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10. Introduction to Malware Analysis

Introduction To Malware & Malware Analysis

It is essential to clarify that this module does not claim to be an all-encompassing or exhaustive program on Malware Analysis. This module provides a robust foundation for SOC analysts, enabling them to confidently tackle key Malware Analysis tasks. The primary focus of the module will be the analysis of malware targeting the Windows Operating System.

Malware Definition

`Malware`, short for malicious software, is a term encompassing various types of software designed to infiltrate, exploit, or damage computer systems, networks, and data.

Although all malware is utilized for malicious intents, the specific objectives of malware can vary among different threat actors. These objectives commonly fall into several categories:

- Disrupting host system operations
- Stealing critical information, including personal and financial data
- Gaining unauthorized access to systems
- Conducting espionage activities
- Sending spam messages
- Utilizing the victim's system for Distributed Denial of Service (DDoS) attacks
- Implementing ransomware to lock up victim's files on their host and demanding ransom

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Malware Types

In today's fast-paced world of cyber threats, we find ourselves up against a broad spectrum of complex and varied malware forms, which pose a relentless challenge to our cyber defenses. It's paramount for us to grasp the multifaceted nature of malicious software as we endeavor to bolster the security of our systems and networks. Let's peel back the layers of some commonly seen types of malware that we frequently grapple with in our cybersecurity endeavors.

- `Viruses`: These notorious forms of malware are designed to infiltrate and multiply within host files, transitioning from one system to another. They latch onto credible programs, springing into action when the infected files are triggered. Their destructive powers can range from corrupting or altering data to disrupting system functions, and even spreading through networks, inflicting widespread havoc.
- `Worms`: Worms are autonomous malware capable of multiplying across networks without needing human intervention. They exploit network weaknesses to infiltrate systems without permission. Once inside, they can either deliver damaging payloads or

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keep multiplying to other vulnerable devices. Worms can initiate swift and escalating infections, resulting in enormous disruption and even potential denial of service attacks.

- `Trojans`: Also known as Trojan Horses, these are disguised as genuine software to trick users into running them. Upon entering a system, they craft backdoors, allowing attackers to gain unauthorized control remotely. Trojans can be weaponized to pilfer sensitive data, such as passwords or financial information, and orchestrate other harmful activities on the compromised system.
- `Ransomware`: This malicious type of malware encrypts files on the target's system, making them unreachable. Attackers then demand a ransom in return for the decryption key, effectively holding the victim's data to ransom. The impacts of ransomware attacks can debilitate organizations and individuals alike, leading to severe financial and reputational harm.
- `Spyware`: This type of malware stealthily gathers sensitive data and user activities without their consent. It can track online browsing habits, record keystrokes, and capture login credentials, posing a severe risk to privacy and security. The pilfered data is often sent to remote servers for harmful purposes.
- `Adware`: Though not as destructive, adware can still be an annoyance and a security threat. It shows uninvited and invasive advertisements on infected systems, often resulting in a poor user experience. Adware may also track user behavior and collect data for targeted advertising.
- `Botnets`: These are networks of compromised devices, often referred to as bots or zombies, controlled by a central command-and-control (C2) server. Botnets can be exploited for a variety of harmful activities, including launching DDoS attacks, spreading spam, or disseminating other malware.
- `Rootkits`: These are stealthy forms of malware designed to gain unauthorized access and control over the fundamental components (the "root") of an operating system. They alter system functions to conceal their presence, making them extremely challenging to spot and eliminate. Attackers can utilize rootkits to maintain prolonged access and dodge security protocols.
- `Backdoors/RATs (Remote Access Trojans)`: Backdoors and RATs are crafted to offer unauthorized access and control over compromised systems from remote locations. Attackers can leverage them to retain prolonged control, extract data, or instigate additional attacks.
- `Droppers`: These are a kind of malware used to transport and install extra malicious payloads onto infected systems. They serve as a conduit for other malware, ensuring the covert installation and execution of more sophisticated threats.
- `Information Stealers`: These are tailored to target and extract sensitive data, like login credentials, personal information, or intellectual property, for harmful purposes. This includes identity theft or selling the data on the dark web.

These examples barely scratch the surface of the types of malware we confront in today's threat landscape. It's essential to remember that cybercriminals consistently refine their

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strategies, techniques, and malware variants to avoid detection and exploit new vulnerabilities.

Malware Samples

When it comes to enhancing our cybersecurity defenses and understanding the threats that exist, sometimes we have to dive into the dark corners of the cyber world. This means getting our hands on actual malware samples, be it for research, analysis, or educational purposes. However, it's crucial to emphasize that dealing with real malware samples should be done in a safe and controlled environment to prevent accidental infections and potential harm. Here are some resources, both free and paid, where we can find such samples.

- VirusShare: An excellent resource for malware researchers, VirusShare houses a vast collection of malware samples. They currently have over 30 million samples in their repository, all of which are freely available to the public.
- Hybrid Analysis: This website allows us to submit files for malware analysis. However, they also have a public feed of their analyses, where malware samples are often shared.
- TheZoo: A GitHub repository that contains a collection of live malware for analysis and education. The repository also contains additional information about each sample, such as its family and the type of activities it performs.
- Malware-Traffic-Analysis.net: This website provides traffic analysis exercises that can be extremely beneficial for people trying to learn about malware traffic patterns. They often provide pcap files of actual malware traffic, which can be quite informative.
- VirusTotal: VirusTotal inspects items with over 70 antivirus scanners and URL/domain blocklisting services, in addition to a myriad of tools to extract signals from the studied content. Any user can select a file from their computer using their browser and send it to VirusTotal. VirusTotal offers a number of file submission methods, including the primary public web interface, desktop uploaders, browser extensions and a programmatic API.
- ANY.RUN: An interactive online sandbox for malware analysis. The service allows researchers to analyze malware behavior by running samples in a controlled environment. While it offers both free and paid tiers, even the free version provides access to public submissions, which can include various malware samples.
- Contagio Malware Dump: Contagio Dump is a collection of malware samples, threat reports, and related resources curated by a malware researcher named Mila. The site provides direct, anonymized access to an extensive range of malware samples, including various types of trojans, worms, ransomware, and exploits. It's frequently used by security researchers and analysts to study malware behavior and develop mitigation techniques.
- VX Underground: VX-Underground is one of the largest collections of malware source code, articles, and papers on the internet. It aims to collect, preserve, and share all kinds of materials related to malware, exploit, and hacking culture. This resource is

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valuable to security researchers and enthusiasts who want to study malware construction and behavior from a more technical and code-centric perspective.

Malware/Evidence Acquisition

When it comes to gathering evidence during a digital forensics investigation or incident response, having the right tools to perform disk imaging and memory acquisition is crucial. Let's discuss some free solutions we can use to collect the necessary data for our investigations.

Disk Imaging Solutions

- FTK Imager: Developed by AccessData (now acquired by Exterro), FTK Imager is one of the most widely used disk imaging tools in the cybersecurity field. It allows us to create perfect copies (or images) of computer disks for analysis, preserving the integrity of the evidence. It also lets us view and analyze the contents of data storage devices without altering the data.
- OSFClone: A free, open-source utility designed for the task of creating and cloning forensic disk images. It's easy to use and supports a wide variety of file systems.
- `DD and DCFLDD` : Both are command-line utilities available on Unix-based systems (including Linux and MacOS). DD is a versatile tool included in most Unix-based systems by default, while DCFLDD is an enhanced version of DD with features specifically useful for forensics, such as hashing.

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Memory Acquisition Solutions

- DumpIt: A simplistic utility that generates a physical memory dump of Windows and Linux machines. On Windows, it concatenates 32-bit and 64-bit system physical memory into a single output file, making it extremely easy to use.
- MemDump: MemDump is a free, straightforward command-line utility that enables us to capture the contents of a system's RAM. It’s quite beneficial in forensics investigations or when analyzing a system for malicious activity. Its simplicity and ease of use make it a popular choice for memory acquisition.
- Belkasoft RAM Capturer: This is another powerful tool we can use for memory acquisition, provided free of charge by Belkasoft. It can capture the RAM of a running Windows computer, even if there's active anti-debugging or anti-dumping protection. This makes it a highly effective tool for extracting as much data as possible during a live forensics investigation.
- Magnet RAM Capture: Developed by Magnet Forensics, this tool provides a free and simple way to capture the volatile memory of a system.
- LiME (Linux Memory Extractor): LiME is a Loadable Kernel Module (LKM) which allows the acquisition of volatile memory. LiME is unique in that it's designed to be transparent to the target system, evading many common anti-forensic measures.

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Other Evidence Acquisition Solutions

- KAPE (Kroll Artifact Parser and Extractor): KAPE is a triage program designed to help in collecting and parsing artifacts in a quick and effective manner. It focuses on targeted collection, reducing the volume of collected data and the time required for analysis. KAPE is free for use and is an essential tool in our digital forensics toolkit.
- Velociraptor: Velociraptor is a versatile tool designed for host-based incident response and digital forensics. It allows for quick, targeted data collection across a wide number of machines. Velociraptor employs Velocidex Query Language (VQL), a powerful tool to collect and manipulate artifacts. The open-source nature of Velociraptor makes it a valuable free tool in our arsenal.

Malware Analysis Definition, Purpose, & Common Activities

The process of comprehending the behavior and inner workings of malware is known as `Malware Analysis`, a crucial aspect of cybersecurity that aids in understanding the threat posed by malicious software and devising effective countermeasures.

In our pursuit of Malware Analysis, we delve into the malware's code, structure, and functionality to gain profound insights into its purpose, propagation methods, and potential impact on targeted systems. By answering pertinent questions, such as the type of malware (e.g., spybot, keylogger, ransomware), its intended behavior on endpoints, the aftermath of its execution (including generated artifacts on the network or endpoint and possible connections to Command and Control (C2) servers), the extent of damage it can inflict, its attribution to specific threat groups, and crafting detection rules based on the analysis to detect the malware across the entire network, we can devise robust defense mechanisms against these threats.

Malware analysis serves several pivotal `purposes`, such as:

- `Detection and Classification`: Through analyzing malware, we can identify and categorize different types of threats based on their unique characteristics, signatures, or patterns. This enables us to develop detection rules and empowers security professionals to gain a comprehensive understanding of the nature of the malware they encounter.
- `Reverse Engineering`: Malware analysis often involves the intricate process of reverse engineering the malware's code to discern its underlying operations and employed techniques. This can unveil concealed functionalities, encryption methods, details about the command-and-control infrastructure, and techniques used for obfuscation and evasion.

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- `Behavioral Analysis`: By meticulously studying the behavior of malware during execution, we gain insights into its actions, such as modifications to the file system, network communications, changes to the system registry, and attempts to exploit vulnerabilities. This analysis provides invaluable information about the impact of the malware on infected systems and assists in devising potential countermeasures.
- `Threat Intelligence`: Through malware analysis, threat researchers can amass critical intelligence about attackers, their tactics, techniques, and procedures (TTPs), and the malware's origins. This valuable intelligence can be shared with the wider security community to enhance detection, prevention, and response capabilities.

The `techniques` employed in malware analysis encompass a wide array of methods and tools, including:

- `Static Analysis`: This approach involves scrutinizing the malware's code without executing it, examining the file structure, identifying strings, searching for known signatures, and studying metadata to gain preliminary insights into the malware's characteristics.
- `Dynamic Analysis`: Dynamic analysis entails executing the malware within a controlled environment, such as a sandbox or virtual machine, to observe its behavior and capture its runtime activities. This includes monitoring network traffic, system calls, file system modifications, and other interactions.
- `Code Analysis`: Code analysis (includes reverse engineering) and involves disassembling or decompiling the malware's code to understand its logic, functions, algorithms, and employed techniques. This helps in identifying concealed functionalities, exploitation methods, encryption methods, details about the command-and-control infrastructure, and techniques used for obfuscation and evasion. Inferentially, code analysis can also help in uncovering potential Indicators of Compromise (IOCs).
- `Memory Analysis`: Analyzing the malware's interactions with system memory helps in identifying injected code, hooks, or other runtime manipulations. This can be instrumental in detecting rootkits, analyzing anti-analysis techniques, or identifying malicious payloads.
- `Malware Unpacking`: This technique refers to the process of extracting and isolating the hidden malicious code within a piece of malware that uses packing techniques to evade detection. Packers are used by malware authors to compress, encrypt, or obfuscate their malicious code, making it harder for antivirus software and other security tools to identify the threat. Unpacking involves reverse-engineering these packing techniques to reveal the original, unobfuscated code for further analysis. This can allow researchers to understand the malware's functionality, behavior, and potential impact.

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In today's ever-evolving threat landscape, the usage of malware analysis plays a pivotal role in our cybersecurity defense strategies. As cyber threats become increasingly sophisticated, we must continually enhance our capabilities to identify, analyze, and mitigate the risks posed by malicious software.

Through malware analysis, we gain invaluable insights into the nature of the threats we face. Understanding the malware's specific attributes allows us to tailor our response tactics accordingly, addressing each threat with precision.

Windows Internals

To conduct effective malware analysis, a profound understanding of Windows internals is essential. Windows operating systems function in two main modes:

- `User Mode`: This mode is where most applications and user processes operate. Applications in user mode have limited access to system resources and must interact with the operating system through Application Programming Interfaces (APIs). These processes are isolated from each other and cannot directly access hardware or critical system functions. However, in this mode, malware can still manipulate files, registry settings, network connections, and other user-accessible resources, and it may attempt to escalate privileges to gain more control over the system.
- `Kernel Mode`: In contrast, kernel mode is a highly privileged mode where the Windows kernel runs. The kernel has unrestricted access to system resources, hardware, and critical functions. It provides core operating system services, manages system resources, and enforces security and stability. Device drivers, which facilitate communication with hardware devices, also run in kernel mode. If malware operates in kernel mode, it gains elevated control and can manipulate system behavior, conceal its presence, intercept system calls, and tamper with security mechanisms.

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Windows Architecture At A High Level

The below image showcases a simplified version of Windows' architecture.

