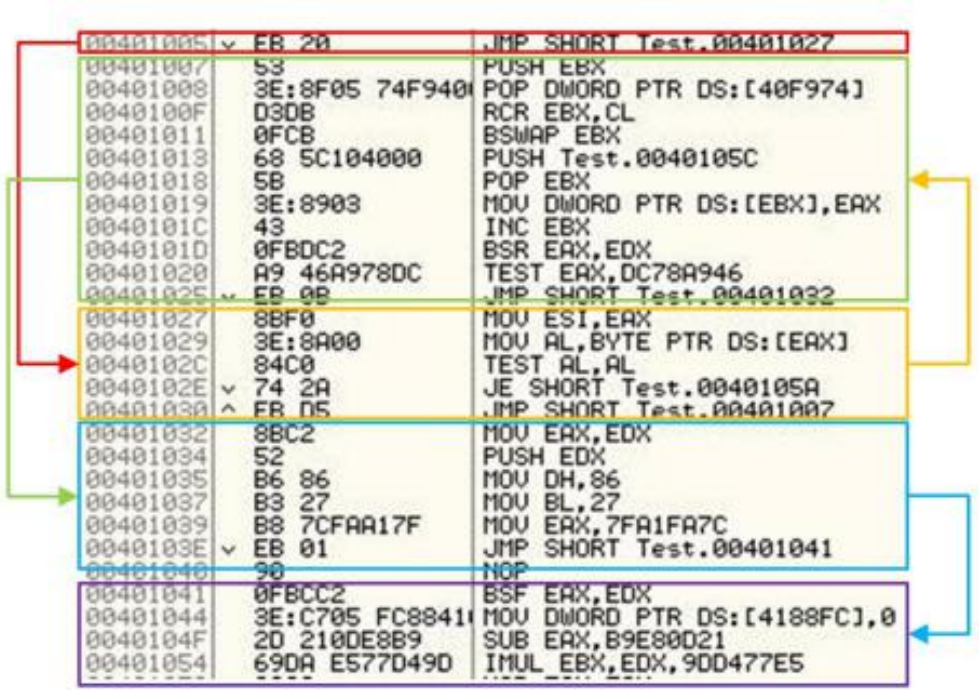
Evasion Techniques: Code Transposition

- Make your code some spaghetti code
- The signature becomes effectively altered

l'idea è dividere il codice in porzioni e mischiarle. L'esecuzione dovrà essere quella originale, quindi verranno sfruttati dei salti per ricomporre il flusso di esecuzione originale. Meglio rispetto alla tecnica precedente, perchè nel caso precedente si può capire che istruzioni come NOP o incremento/decremento di un registro non apportano modifiche.

E' possibile "mischiare" ogni volta pezzi diversi usando diverse chiavi di decoding.

Ovviamente anche queste possono essere ricostruite, in quanto, come abbiamo detto, il flusso di esecuzione sarà sempre unico, ed infatti con le jmp torniamo a quelle.



Polymorphic viruses

- Polymorphic viruses change the decryptor body in the successive generation, during the infection
  - This is similar in spirit to polymorphic code

quindi converto istruzioni (o blocchi) in altri blocchi, sintatticamente diversi, ma semanticamente uguali.

- Simplest implementations use a large number of decryptors, on the order of hundreds (*olygomorphic* viruses).
- Multiple decryptors can be used at once
- The pieces used to build the decryptors are usually common code
  - signature based detection doesn't behave well in this context

Metamorphic virus

non c'è un "unico" momento in cui il malware cambia,
potrebbe essere quando viene aperto, ricevuto, durante l'invio...

- Metamorphic viruses output a logically-equivalent version of its own code under some interpretation.
- Metamorphic viruses often translate their own binary code into a temporary representation which is altered
- The altered temporary representation is then translated back to machine code again
- The main difference from polymorphic viruses is that also the encryption/decryption engine is modified

se non ci concentriamo sul payload, e non su come muta, l'idea è che il malware farà qualcosa!

Behavioral Signatures

- Behavior-based malware detection techniques observe the behavior of a program to conclude whether it is malicious or not
- A behavior based detector concludes whether a program is malicious by inspecting what it does rather than what it says.