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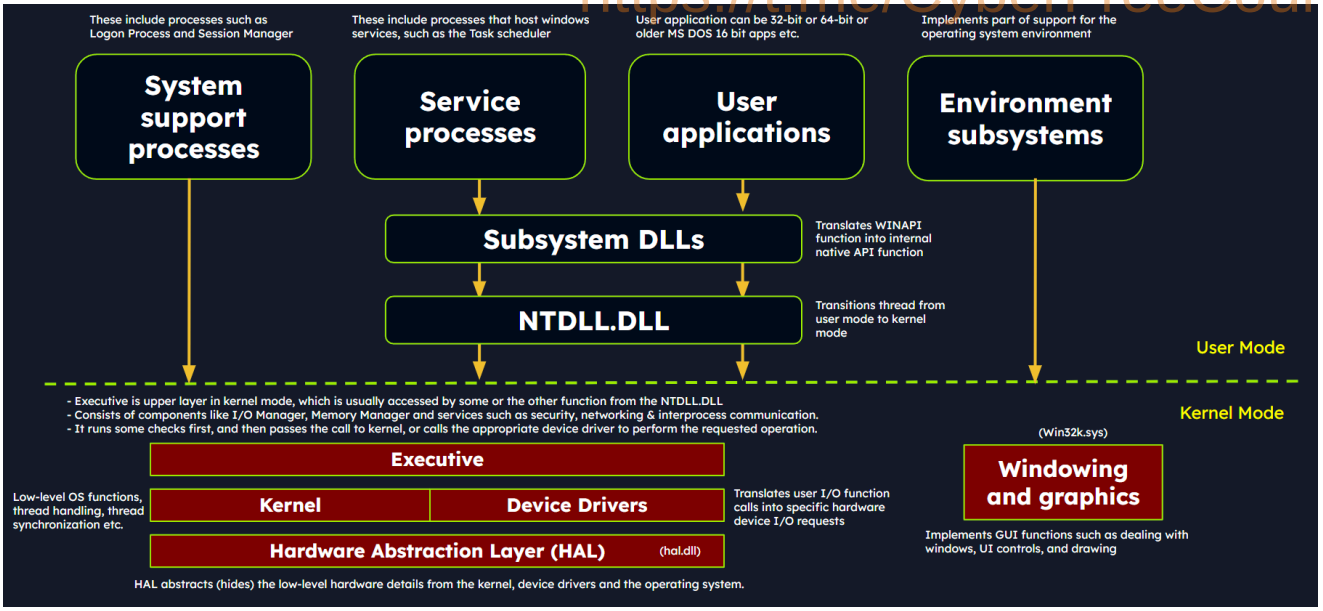

The simplified Windows architecture comprises both user-mode and kernel-mode components, each with distinct responsibilities in the system's functioning.

User-mode Components

`User-mode components` are those parts of the operating system that don't have direct access to hardware or kernel data structures. They interact with system resources through APIs and system calls. Let's discuss some of them:

- `System Support Processes`: These are essential components that provide crucial functionalities and services such as logon processes (`winlogon.exe`), Session Manager (`smss.exe`), and Service Control Manager (`services.exe`). These aren't Windows services but they are necessary for the proper functioning of the system.
- `Service Processes`: These processes host Windows services like the `Windows Update Service`, `Task Scheduler`, and `Print Spooler` services. They usually run in the background, executing tasks according to their configuration and parameters.
- `User Applications`: These are the processes created by user programs, including both 32-bit and 64-bit applications. They interact with the operating system through APIs provided by Windows. These API calls get redirected to NTDLL.DLL, triggering a transition from user mode to kernel mode, where the system call gets executed. The result is then returned to the user-mode application, and a transition back to user mode occurs.
- `Environment Subsystems`: These components are responsible for providing execution environments for specific types of applications or processes. They include the Win32 Subsystem, POSIX, and OS/2.
- `Subsystem DLLs`: These dynamic-link libraries translate documented functions into appropriate internal native system calls, primarily implemented in `NTDLL.DLL`. Examples include `kernelbase.dll`, `user32.dll`, `wininet.dll`, and `advapi32.dll`.

Kernel-mode Components

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`Kernel-mode components` are those parts of the operating system that have direct access to hardware and kernel data structures. These include:

- `Executive`: This upper layer in kernel mode gets accessed through functions from `NTDLL.DLL`. It consists of components like the `I/O Manager`, `Object Manager`, `Security Reference Monitor`, `Process Manager`, and others, managing the core aspects of the operating system such as I/O operations, object management, security, and processes. It runs some checks first, and then passes the call to kernel, or calls the appropriate device driver to perform the requested operation.
- `Kernel`: This component manages system resources, providing low-level services like `thread scheduling`, `interrupt and exception dispatching`, and `multiprocessor synchronization`.
- `Device Drivers`: These software components enable the OS to interact with hardware devices. They serve as intermediaries, allowing the system to manage and control hardware and software resources.
- `Hardware Abstraction Layer (HAL)`: This component provides an abstraction layer between the hardware devices and the OS. It allows software developers to interact with hardware in a consistent and platform-independent manner.
- `Windowing and Graphics System (Win32k.sys)`: This subsystem is responsible for managing the graphical user interface (GUI) and rendering visual elements on the screen.

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Now, let's discuss in what happens behind the scenes when an user application calls a Windows API function.

Windows API Call Flow

Malware often utilize Windows API calls to interact with the system and carry out malicious operations. By understanding the internal details of API functions, their parameters, and expected behavior, analysts can identify suspicious or unauthorized API usage.

Let's consider an example of a Windows API call flow, where a user-mode application tries to access privileged operations and system resources using the ReadProcessMemory function. This function allows a process to read the memory of a different process.

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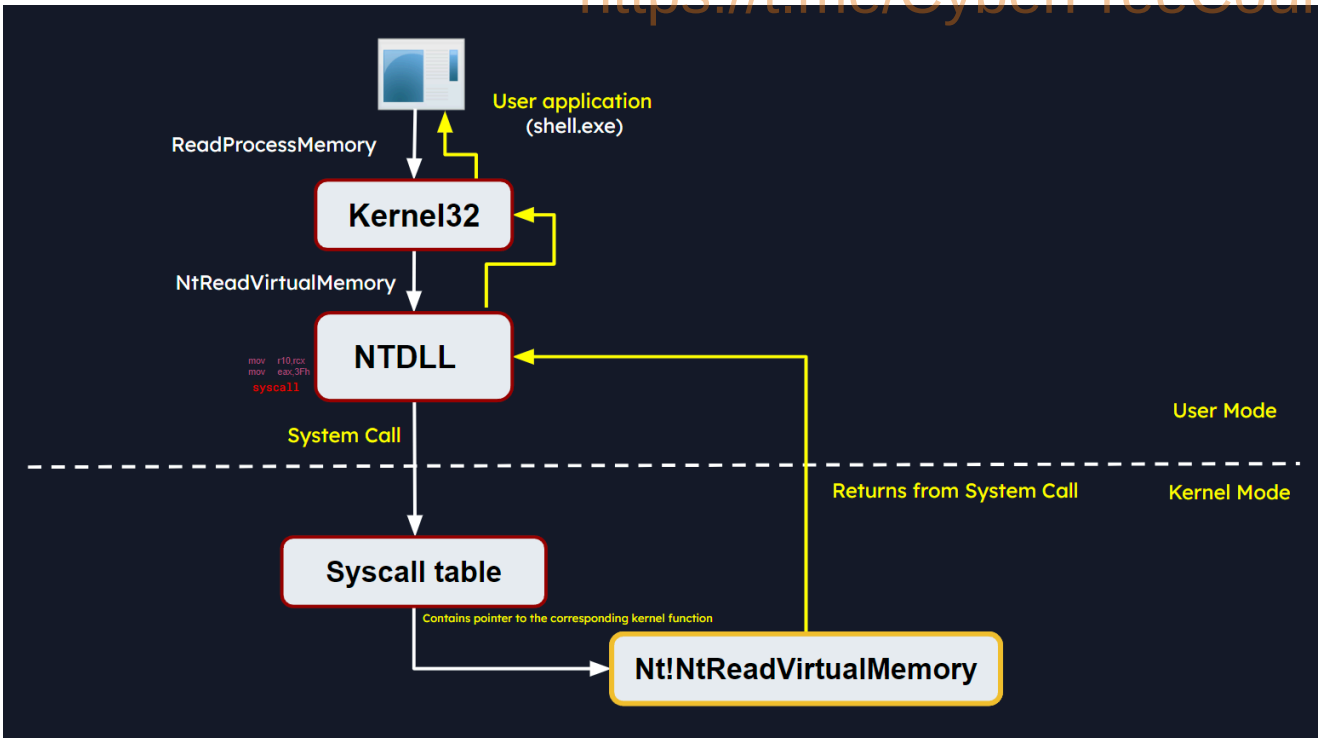

When this function is called, some required parameters are also passed to it, such as the handle to the target process, the source address to read from, a buffer in its own memory space to store the read data, and the number of bytes to read. Below is the syntax of `ReadProcessMemory` WINAPI function as per Microsoft documentation.

```
BOOL ReadProcessMemory(
  [in]  HANDLE  hProcess,
  [in]  LPCVOID lpBaseAddress,
  [out] LPVOID  lpBuffer,
  [in]  SIZE_T  nSize,
  [out] SIZE_T  *lpNumberOfBytesRead
);
```

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```C++
BOOL ReadProcessMemory(
  [in]  HANDLE  hProcess,
  [in]  LPCVOID lpBaseAddress,
  [out] LPVOID  lpBuffer,
  [in]  SIZE_T  nSize,
  [out] SIZE_T  *lpNumberOfBytesRead
);
```

`ReadProcessMemory` is a Windows API function that belongs to the `kernel32.dll` library. So, this call is invoked via the `kernel32.dll` module which serves as the user mode interface to the Windows API. Internally, the `kernel32.dll` module interacts with the `NTDLL.DLL` module, which provides a lower-level interface to the Windows kernel. Then, this function request is translated to the corresponding Native API call, which is

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`NtReadVirtualMemory`. The below screenshot from `x64dbg` demonstrates how this looks like in a debugger.

```
48:83EC 48          sub rsp,48                                  ReadProcessMemory
48:8D4424 30        lea rax,qword ptr ss:[rsp+30]
48:894424 20        mov qword ptr ss:[rsp+20],rax
48:FF15 F30416      call qword ptr ds:[<&NtReadVirtualMemory>]
0F1F4400 00         nop dword ptr ds:[rax+rax],eax
48:8B5424 70        mov rdx,qword ptr ss:[rsp+70]
48:85D2             test rdx,rdx
```

The `NTDLL.DLL` module utilizes system calls (syscalls).

```
4C:8BD1             mov r10,rcx                                 NtReadVirtualMemory
B8 3F000000         mov eax,3F   Syscall Number                 3F:'?'
F60425 0803FE7      test byte ptr ds:[7FFE0308],1
75 03               jne ntdll.7FFD0C1CD7E5
0F05                syscall   Syscall instruction
C3                  ret
CD 2E               int 2E
C3                  ret
```

The `syscall` instruction triggers the system call using the parameters set in the previous instructions. It transfers control from user mode to kernel mode, where the kernel performs the requested operation after validating the parameters and checking the access rights of the calling process.

If the request is authorized, the thread is transitioned from user mode into the kernel mode. The kernel maintains a table known as the `System Service Descriptor Table (SSDT)` or the `syscall table (System Call Table)`, which is a data structure that contains pointers to the various system service routines. These routines are responsible for handling system calls made by user-mode applications. Each entry in the syscall table corresponds to a specific system call number, and the associated pointer points to the corresponding kernel function that implements the requested operation.

The syscall responsible for `ReadProcessMemory` is executed in the kernel, where the Windows memory management and process isolation mechanisms are leveraged. The kernel performs necessary validations, access checks, and memory operations to read the memory from the target process. The kernel retrieves the physical memory pages corresponding to the requested virtual addresses and copies the data into the provided buffer.

Once the kernel has finished reading the memory, it transitions the thread back to user mode and control is handed back to the original user mode application. The application can then access the data that was read from the target process's memory and continue its execution.

Let's now navigate to the bottom of this section and click on "Click here to spawn the target system!". Then, let's RDP into the Target IP using the provided credentials. The vast majority of the actions/commands covered from this point up to end of this section can be replicated inside the target, offering a more comprehensive grasp of the topics presented.

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```
xfreerdp /u:htb-student /p:'HTB_@cademy_stdnt!' /v:[Target IP] /dynamic-resolution
```

Portable Executable

Windows operating systems employ the `Portable Executable (PE)` format to encapsulate executable programs, `DLLs (Dynamic Link Libraries)`, and other integral system components. In the realm of malware analysis, an intricate understanding of the PE file format is indispensable. It allows us to gain significant insights into the executable's structure, operations, and potential malign activities embedded within the file.

PE files accommodate a wide variety of data types including `executables (.exe)`, `dynamic link libraries (.dll)`, `kernel modules (.srv)`, `control panel applications (.cpl)`, and many more. The PE file format is fundamentally a data structure containing the vital information required for the Windows OS loader to manage the executable code, effectively loading it into memory.

PE Sections

The PE Structure also houses a `Section Table`, an element comprising several sections dedicated to distinct purposes. The sections are essentially the repositories where the actual content of the file, including the data, resources utilized by the program, and the executable code, is stored. The `.text` section is often under scrutiny for potential artifacts related to injection attacks.

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Common PE sections include:

- `Text Section (.text)`: The hub where the executable code of the program resides.
- `Data Section (.data)`: A storage for initialized global and static data variables.
- `Read-only initialized data (.rdata)`: Houses read-only data such as constant values, string literals, and initialized global and static variables.
- `Exception information (.pdata)`: A collection of function table entries utilized for exception handling.
- `BSS Section (.bss)`: Holds uninitialized global and static data variables.
- `Resource Section (.rsrc)`: Safeguards resources such as images, icons, strings, and version information.
- `Import Section (.idata)`: Details about functions imported from other DLLs.
- `Export Section (.edata)`: Information about functions exported by the executable.
- `Relocation Section (.reloc)`: Details for relocating the executable's code and data when loaded at a different memory address.

We can visualize the sections of a portable executable using a tool like `pestudio` as demonstrated below.

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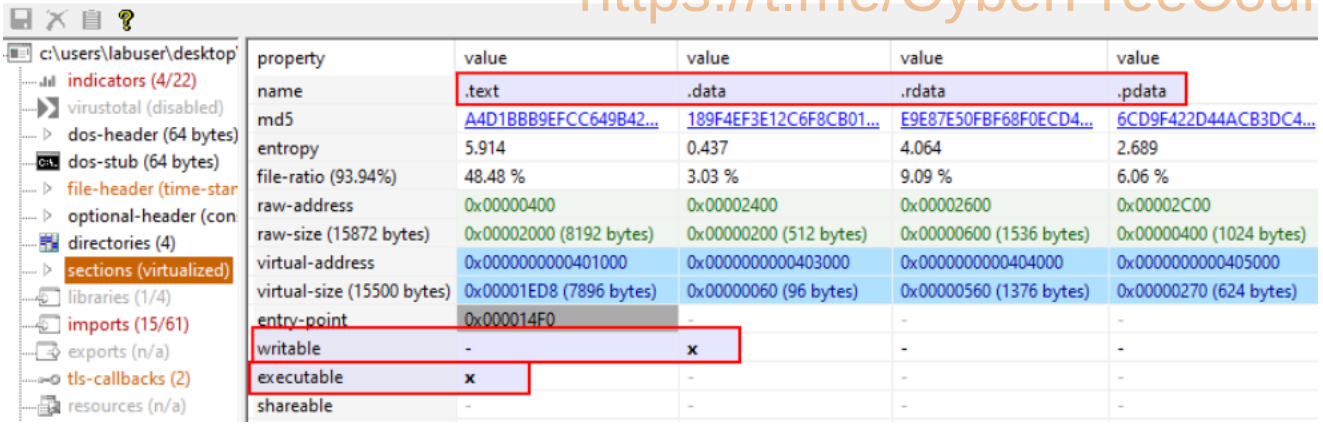

c:\users\labuser\desktop'
- indicators (4/22)
- virustotal (disabled)
- dos-header (64 bytes)
- dos-stub (64 bytes)
- file-header (time-star
- optional-header (con
- directories (4)
- sections (virtualized)
- libraries (1/4)
- imports (15/61)
- exports (n/a)
- tls-callbacks (2)
- resources (n/a)

property	value	value	value	value
name	.text	.data	.rdata	.pdata
md5	A4D1BBB9EFCC649B42...	189F4EF3E12C6F8CB01...	E9E87E50FBF68F0ECD4...	6CD9F422D44ACB3DC4...
entropy	5.914	0.437	4.064	2.689
file-ratio (93.94%)	48.48 %	3.03 %	9.09 %	6.06 %
raw-address	0x00000400	0x00002400	0x00002600	0x00002C00
raw-size (15872 bytes)	0x00002000 (8192 bytes)	0x00000200 (512 bytes)	0x00000600 (1536 bytes)	0x00000400 (1024 bytes)
virtual-address	0x0000000000401000	0x0000000000403000	0x0000000000404000	0x0000000000405000
virtual-size (15500 bytes)	0x00001ED8 (7896 bytes)	0x00000060 (96 bytes)	0x00000560 (1376 bytes)	0x00000270 (624 bytes)
entry-point	0x000014F0	-	-	-
writable	-	x	-	-
executable	x	-	-	-
shareable	-	-	-	-

Delving into the Portable Executable (PE) file format is pivotal for malware analysis, offering insights into the file's structure, code analysis, import and export functions, resource analysis, anti-analysis techniques, and extraction of indicators of compromise. Our comprehension of this foundation paves the way for efficacious malware analysis.

Processes

In the simplest terms, a process is an instance of an executing program. It represents a slice of a program's execution in memory and consists of various resources, including memory, file handles, threads, and security contexts.

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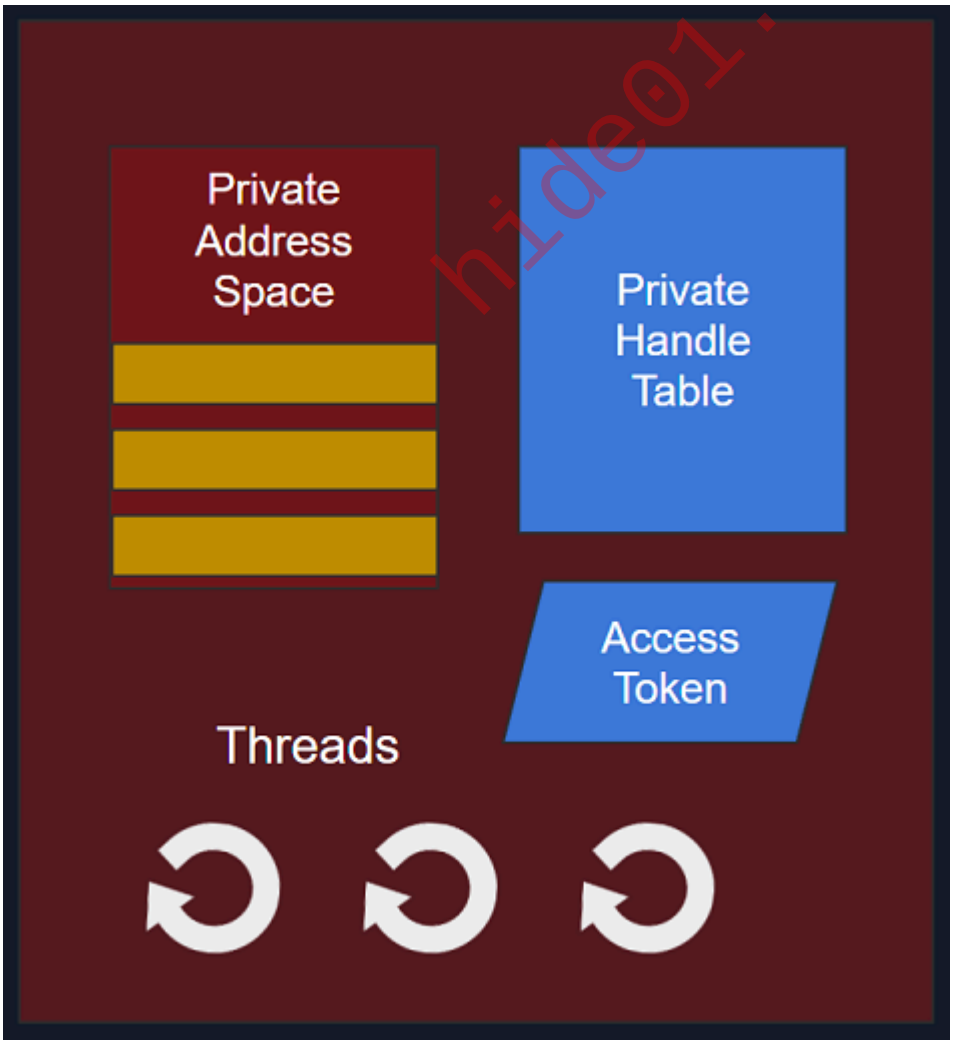

Each process is characterized by:

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- `A unique PID (Process Identifier)`: A unique Process Identifier (PID) is assigned to each process within the operating system. This numeric identifier facilitates the tracking and management of the process by the operating system.
- `Virtual Address Space (VAS)`: In the Windows OS, every process is allocated its own virtual address space, offering a virtualized view of the memory for the process. The VAS is sectioned into segments, including code, data, and stack segments, allowing the process isolated memory access.
- `Executable Code (Image File on Disk)`: The executable code, or the image file, signifies the binary executable file stored on the disk. It houses the instructions and resources necessary for the process to operate.
- `Table of Handles to System Objects`: Processes maintain a table of handles, a reference catalogue for various system objects. System objects can span files, devices, registry keys, synchronization objects, and other resources.
- `Security Context (Access Token)`: Each process has a security context associated with it, embodied by an `Access Token`. This `Access Token` encapsulates information about the process's security privileges, including the user account under which the process operates and the access rights granted to the process.
- `One or More Threads Running in its Context`: Processes consist of one or more threads, where a thread embodies a unit of execution within the process. Threads enable concurrent execution within the process and facilitate multitasking.

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Dynamic-link library (DLL)

A Dynamic-link library (DLL) is a type of PE which represents "Microsoft's implementation of the shared library concept in the Microsoft Windows OS". DLLs expose an array of functions which can be exploited by malware, which we'll scrutinize later. First, let's unravel the import and export functions in a DLL.

Import Functions

- Import functions are functionalities that a binary dynamically links to from external libraries or modules during runtime. These functions enable the binary to leverage the functionalities offered by these libraries.
- During malware analysis, examining import functions may shed light on the external libraries or modules that the malware is dependent on. This information aids in identifying the APIs that the malware might interact with, and also the resources such as the file system, processes, registry etc.
- By identifying specific functions imported, it becomes possible to ascertain the actions the malware can perform, such as file operations, network communication, registry manipulation, and more.
- Import function names or hashes can serve as IOCs (Indicators of Compromise) that assist in identifying malware variants or related samples.

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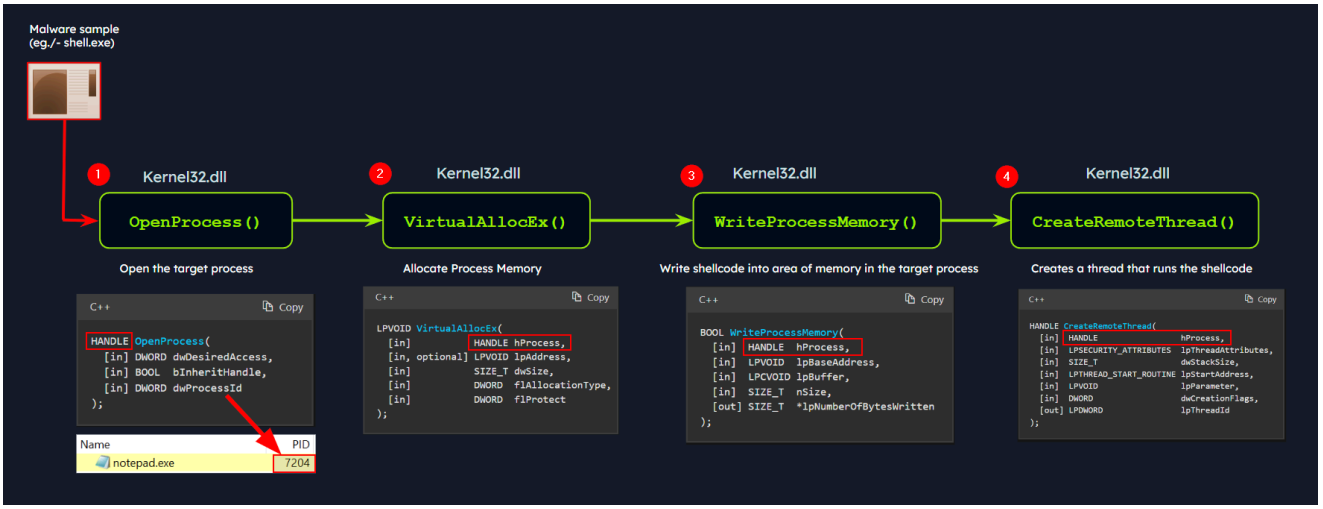
Below is an example of identifying process injection using DLL imports and function names:



In this diagram, the malware process (`shell.exe`) performs process injection to inject code into a target process (`notepad.exe`) using the following functions imported from the DLL `kernel32.exe` :

- `OpenProcess` : Opens a handle to the target process (notepad.exe), providing the necessary access rights to manipulate its memory.
- `VirtualAllocEx` : Allocates a block of memory within the address space of the target process to store the injected code.
- `WriteProcessMemory` : Writes the desired code into the allocated memory block of the target process.
- `CreateRemoteThread` : Creates a new thread within the target process, specifying the entry point of the injected code as the starting point.

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As a result, the injected code is executed within the context of the target process by the newly created remote thread. This technique allows the malware to run arbitrary code within the target process.

The functions above are WINAPI (Windows API) functions. Don't worry about WINAPI functions as of now. We'll discuss these in detail later.

We can examine the DLL imports of `shell.exe` (residing in the `C:\Samples\MalwareAnalysis` directory) using `CFF Explorer` (available at `C:\Tools\Explorer Suite`) as follows.

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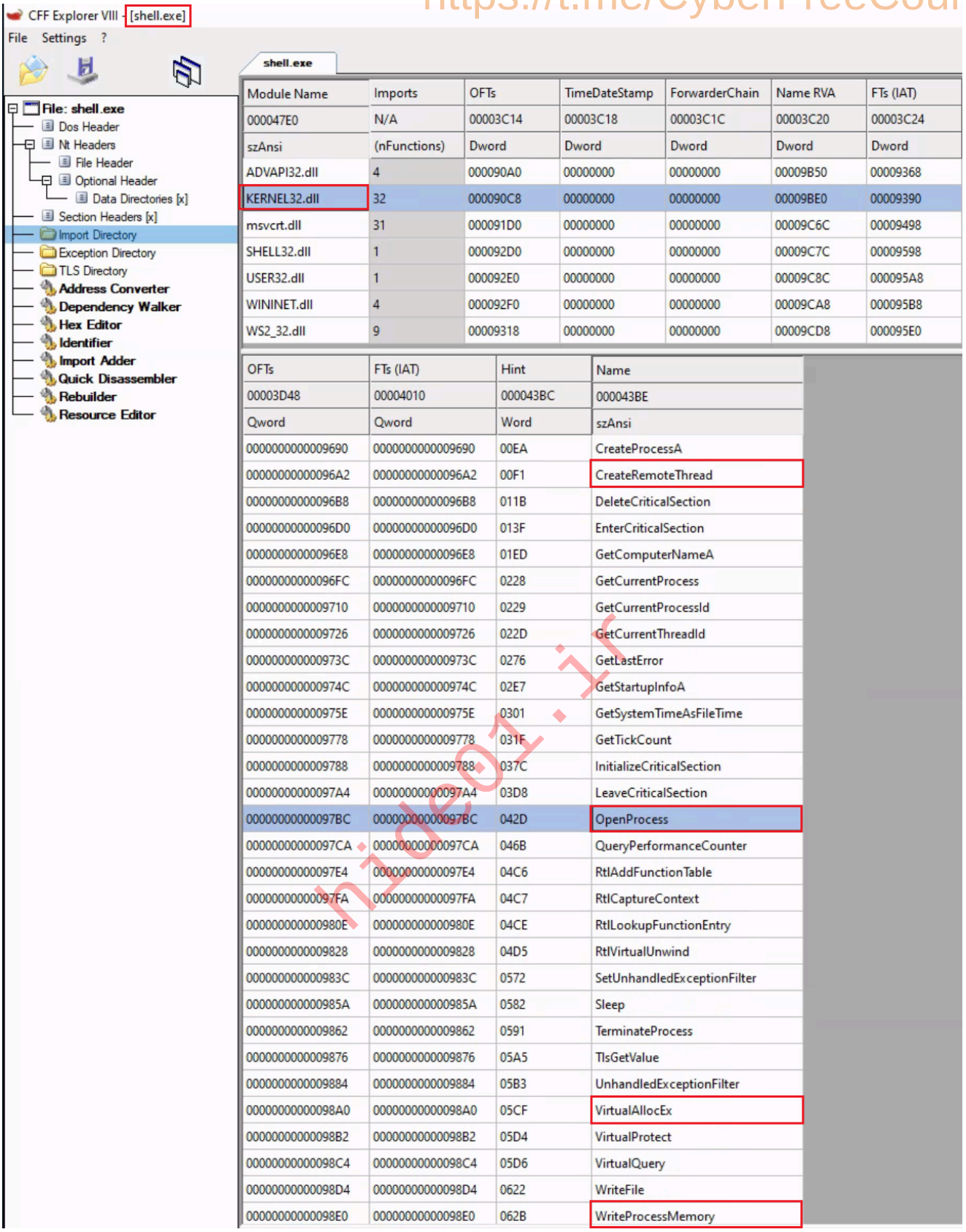

Export Functions

- Export functions are the functions that a binary exposes for use by other modules or applications.
- These functions provide an interface for other software to interact with the binary.