- Histogram-based malicious code detection (Symantec)
  - Keep track of occurrence of instructions
  - Keep track of occurrence of *pairs* of instructions
  - Use the histogram (binning) to match against signatures

- Such an approach is typically used in emulated executions

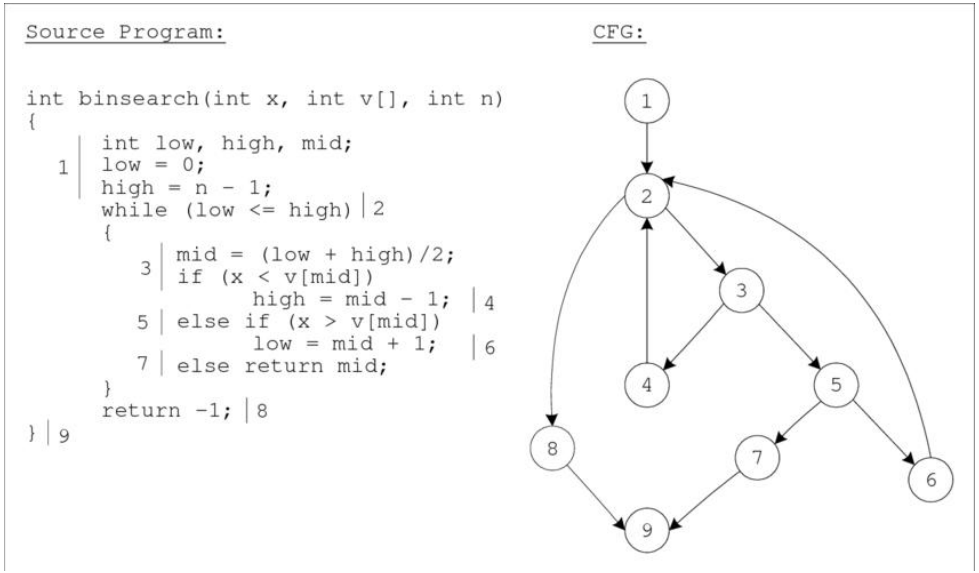
Heuristic Engines

- Typically based on ML techniques, especially classifiers
- API call sequences as a feature of a malware
  - The interaction of a malware with the OS can be an indication of the actions that the application is taking
  - Typically based on classification: millions of malware and benignware used as training sets
- OpCode Sequences
  - The sequence (or binning) of machine instructions can be an indication of the operations that the applications is carrying out
  - Applications are analyzed to determine the frequency of opcodes in the binaries
  - Benignware and malware datasets are filtered using the Mutual Information filtering method
  - Weighted Term Frequency is the used to make a suitable feature vector extracted from executables

Heuristic Engines

sequenza di istruzioni tali che,
se la prima istruzione è eseguita,
allora tutte sono eseguite

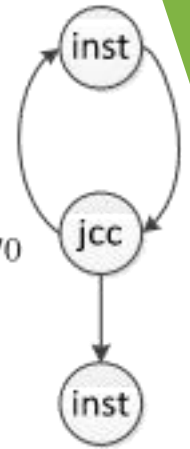
- Call Function Graph is a technique to extract *basic blocks* from a binary
- The links between basic blocks can be an indication of the *semantic* of an application, independently of possible mutations



Heuristic Engines

- Four types of instruction are considered:
  - non-conditional jumps (jmp)
  - conditional jumps (jcc)
  - function calls (call)
  - function returns (ret).

```
0x1288 push ebp
0x128b mov ebp, esp
0x1291 lea edi, [0x405814]
0x1293 mov eax, [ebp+0x8]
0x1299 cmp dword [0x4056c5], 0x270
0x12a3 jnz 0x1288
0x12a5 pop edi
```



- They abstract any contiguous sequence of instructions in a node named “inst”,
- The end of the program comes in a node named “end”.
- These nodes are then reduced:
  - any node of kind inst or jmp, is removed from the graph
  - all its predecessors are linked to its unique successor.
- This graph is used as a signature

n-grams

- In linguistics, an *n-gram* is a contiguous sequence of *n* items from a given sample of text or speech
  - co-occurring words within a given window
  - when computing the n-grams you typically move one word forward
- Example: "*The cow jumps over the moon*", with *n*=2
  - the cow
  - cow jumps
  - jumps over
  - over the
  - the moon

features per individuare i blocchi

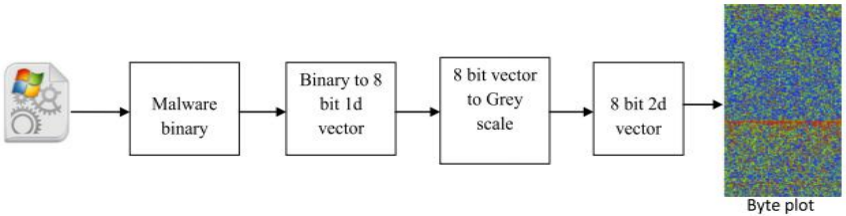
- n-grams over bytes are used with ML methods to detect malicious executables.
- Typical classifiers: Naive-Bayes, Support Vector Machine, Decision Tree