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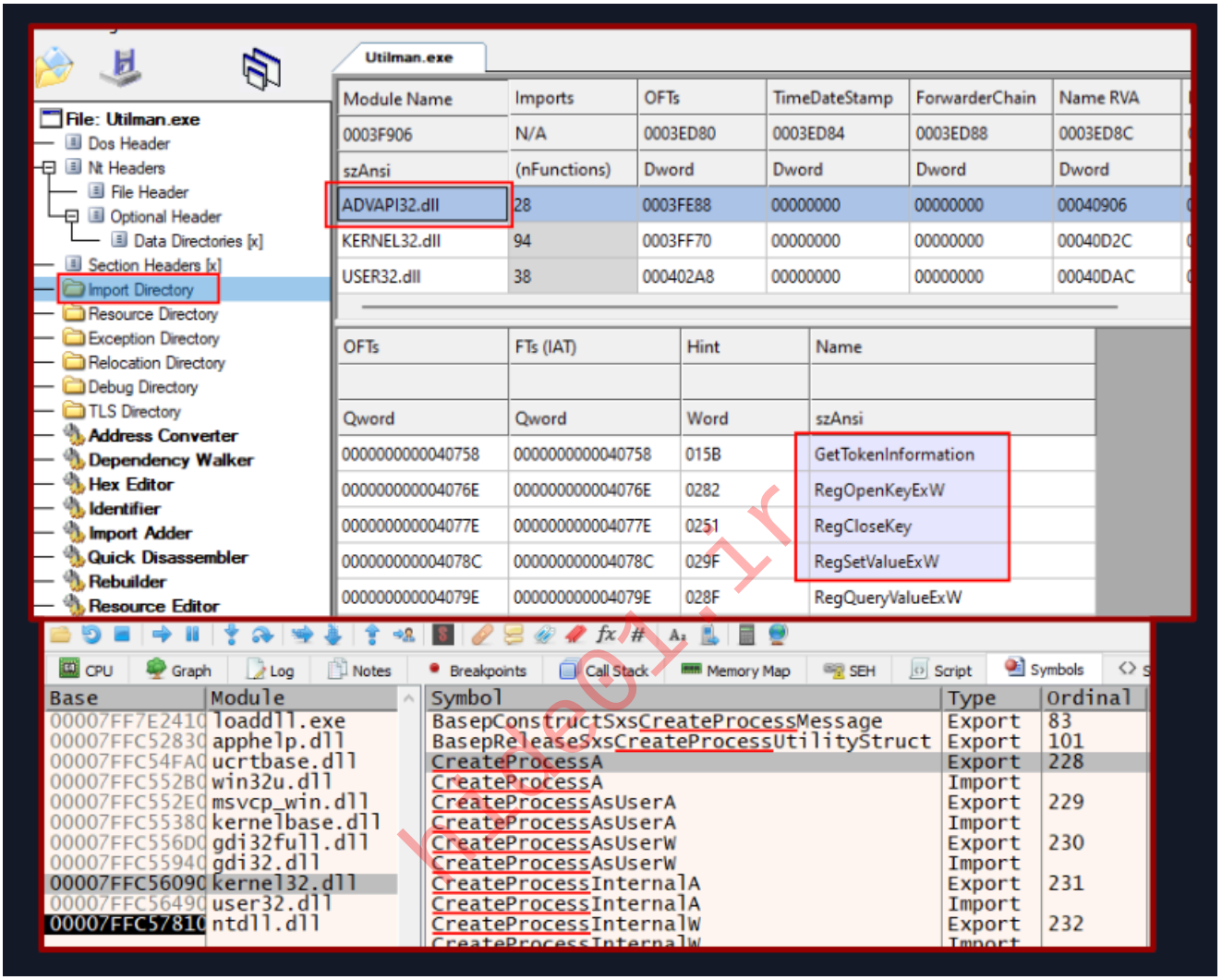
In the below screenshot, we can see an example of DLL imports (using `CFF Explorer`) and exports (using `x64dbg` - `Symbols` tab):

- `Imports`: This shows the DLLs and their functions imported by an executable `Utilman.exe`.
- `Exports`: This shows the functions exported by a DLL `Kernel32.dll`.



In the context of malware analysis, understanding import and export functions assists in discerning the behavior, capabilities, and interactions of the binary with external entities. It yields valuable information for threat detection, classification, and gauging the impact of the malware on the system.

Static Analysis On Linux

In the realm of malware analysis, we exercise a method called static analysis to scrutinize malware without necessitating its execution. This involves the meticulous investigation of malware's code, data, and structural components, serving as a vital precursor for further, more detailed analysis.

Through static analysis, we endeavor to extract pivotal information which includes:

- File type

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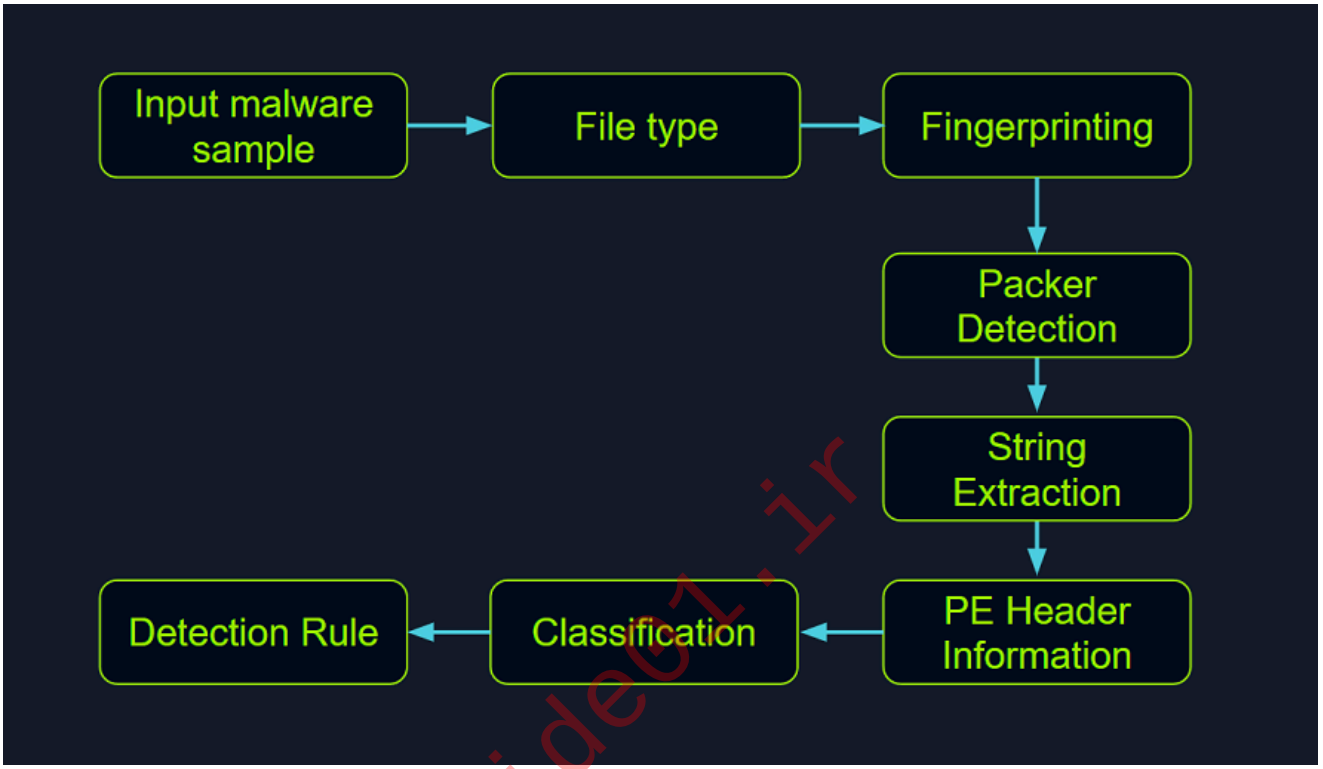
- File hash
- Strings
- Embedded elements
- Packer information
- Imports
- Exports
- Assembly code



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Let's now navigate to the bottom of this section and click on "Click here to spawn the target system!". Then, let's SSH into the Target IP using the provided credentials. The vast majority of the actions/commands covered from this point up to end of this section can be replicated inside the target, offering a more comprehensive grasp of the topics presented.

Identifying The File Type

Our first port of call in this stage is to ascertain the rudimentary information about the malware specimen to lay the groundwork for our investigation. Given that file extensions can be manipulated and changed, our task is to devise a method to identify the actual file type we are encountering. Establishing the file type plays an integral role in static analysis, ensuring that the procedures we apply are appropriate and the results obtained are accurate.

Let's use a Windows-based malware named `Ransomware.wannacry.exe` residing in the `/home/htb-student/Samples/MalwareAnalysis` directory of this section's target as an illustration.

The command for checking the file type of this malware would be the following.

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```
file /home/htb-student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
/home/htb-student/Samples/MalwareAnalysis/Ransomware.wannacry.exe: PE32
executable (GUI) Intel 80386, for MS Windows
```

We can also do the same by manually checking the header with the help of the `hexdump` command as follows.

```
hexdump -C /home/htb-
student/Samples/MalwareAnalysis/Ransomware.wannacry.exe | more
00000000  4d 5a 90 00 03 00 00 00  04 00 00 00 ff ff 00 00
|MZ..............|
00000010  b8 00 00 00 00 00 00 00  40 00 00 00 00 00 00 00
|........@.......|
00000020  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
|................|
00000030  00 00 00 00 00 00 00 00  00 00 00 00 f8 00 00 00
|................|
00000040  0e 1f ba 0e 00 b4 09 cd  21 b8 01 4c cd 21 54 68
|........!..L.!Th|
00000050  69 73 20 70 72 6f 67 72  61 6d 20 63 61 6e 6e 6f  |is program
canno|
00000060  74 20 62 65 20 72 75 6e  20 69 6e 20 44 4f 53 20  |t be run in
DOS |
00000070  6d 6f 64 65 2e 0d 0d 0a  24 00 00 00 00 00 00 00
|mode....$.......|
00000080  55 3c 53 90 11 5d 3d c3  11 5d 3d c3 11 5d 3d c3
|U<S..]=..]=..]=.|
00000090  6a 41 31 c3 10 5d 3d c3  92 41 33 c3 15 5d 3d c3
|jA1..]=..A3..]=.|
000000a0  7e 42 37 c3 1a 5d 3d c3  7e 42 36 c3 10 5d 3d c3
|~B7..]=.~B6..]=.|
000000b0  7e 42 39 c3 15 5d 3d c3  d2 52 60 c3 1a 5d 3d c3
|~B9..]=..R`..]=.|
000000c0  11 5d 3c c3 4a 5d 3d c3  27 7b 36 c3 10 5d 3d c3  |.]
<.J]=.'{6..]=.|
000000d0  d6 5b 3b c3 10 5d 3d c3  52 69 63 68 11 5d 3d c3  |.
[;..]=.Rich.]=.|
000000e0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
|................|
000000f0  00 00 00 00 00 00 00 00  50 45 00 00 4c 01 04 00
|........PE..L...|
00000100  cc 8e e7 4c 00 00 00 00  00 00 00 00 e0 00 0f 01
|...L............|
00000110  0b 01 06 00 00 90 00 00  00 30 38 00 00 00 00 00
|.........08.....|
00000120  16 9a 00 00 00 10 00 00  00 a0 00 00 00 00 40 00
|..............@.|
```

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```
00000130  00 10 00 00 00 10 00 00  04 00 00 00 00 00 00 00
|................|
00000140  04 00 00 00 00 00 00 00  00 b0 66 00 00 10 00 00
|..........f.....|
00000150  00 00 00 00 02 00 00 00  00 00 10 00 00 10 00 00
|................|
00000160  00 00 10 00 00 10 00 00  00 00 00 00 10 00 00 00
|................|
00000170  00 00 00 00 00 00 00 00  e0 a1 00 00 a0 00 00 00
|................|
00000180  00 00 31 00 54 a4 35 00  00 00 00 00 00 00 00 00
|..1.T.5.........|
00000190  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
|................|
*
```

On a Windows system, the presence of the ASCII string `MZ` (in hexadecimal: `4D 5A`) at the start of a file (known as the "magic number") denotes an executable file. `MZ` stands for Mark Zbikowski, a key architect of MS-DOS.

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Malware Fingerprinting

In this stage, our mission is to create a unique identifier for the malware sample. This typically takes the form of a cryptographic hash - MD5, SHA1, or SHA256.

Fingerprinting is employed for numerous purposes, encompassing:

- Identification and tracking of malware samples
- Scanning an entire system for the presence of identical malware
- Confirmation of previous encounters and analyses of the same malware
- Sharing with stakeholders as IoC (Indicators of Compromise) or as part of threat intelligence reports

As an illustration, to check the MD5 file hash of the abovementioned malware the command would be the following.

```
md5sum /home/htb-student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
db349b97c37d22f5ea1d1841e3c89eb4  /home/htb-
student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
```

To check the SHA256 file hash of the abovementioned malware the command would be the following.

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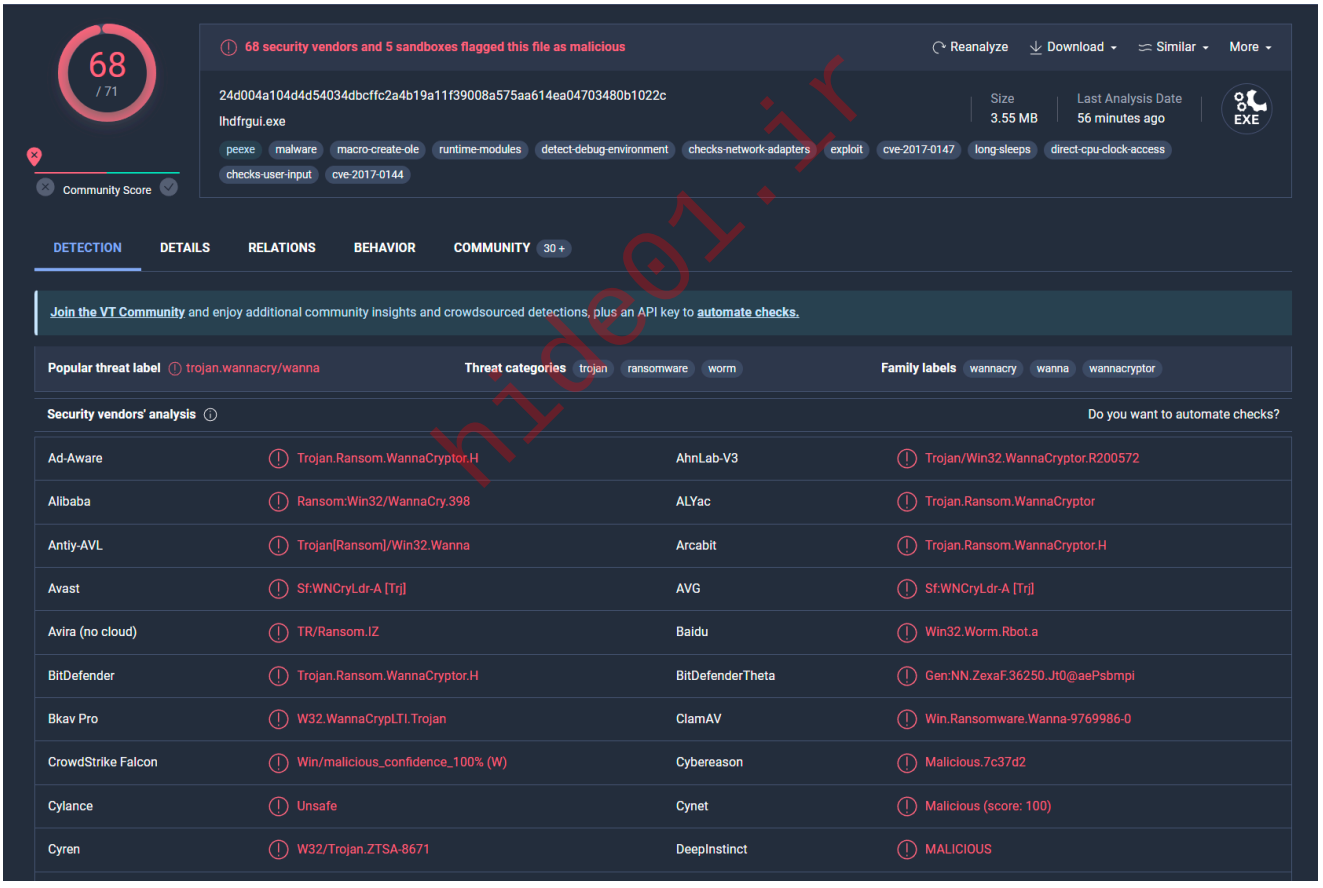
```
sha256sum /home/htb-
student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
24d004a104d4d54034dbcffc2a4b19a11f39008a575aa614ea04703480b1022c
/home/htb-student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
```

File Hash Lookup

The ensuing step involves checking the file hash produced in the prior step against online malware scanners and sandboxes such as Cuckoo sandbox. For instance, VirusTotal, an online malware scanning engine, which collaborates with various antivirus vendors, allows us to search for the file hash. This step aids us in comparing our results with existing knowledge about the malware sample.

The following image displays the results from VirusTotal after the SHA256 file hash of the aforementioned malware was submitted.



Even though a file hash like MD5, SHA1, or SHA256 is valuable for identifying identical samples with disparate names, it falls short when identifying similar malware samples. This is primarily because a malware author can alter the file hash value by making minor modifications to the code and recompiling it.

Nonetheless, there exist techniques that can aid in identifying similar samples:

Import Hashing (IMPHASH)

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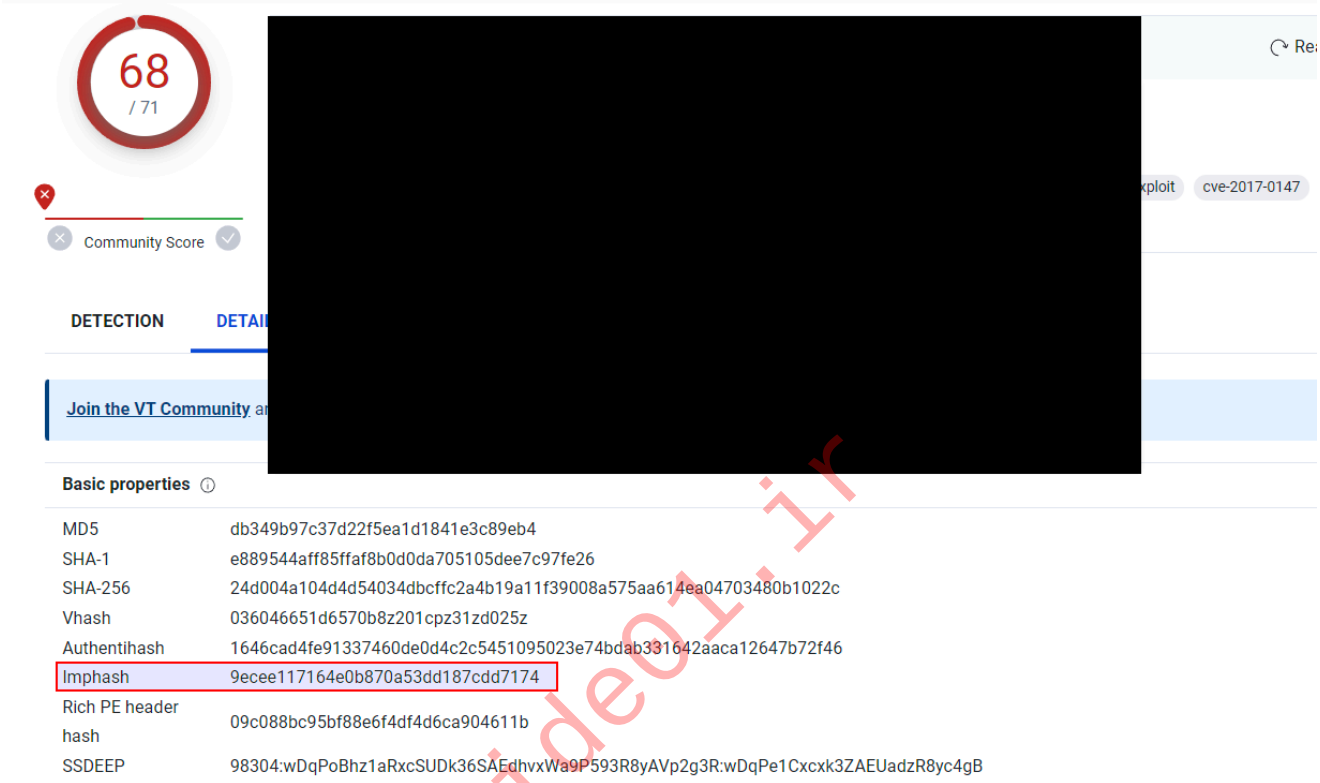
`IMPHASH`, an abbreviation for "Import Hash", is a cryptographic hash calculated from the import functions of a Windows Portable Executable (PE) file. Its algorithm functions by first converting all imported function names to lowercase. Following this, the DLL names and function names are fused together and arranged in alphabetical order. Finally, an MD5 hash is generated from the resulting string. Therefore, two PE files with identical import functions, in the same sequence, will share an `IMPHASH` value.

We can find the `IMPHASH` in the `Details` tab of the VirusTotal results.



Note that we can also use the pefile Python module to compute the IMPHASH of a file as follows.

```
import sys
import pefile
import peutils

pe_file = sys.argv[1]
pe = pefile.PE(pe_file)
imphash = pe.get_imphash()

print(imphash)
```

To check the IMPHASH of the abovementioned WannaCry malware the command would be the following. `imphash_calc.py` (available at `/home/htb-student`) contains the Python code above.

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```
python3 imphash_calc.py /home/htb-
student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
9ecee117164e0b870a53dd187cdd7174
```

Fuzzy Hashing (SSDEEP)

`Fuzzy Hashing (SSDEEP)`, also referred to as context-triggered piecewise hashing (CTPH), is a hashing technique designed to compute a hash value indicative of content similarity between two files. This technique dissects a file into smaller, fixed-size blocks and calculates a hash for each block. The resulting hash values are then consolidated to generate the final fuzzy hash.

The `SSDEEP` algorithm allocates more weight to longer sequences of common blocks, making it highly effective in identifying files that have undergone minor modifications, or are similar but not identical, such as different variations of a malicious sample.

We can find the `SSDEEP` hash of a malware in the `Details` tab of the VirusTotal results.

We can also use the `ssdeep` command to calculate the `SSDEEP` hash of a file. To check the `SSDEEP` hash of the abovementioned WannaCry malware the command would be the following.

```
ssdeep /home/htb-student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
ssdeep,1.1--blocksize:hash:hash,filename
98304:wDqPoBhz1aRxcSUDk36SAEdhvxWa9P593R8yAVp2g3R:wDqPe1Cxcxk3ZAEUadzR8yc4
gB,"/home/htb-student/Samples/MalwareAnalysis/Ransomware.wannacry.exe"
```

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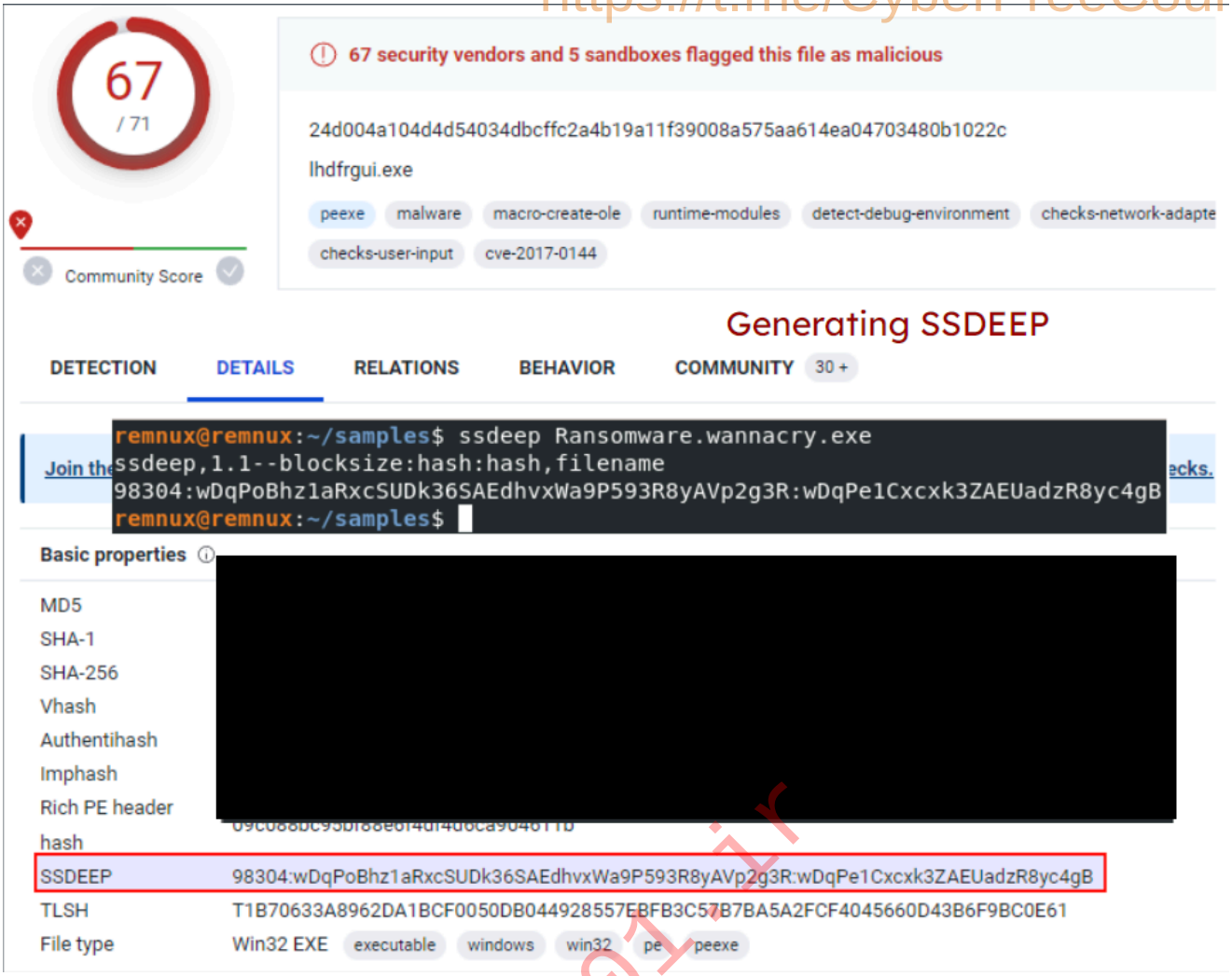

The command line arguments `-pb` can be used to initiate matching mode in `SSDEEP` (while we are on the directory where the malware samples are stored - `/home/htb-student/Samples/MalwareAnalysis` in our case).

```
ssdeep -pb *
potato.exe matches svchost.exe (99)

svchost.exe matches potato.exe (99)
```

`-p` denotes Pretty matching mode, and `-b` is used to display only the file names, sans the full path.

In the example above, a 99% similarity was observed between two malware samples (`svchost.exe` and `potato.exe`) using `SSDEEP` .

Section Hashing (Hashing PE Sections)

`Section hashing` , (hashing PE sections) is a powerful technique that allows analysts to identify sections of a Portable Executable (PE) file that have been modified. This can be particularly useful for identifying minor variations in malware samples, a common tactic employed by attackers to evade detection.

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The `Section Hashing` technique works by calculating the cryptographic hash of each of these sections. When comparing two PE files, if the hash of corresponding sections in the two files matches, it suggests that the particular section has not been modified between the two versions of the file.

By applying `section hashing`, security analysts can identify parts of a PE file that have been tampered with or altered. This can help identify similar malware samples, even if they have been slightly modified to evade traditional signature-based detection methods.

Tools such as `pefile` in Python can be used to perform `section hashing`. In Python, for example, you can use the pefile module to access and hash the data in individual sections of a PE file as follows.