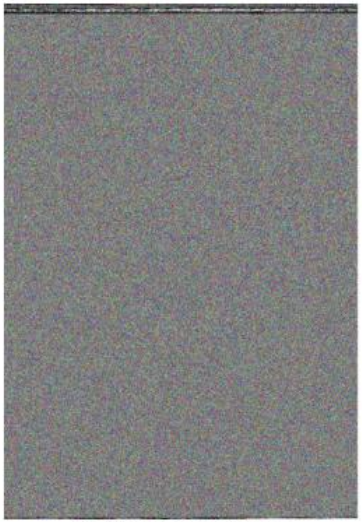
riuso il training set per migliorare la classificazione

- Boosted decision tree typically give the best classification results

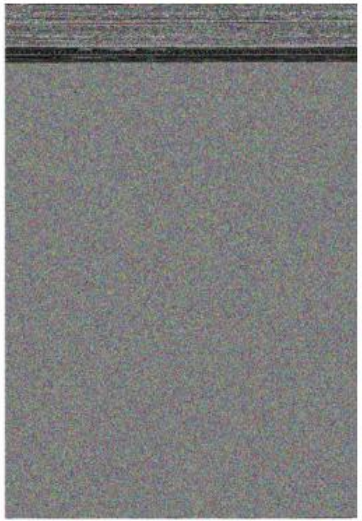
Byteplots

- Transform binaries into images
- Compare the images against known malware




Benign executable

zona nera con molta entropia (visto anche ad AM)


Malware

Emulators

- Signature-based detection or heuristics can be easily circumvented
- Some AVs carry out emulators that allow running applications in sandboxes Antivirus carica malware su sandox per osservare il suo comportamento
  - They implement CPU ISAs
  - They implement APIs offered by operating systems
- Running an application in a sandbox can allow to bypass malware obfuscation techniques
- The application is analyzed within the sandbox

Gli antivirus sono di sicurezza media, quindi questo avvio nelle sandbox è limitato. Questo può portare un virus ad agire normalmente per x secondi, e agire in modo malevolo successivamente. E' facile farlo, basta mettere un loop di 10 secondi per trarre in inganno il malware.

Evasion Techniques: Fingerprinting

- Emulators cannot fully emulate all the services from the OS
- Many functions are simple stubs that return hardcoded values
- An example: `OpenMutexW` in Comodo: (è un antivirus)
  - always returns the magic value `0xBBBB` valore ok per la syscall originale se stiamo in sandbox
  - Chances that an actual call to `OpenMutexW` returns this value are low
- A malware can easily check against hardcoded values returned from stubs
- If a stub is detected, the malware will run some legitimate code

Encrypted Traffic Analysis

- Some antivirus products advertise that they can inspect HTTPS
- They use the same actions that malware does to inspect network traffic and protect customers
  - They launch a MITM attack and install a certificate signed with a trusted certificate authority for the specific domain to be inspected
  - Or, they create new certificates for each new site that its users visit, signing them with a valid CA
  - This is done in Windows by installing a new root certificate
- This approach might lower security
  - It breaks HTTP Public Key Pinning (HPKP)
  - If the implementation is not right, the traffic is vulnerable to TLS attacks
  - Some implementations accept 8-bit Diffie-Hellman key exchanges!
  - A weaker TLS implementation might make vulnerable also antivirus updates

antivirus guarda http traffic, malware lo vede, se la chiave dell'antivirus è debole, malware la scopre e fa MITM, e quindi si protegge cambiando la signature che stiamo scaricando da internet (lo stava facendo l'AV)

Should you trust your AV?

- AVs are complex pieces of software
  - They play an invaluable role at reducing the dissemination of malware
- They are pieces of software anyhow
  - Detection techniques can be jeopardized
  - Some implementations might be buggy
  - Some techniques might lower the security of your system
- Having an antivirus installed is often referred to as the ultimate solution to computer security
- Remember: a secure computer does not exist!
- Feeling safe just because you installed a software might lower the attention of the user