```
import sys
import pefile
pe_file = sys.argv[1]
pe = pefile.PE(pe_file)
for section in pe.sections:
    print (section.Name, "MD5 hash:", section.get_hash_md5())
    print (section.Name, "SHA256 hash:", section.get_hash_sha256())
```

Remember that while `section hashing` is a powerful technique, it is not foolproof. Malware authors might employ tactics like section name obfuscation or dynamically generating section names to try and bypass this kind of analysis.

As an illustration, to check the MD5 and SHA256 PE section hashes of a Wannacry executable stored in the `/home/htb-student/Samples/MalwareAnalysis` directory, the command would be the following. `section_hashing.py` (available at `/home/htb-student`) contains the Python code above.

```
python3 section_hashing.py /home/htb-
student/Samples/MalwareAnalysis/Ransomware.wannacry.exe
b'.text\x00\x00\x00' MD5 hash: c7613102e2ecec5dcefc144f83189153
b'.text\x00\x00\x00' SHA256 hash:
7609ecc798a357dd1a2f0134f9a6ea06511a8885ec322c7acd0d84c569398678
b'.rdata\x00\x00' MD5 hash: d8037d744b539326c06e897625751cc9
b'.rdata\x00\x00' SHA256 hash:
532e9419f23eaf5eb0e8828b211a7164cbf80ad54461bc748c1ec2349552e6a2
b'.data\x00\x00\x00' MD5 hash: 22a8598dc29cad7078c291e94612ce26
b'.data\x00\x00\x00' SHA256 hash:
6f93fb1b241a990ecc281f9c782f0da471628f6068925aaf580c1b1de86bce8a
b'.rsrc\x00\x00\x00' MD5 hash: 12e1bd7375d82cca3a51ca48fe22d1a9
b'.rsrc\x00\x00\x00' SHA256 hash:
1efe677209c1284357ef0c7996a1318b7de3836dfb11f97d85335d6d3b8a8e42
```

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String Analysis

In this phase, our objective is to extract strings (ASCII & Unicode) from a binary. Strings can furnish clues and valuable insight into the functionality of the malware. Occasionally, we can unearth unique embedded strings in a malware sample, such as:

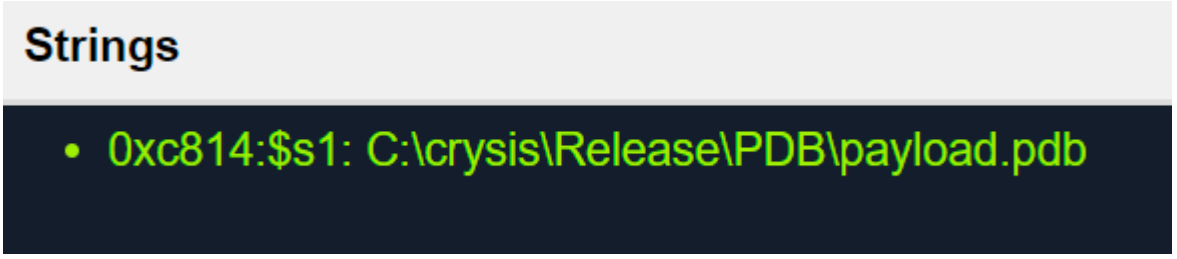
- Embedded filenames (e.g., dropped files)
- IP addresses or domain names
- Registry paths or keys
- Windows API functions
- Command-line arguments
- Unique information that might hint at a particular threat actor

The Linux `strings` command can be deployed to display the strings contained within a malware. For instance, the command below will reveal strings for a ransomware sample named `dharma_sample.exe` residing in the `/home/htb-student/Samples/MalwareAnalysis` directory of this section's target.

```
strings -n 15 /home/htb-student/Samples/MalwareAnalysis/dharma_sample.exe
!This program cannot be run in DOS mode.
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@>@@@?456789:;<=@@@@@@@
!"#$%&'()*+,-./0123@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
@@@@ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789+/
WaitForSingleObject
InitializeCriticalSectionAndSpinCount
LeaveCriticalSection
EnterCriticalSection
C:\crysis\Release\PDB\payload.pdb
0123456789ABCDEF
```

`-n` specifies to print a sequence of at least the number specified - in our case, `15`.

Occasionally, string analysis can facilitate the linkage of a malware sample to a specific threat group if significant similarities are identified. For example, in the link provided, a string containing a PDB path was used to link the malware sample to the Dharma/Crysis family of ransomware.



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It should be noted that another string analysis solution exists called `FLOSS`. `FLOSS`, short for "FireEye Labs Obfuscated String Solver", is a tool developed by FireEye's FLARE team to automatically deobfuscate strings in malware. It's designed to supplement the use of traditional string tools, like the strings command in Unix-based systems, which can miss obfuscated strings that are commonly used by malware to evade detection.

For instance, the command below will reveal strings for a ransomware sample named `dharma_sample.exe` residing in the `/home/htb-student/Samples/MalwareAnalysis` directory of this section's target.

```
floss /home/htb-student/Samples/MalwareAnalysis/dharma_sample.exe
INFO: floss: extracting static strings...
finding decoding function features: 100%|
                                        | 238/238 [00:00<00:00, 838.37
functions/s, skipped 5 library functions (2%)]
INFO: floss.stackstrings: extracting stackstrings from 223 functions
INFO: floss.results: %sh(
extracting stackstrings: 100%|
                                                                        |
          | 223/223 [00:01<00:00, 133.51 functions/s]
INFO: floss.tightstrings: extracting tightstrings from 10 functions...
extracting tightstrings from function 0x4065e0: 100%|
                                                                        | 10/10
[00:01<00:00,  5.91 functions/s]
INFO: floss.string_decoder: decoding strings
INFO: floss.results: EEED
INFO: floss.results: EEEDnnn
INFO: floss.results: uOKm
INFO: floss.results: %sh(
INFO: floss.results: uBIA
INFO: floss.results: uBIA
INFO: floss.results: \t\t\t\t\t\t\t\t
emulating function 0x405840 (call 4/9): 100%|
                                                                        |
25/25 [00:11<00:00,  2.19 functions/s]
INFO: floss: finished execution after 23.56 seconds

FLARE FLOSS RESULTS (version v2.0.0-0-gdd9bea8)
+------------------------+------------------------------------------------
-----------------------------------+
| file path              | /home/htb-
student/Samples/MalwareAnalysis/dharma_sample.exe                       |
| extracted strings      |
|
|   static strings       | 720
|
|   stack strings        | 1
```

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```
|
|  tight strings          | 0
|
|  decoded strings        | 7
|
+-------------------------+-------------------------------------------------
-----------------------------------+

------------------------------
| FLOSS STATIC STRINGS (720) |
------------------------------
------------------------------
| FLOSS ASCII STRINGS (716) |
------------------------------
!This program cannot be run in DOS mode.
Rich
.text
`.rdata
@.data
9A s
9A$v
A +B$
---SNIP---
+o*7
0123456789ABCDEF

------------------------------
| FLOSS UTF-16LE STRINGS (4) |
------------------------------
jjjj
%sh(
ssbss
0123456789ABCDEF

---------------------------
| FLOSS STACK STRINGS (1) |
---------------------------
%sh(

---------------------------
| FLOSS TIGHT STRINGS (0) |
---------------------------

------------------------------
| FLOSS DECODED STRINGS (7) |
------------------------------
EEED
EEEDnnn
uOKm
%sh(
```

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```
uBIA
uBIA
\t\t\t\t\t\t\t\t
```

Unpacking UPX-packed Malware

In our static analysis, we might stumble upon a malware sample that's been compressed or obfuscated using a technique referred to as packing. Packing serves several purposes:

- It obfuscates the code, making it more challenging to discern its structure or functionality.
- It reduces the size of the executable, making it quicker to transfer or less conspicuous.
- It confounds security researchers by hindering traditional reverse engineering attempts.

This can impair string analysis because the references to strings are typically obscured or eliminated. It also replaces or camouflages conventional PE sections with a compact loader stub, which retrieves the original code from a compressed data section. As a result, the malware file becomes both smaller and more difficult to analyze, as the original code isn't directly observable.

A popular packer used in many malware variants is the `Ultimate Packer for Executables (UPX)`.

Let's first see what happens when we run the `strings` command on a UPX-packed malware sample named `credential_stealer.exe` residing in the `/home/htb-student/Samples/MalwareAnalysis/packed` directory of this section's target.

```
strings /home/htb-
student/Samples/MalwareAnalysis/packed/credential_stealer.exe
!This program cannot be run in DOS mode.
UPX0
UPX1
UPX2
3.96
UPX!
8MZu
HcP<H
VDgxt
$ /uX
OAUATUWVSH
%0rv
o?H9
c`fG
[^_]A\A]
> -P
        fo{Wnl
```

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```
c9"^$!=
v/7>
07ZC
_L$AAl
mug.%(
#8%,X
e]'^
---SNIP---
```

Observe the strings that include `UPX`, and take note that the remainder of the output doesn't yield any valuable information regarding the functionality of the malware.

We can unpack the malware using the `UPX` tool with the following command (while we are on the directory where the packed malware samples are stored - `/home/htb-student/Samples/MalwareAnalysis/packed` in our case).

```
upx -d -o unpacked_credential_stealer.exe credential_stealer.exe
                       Ultimate Packer for eXecutables
                          Copyright (C) 1996 - 2020
UPX 3.96        Markus Oberhumer, Laszlo Molnar & John Reiser   Jan 23rd
2020

        File size         Ratio      Format      Name
   --------------------   ------   -----------   -----------
     16896 <-      8704   51.52%   win64/pe
unpacked_credential_stealer.exe

Unpacked 1 file.
```

Let's now run the `strings` command on the unpacked sample.

```
strings unpacked_credential_stealer.exe
!This program cannot be run in DOS mode.
.text
P`.data
.rdata
`@.pdata
[email protected]
[email protected]
.idata
.CRT
.tls
---SNIP---
AVAUATH
@A\A]A^
SeDebugPrivilege
```

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```
SE Debug Privilege is adjusted
lsass.exe
Searching lsass PID
Lsass PID is: %lu
Error is - %lu
lsassmem.dmp
LSASS Memory is dumped successfully
Err 2: %lu
Unknown error
Argument domain error (DOMAIN)
Overflow range error (OVERFLOW)
Partial loss of significance (PLOSS)
Total loss of significance (TLOSS)
The result is too small to be represented (UNDERFLOW)
Argument singularity (SIGN)
_matherr(): %s in %s(%g, %g)  (retval=%g)
Mingw-w64 runtime failure:
Address %p has no image-section
  VirtualQuery failed for %d bytes at address %p
  VirtualProtect failed with code 0x%x
  Unknown pseudo relocation protocol version %d.
  Unknown pseudo relocation bit size %d.
.pdata
AdjustTokenPrivileges
LookupPrivilegeValueA
OpenProcessToken
MiniDumpWriteDump
CloseHandle
CreateFileA
CreateToolhelp32Snapshot
DeleteCriticalSection
EnterCriticalSection
GetCurrentProcess
GetCurrentProcessId
GetCurrentThreadId
GetLastError
GetStartupInfoA
GetSystemTimeAsFileTime
GetTickCount
InitializeCriticalSection
LeaveCriticalSection
OpenProcess
Process32First
Process32Next
QueryPerformanceCounter
RtlAddFunctionTable
RtlCaptureContext
RtlLookupFunctionEntry
RtlVirtualUnwind
SetUnhandledExceptionFilter
```

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```
Sleep
TerminateProcess
TlsGetValue
UnhandledExceptionFilter
VirtualProtect
VirtualQuery
__C_specific_handler
__getmainargs
__initenv
__iob_func
__lconv_init
__set_app_type
__setusermatherr
_acmdln
_amsg_exit
_cexit
_fmode
_initterm
_onexit
abort
calloc
exit
fprintf
free
fwrite
malloc
memcpy
printf
puts
signal
strcmp
strlen
strncmp
vfprintf
ADVAPI32.dll
dbghelp.dll
KERNEL32.DLL
msvcrt.dll
```

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Now, we observe a more comprehensible output that includes the actual strings present in the sample.

Static Analysis On Windows

In this segment, our focus will be on reproducing some of the static analysis tasks we carried out on a Linux machine, but this time, we'll be employing a Windows machine.

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Let's now navigate to the bottom of this section and click on "Click here to spawn the target system!". Then, let's RDP into the Target IP using the provided credentials. The vast majority of the actions/commands covered from this point up to end of this section can be replicated inside the target, offering a more comprehensive grasp of the topics presented.

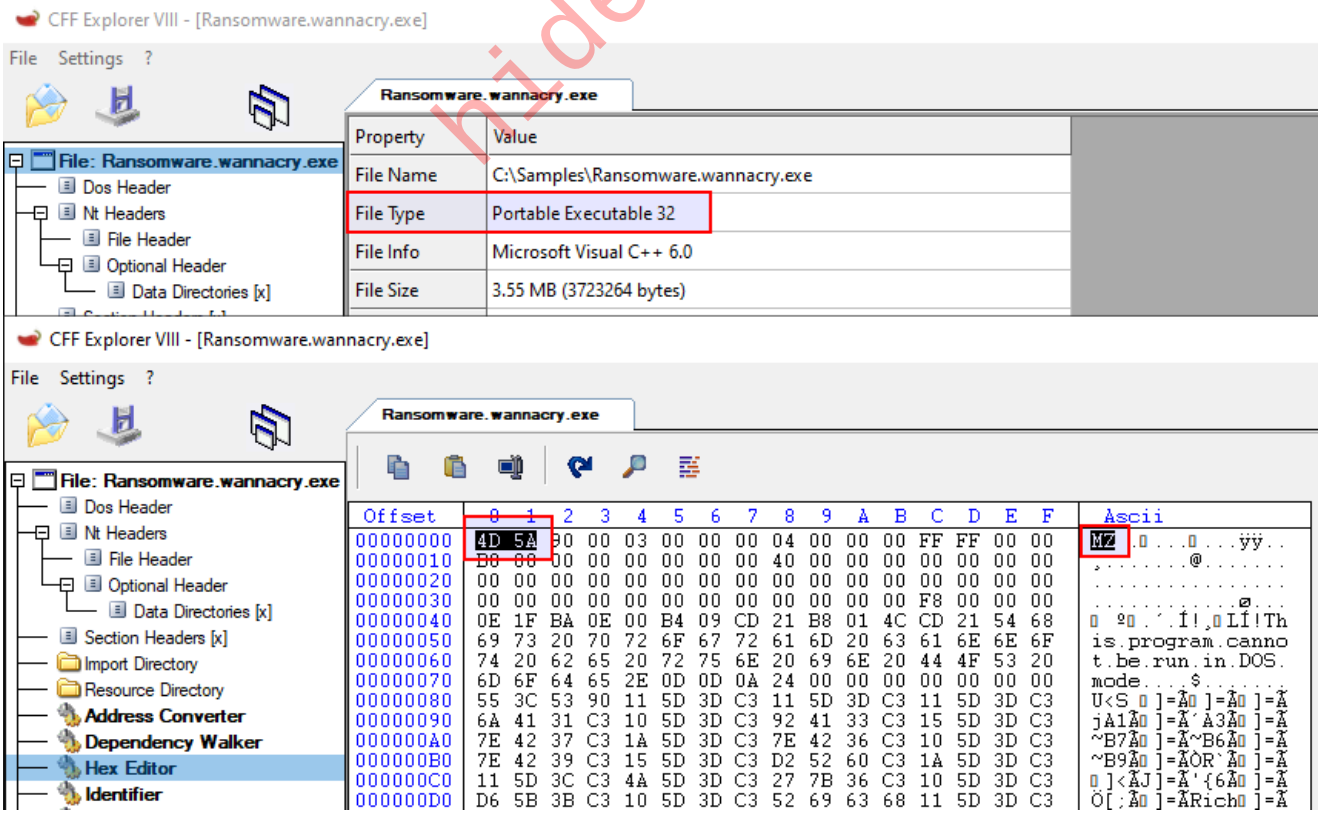
```
xfreerdp /u:htb-student /p:'HTB_@cademy_stdnt!' /v:[Target IP] /dynamic-resolution
```

Identifying The File Type

Our first port of call in this stage is to ascertain the rudimentary information about the malware specimen to lay the groundwork for our investigation. Given that file extensions can be manipulated and changed, our task is to devise a method to identify the actual file type we are encountering. Establishing the file type plays an integral role in static analysis, ensuring that the procedures we apply are appropriate and the results obtained are accurate.

Let's use a Windows-based malware named `Ransomware.wannacry.exe` residing in the `C:\Samples\MalwareAnalysis` directory of this section's target as an illustration.

We can use a solution like `CFF Explorer` (available at `C:\Tools\Explorer Suite`) to check the file type of this malware as follows.



On a Windows system, the presence of the ASCII string `MZ` (in hexadecimal: `4D 5A`) at the start of a file (known as the "magic number") denotes an executable file. `MZ` stands for Mark

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Zbikowski, a key architect of MS-DOS.

Malware Fingerprinting

In this stage, our mission is to create a unique identifier for the malware sample. This typically takes the form of a cryptographic hash - MD5, SHA1, or SHA256.

Fingerprinting is employed for numerous purposes, encompassing:

- Identification and tracking of malware samples
- Scanning an entire system for the presence of identical malware
- Confirmation of previous encounters and analyses of the same malware
- Sharing with stakeholders as IoC (Indicators of Compromise) or as part of threat intelligence reports

As an illustration, to check the MD5 file hash of the abovementioned malware we can use the `Get-FileHash` PowerShell cmdlet as follows.

```
PS C:\Users\htb-student> Get-FileHash -Algorithm MD5
C:\Samples\MalwareAnalysis\Ransomware.wannacry.exe

Algorithm       Hash
Path
---------       ----
----
MD5             DB349B97C37D22F5EA1D1841E3C89EB4
C:\Samples\MalwareAnalysis\Ra...
```

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To check the SHA256 file hash of the abovementioned malware the command would be the following.

```
PS C:\Users\htb-student> Get-FileHash -Algorithm SHA256
C:\Samples\MalwareAnalysis\Ransomware.wannacry.exe

Algorithm       Hash
Path
---------       ----
----
SHA256
24D004A104D4D54034DBCFFC2A4B19A11F39008A575AA614EA04703480B1022C
C:\Samples\MalwareAnalysis\Ra...
```

File Hash Lookup

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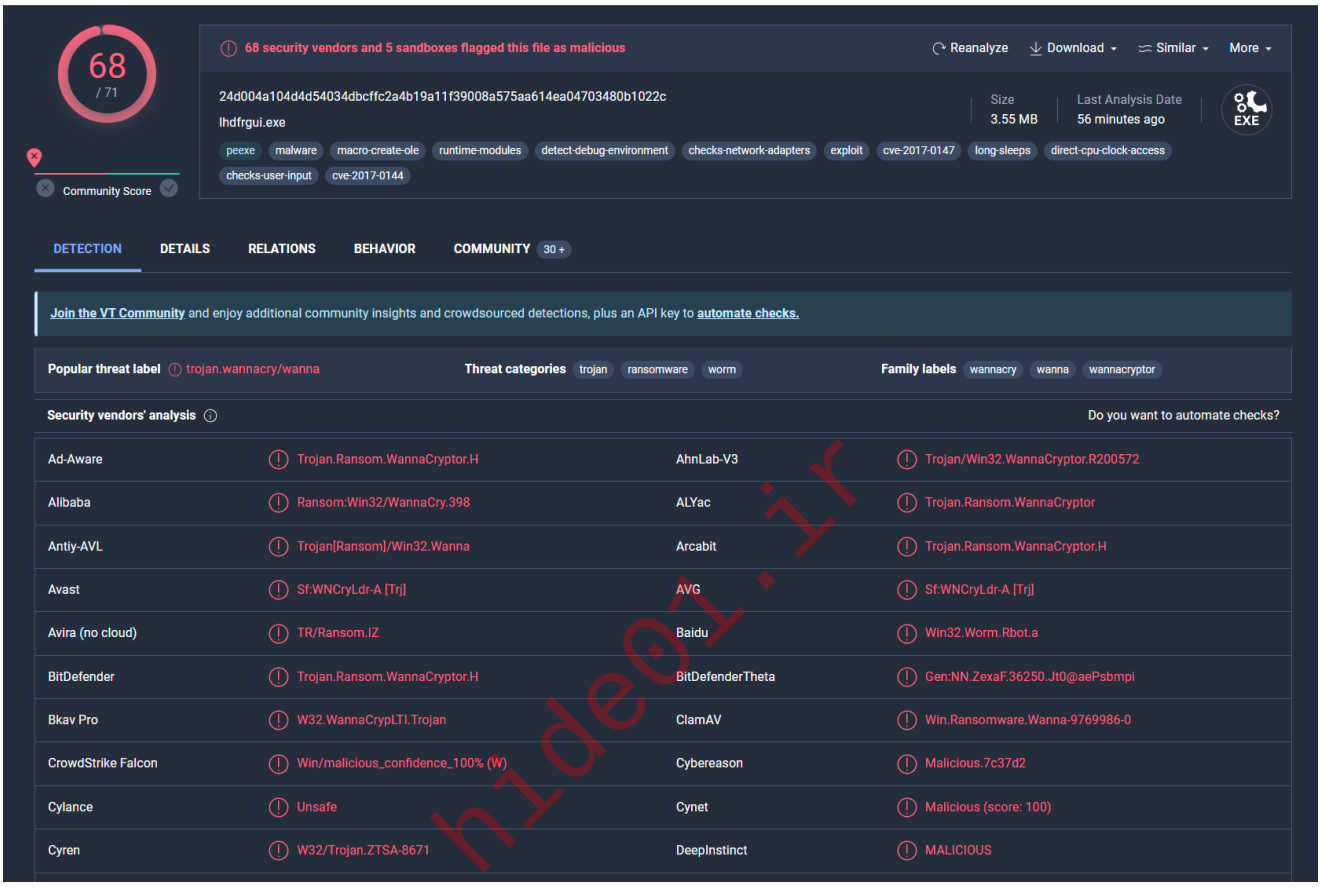
The ensuing step involves checking the file hash produced in the prior step against online malware scanners and sandboxes such as Cuckoo sandbox. For instance, VirusTotal, an online malware scanning engine, which collaborates with various antivirus vendors, allows us to search for the file hash. This step aids us in comparing our results with existing knowledge about the malware sample.

The following image displays the results from VirusTotal after the SHA256 file hash of the aforementioned malware was submitted.



Even though a file hash like MD5, SHA1, or SHA256 is valuable for identifying identical samples with disparate names, it falls short when identifying similar malware samples. This is primarily because a malware author can alter the file hash value by making minor modifications to the code and recompiling it.

Nonetheless, there exist techniques that can aid in identifying similar samples:

Import Hashing (IMPHASH)

`IMPHASH`, an abbreviation for "Import Hash", is a cryptographic hash calculated from the import functions of a Windows Portable Executable (PE) file. Its algorithm functions by first converting all imported function names to lowercase. Following this, the DLL names and function names are fused together and arranged in alphabetical order. Finally, an MD5 hash is generated from the resulting string. Therefore, two PE files with identical import functions, in the same sequence, will share an `IMPHASH` value.

We can find the `IMPHASH` in the `Details` tab of the VirusTotal results.

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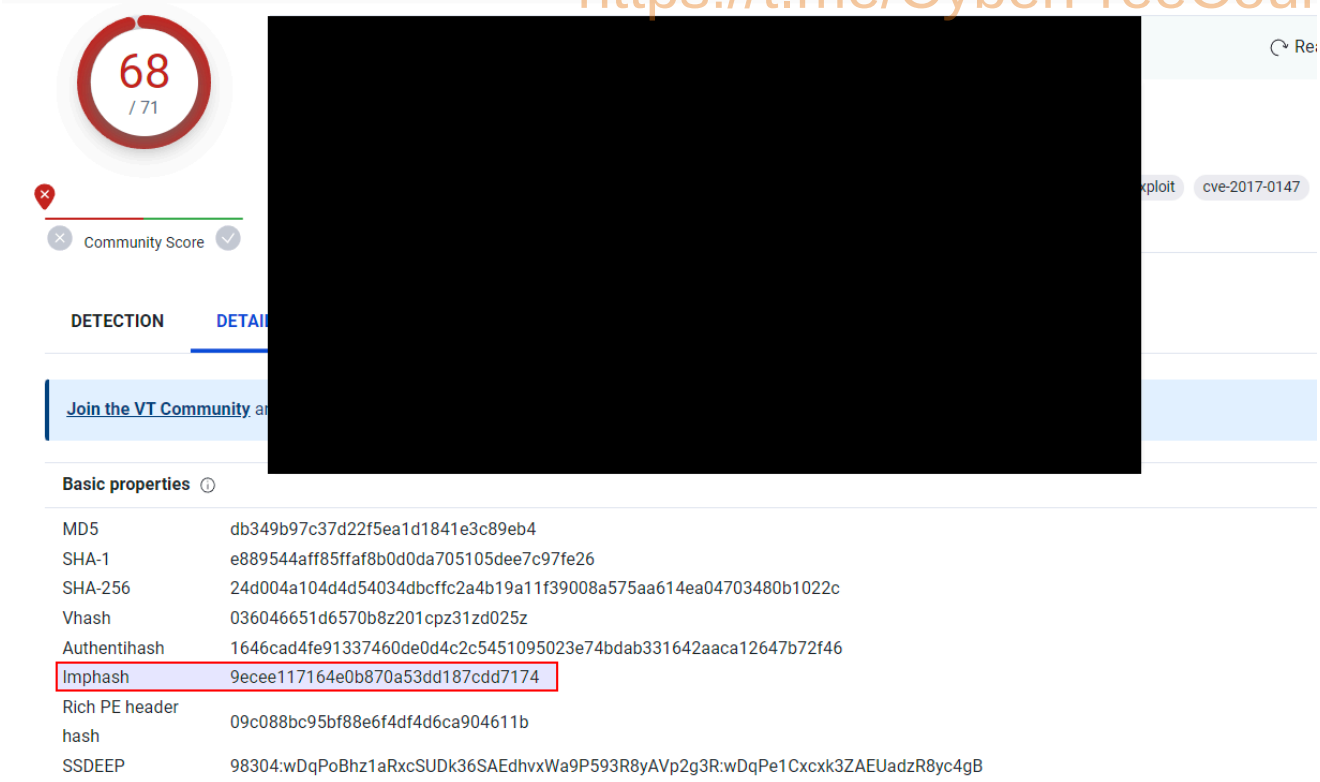

Note that we can also use the pefile Python module to compute the `IMPHASH` of a file as follows.

```
import sys
import pefile
import peutils

pe_file = sys.argv[1]
pe = pefile.PE(pe_file)
imphash = pe.get_imphash()

print(imphash)
```

To check the `IMPHASH` of the abovementioned WannaCry malware the command would be the following. `imphash_calc.py` contains the Python code above.

```
C:\Scripts> python imphash_calc.py
C:\Samples\MalwareAnalysis\Ransomware.wannacry.exe
9ecee117164e0b870a53dd187cdd7174
```

Fuzzy Hashing (SSDEEP)

`Fuzzy Hashing (SSDEEP)`, also referred to as context-triggered piecewise hashing (CTPH), is a hashing technique designed to compute a hash value indicative of content similarity between two files. This technique dissects a file into smaller, fixed-size blocks and calculates

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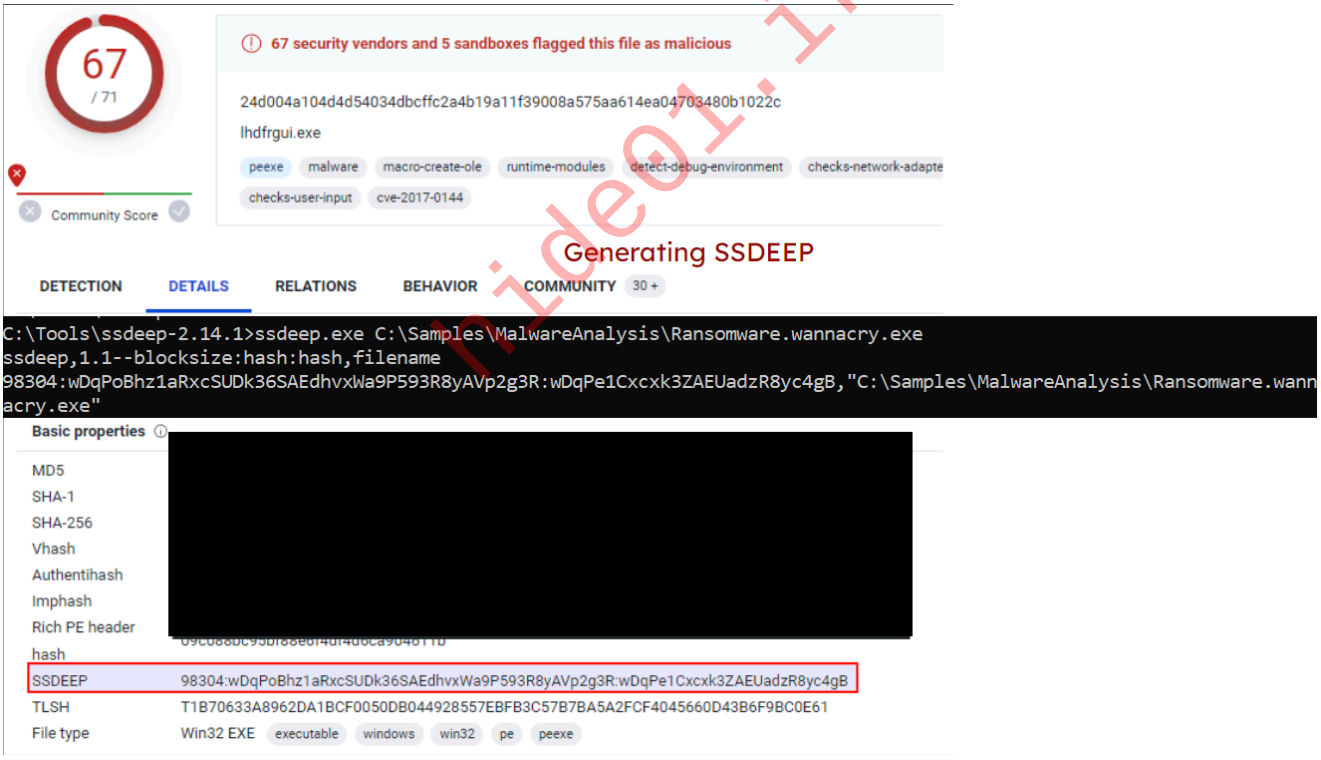
a hash for each block. The resulting hash values are then consolidated to generate the final fuzzy hash.

The `SSDEEP` algorithm allocates more weight to longer sequences of common blocks, making it highly effective in identifying files that have undergone minor modifications, or are similar but not identical, such as different variations of a malicious sample.

We can find the `SSDEEP` hash of a malware in the `Details` tab of the VirusTotal results.

We can also use the `ssdeep` tool (available at `C:\Tools\ssdeep-2.14.1`) to calculate the `SSDEEP` hash of a file. To check the `SSDEEP` hash of the abovementioned WannaCry malware the command would be the following.

```
C:\Tools\ssdeep-2.14.1> ssdeep.exe
C:\Samples\MalwareAnalysis\Ransomware.wannacry.exe
ssdeep,1.1--blocksize:hash:hash,filename
98304:wDqPoBhz1aRxcSUDk36SAEdhvxWa9P593R8yAVp2g3R:wDqPe1Cxcxk3ZAEUadzR8yc4
gB,"C:\Samples\MalwareAnalysis\Ransomware.wannacry.exe"
```



Section Hashing (Hashing PE Sections)

`Section hashing`, (hashing PE sections) is a powerful technique that allows analysts to identify sections of a Portable Executable (PE) file that have been modified. This can be particularly useful for identifying minor variations in malware samples, a common tactic employed by attackers to evade detection.

The `Section Hashing` technique works by calculating the cryptographic hash of each of these sections. When comparing two PE files, if the hash of corresponding sections in the

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two files matches, it suggests that the particular section has not been modified between the two versions of the file.

By applying `section hashing`, security analysts can identify parts of a PE file that have been tampered with or altered. This can help identify similar malware samples, even if they have been slightly modified to evade traditional signature-based detection methods.

Tools such as `pefile` in Python can be used to perform `section hashing`. In Python, for example, you can use the pefile module to access and hash the data in individual sections of a PE file as follows.

```
import sys
import pefile
pe_file = sys.argv[1]
pe = pefile.PE(pe_file)
for section in pe.sections:
    print (section.Name, "MD5 hash:", section.get_hash_md5())
    print (section.Name, "SHA256 hash:", section.get_hash_sha256())
```

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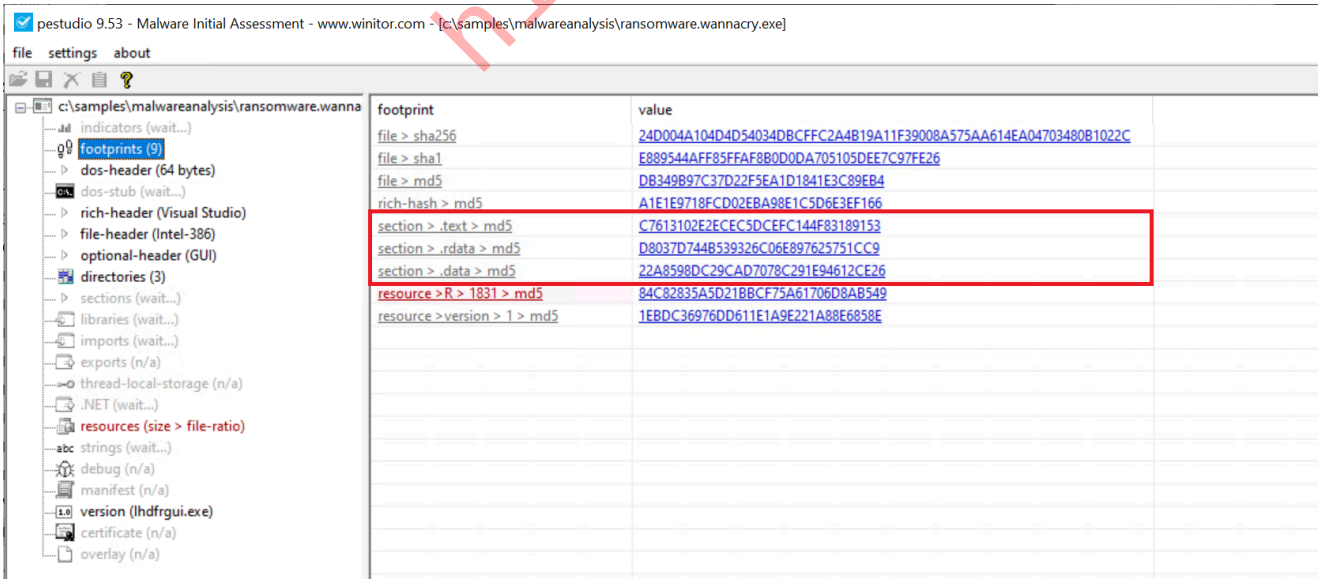
Remember that while `section hashing` is a powerful technique, it is not foolproof. Malware authors might employ tactics like section name obfuscation or dynamically generating section names to try and bypass this kind of analysis.

As an illustration, to check the MD5 file hash of the abovementioned malware we can use `pestudio` (available at `C:\Tools\pestudio\pestudio`) as follows.



String Analysis

In this phase, our objective is to extract strings (ASCII & Unicode) from a binary. Strings can furnish clues and valuable insight into the functionality of the malware. Occasionally, we can unearth unique embedded strings in a malware sample, such as:

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- Embedded filenames (e.g., dropped files)
- IP addresses or domain names
- Registry paths or keys
- Windows API functions
- Command-line arguments
- Unique information that might hint at a particular threat actor

The Windows `strings` binary from `Sysinternals` can be deployed to display the strings contained within a malware. For instance, the command below will reveal strings for a ransomware sample named `dharma_sample.exe` residing in the `C:\Samples\MalwareAnalysis` directory of this section's target.

```
C:\Users\htb-student> strings C:\Samples\MalwareAnalysis\dharma_sample.exe

Strings v2.54 - Search for ANSI and Unicode strings in binary images.
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Sysinternals - www.sysinternals.com

!This program cannot be run in DOS mode.
gaT
Rich
.text
`.rdata
@.data
HQh
9A s
9A$v
---SNIP---
GetProcAddress
LoadLibraryA
WaitForSingleObject
InitializeCriticalSectionAndSpinCount
LeaveCriticalSection
GetLastError
EnterCriticalSection
ReleaseMutex
CloseHandle
KERNEL32.dll
RSDS%~m
#ka
C:\crysis\Release\PDB\payload.pdb
---SNIP---
```

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Occasionally, string analysis can facilitate the linkage of a malware sample to a specific threat group if significant similarities are identified. For example, in the link provided, a string

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containing a PDB path was used to link the malware sample to the Dharma/Crysis family of ransomware.

Strings

- 0xc814:$s1: C:\crysis\Release\PDB\payload.pdb

It should be noted that the `FLOSS` tool is also available for Windows Operating Systems.

The command below will reveal strings for a malware sample named `shell.exe` residing in the `C:\Samples\MalwareAnalysis` directory of this section's target.

```
C:\Samples\MalwareAnalysis> floss shell.exe
INFO: floss: extracting static strings...
finding decoding function features: 100%|
                                                                                | 85/85 [00:00<00:00, 1361.51
functions/s, skipped 0 library functions]
INFO: floss.stackstrings: extracting stackstrings from 56 functions
INFO: floss.results: AQAPRQVH1
INFO: floss.results: JJM1
INFO: floss.results: RAQH
INFO: floss.results: AXAX^YZAXAYAZH
INFO: floss.results: XAYZH
INFO: floss.results: ws232
extracting stackstrings: 100%|
                                                                                
                                                                                
            | 56/56 [00:00<00:00, 81.46 functions/s]
INFO: floss.tightstrings: extracting tightstrings from 4 functions...
extracting tightstrings from function 0x402a90: 100%|
                                                                                | 4/4
[00:00<00:00, 25.59 functions/s]
INFO: floss.string_decoder: decoding strings
emulating function 0x402a90 (call 1/1): 100%|
                                                                                
                                                                                |
22/22 [00:14<00:00,  1.51 functions/s]
INFO: floss: finished execution after 25.20 seconds

FLARE FLOSS RESULTS (version v2.3.0-0-g037fc4b)

+-----------------------+------------------------------------------------
-----------------------------------+
| file path             | shell.exe
|
```

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```
| extracted strings      |
|
|  static strings        | 254
|
|  stack strings         | 6
|
|  tight strings         | 0
|
|  decoded strings       | 0
|
+------------------------+-------------------------------------------------
-----------------------------------+

 ________________________
  FLOSS STATIC STRINGS
 ________________________

+-----------------------------------+
| FLOSS STATIC STRINGS: ASCII (254) |
+-----------------------------------+

!This program cannot be run in DOS mode.
.text
P`.data
.rdata
`@.pdata
[email protected]
[email protected]
.idata
.CRT
.tls
8MZu
HcP<H
D$ H
AUATUWVSH
D$ L
---SNIP---
C:\Windows\System32\notepad.exe
Message
Connection sent to C2
[-] Error code is : %lu
AQAPRQVH1
JJM1
RAQH
AXAX^YZAXAYAZH
XAYZH
ws2_32
PPM1
APAPH
WWWM1
```

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```
VPAPAPAPI
Windows-Update/7.6.7600.256 %s
1Lbcfr7sAHTD9CgdQo3HTMTkV8LK4ZnX71
open
SOFTWARE\Microsoft\Windows\CurrentVersion\Run
WindowsUpdater
---SNIP---
TEMP
svchost.exe
%s\%s
http://ms-windows-update.com/svchost.exe
45.33.32.156
Sandbox detected
iuqerfsodp9ifjaposdfjhgosurijfaewrwergwea.com
SOFTWARE\VMware, Inc.\VMware Tools
InstallPath
C:\Program Files\VMware\VMware Tools\
Failed to open the registry key.
Unknown error
Argument domain error (DOMAIN)
Overflow range error (OVERFLOW)
Partial loss of significance (PLOSS)
Total loss of significance (TLOSS)
The result is too small to be represented (UNDERFLOW)
Argument singularity (SIGN)
_matherr(): %s in %s(%g, %g)  (retval=%g)
Mingw-w64 runtime failure:
Address %p has no image-section
  VirtualQuery failed for %d bytes at address %p
  VirtualProtect failed with code 0x%x
  Unknown pseudo relocation protocol version %d.
  Unknown pseudo relocation bit size %d.
.pdata
RegCloseKey
RegOpenKeyExA
RegQueryValueExA
RegSetValueExA
CloseHandle
CreateFileA
CreateProcessA
CreateRemoteThread
DeleteCriticalSection
EnterCriticalSection
GetComputerNameA
GetCurrentProcess
GetCurrentProcessId
GetCurrentThreadId
GetLastError
GetStartupInfoA
GetSystemTimeAsFileTime
```

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```
GetTickCount
InitializeCriticalSection
LeaveCriticalSection
OpenProcess
QueryPerformanceCounter
RtlAddFunctionTable
RtlCaptureContext
RtlLookupFunctionEntry
RtlVirtualUnwind
SetUnhandledExceptionFilter
Sleep
TerminateProcess
TlsGetValue
UnhandledExceptionFilter
VirtualAllocEx
VirtualProtect
VirtualQuery
WriteFile
WriteProcessMemory
__C_specific_handler
__getmainargs
__initenv
__iob_func
__lconv_init
__set_app_type
__setusermatherr
_acmdln
_amsg_exit
_cexit
_fmode
_initterm
_onexit
_vsnprintf
abort
calloc
exit
fprintf
free
fwrite
getenv
malloc
memcpy
printf
puts
signal
sprintf
strcmp
strlen
strncmp
vfprintf
```

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```
ShellExecuteA
MessageBoxA
InternetCloseHandle
InternetOpenA
InternetOpenUrlA
InternetReadFile
WSACleanup
WSAStartup
closesocket
connect
freeaddrinfo
getaddrinfo
htons
inet_addr
socket
ADVAPI32.dll
KERNEL32.dll
msvcrt.dll
SHELL32.dll
USER32.dll
WININET.dll
WS2_32.dll

+------------------------------------+
| FLOSS STATIC STRINGS: UTF-16LE (0) |
+------------------------------------+

 ________________________
  FLOSS STACK STRINGS
 ________________________

AQAPRQVH1
JJM1
RAQH
AXAX^YZAXAYAZH
XAYZH
ws232

 ________________________
  FLOSS TIGHT STRINGS
 ________________________

 _________________________
  FLOSS DECODED STRINGS
 _________________________
```

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Unpacking UPX-packed Malware

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In our static analysis, we might stumble upon a malware sample that's been compressed or obfuscated using a technique referred to as packing. Packing serves several purposes:

- It obfuscates the code, making it more challenging to discern its structure or functionality.
- It reduces the size of the executable, making it quicker to transfer or less conspicuous.
- It confounds security researchers by hindering traditional reverse engineering attempts.

This can impair string analysis because the references to strings are typically obscured or eliminated. It also replaces or camouflages conventional PE sections with a compact loader stub, which retrieves the original code from a compressed data section. As a result, the malware file becomes both smaller and more difficult to analyze, as the original code isn't directly observable.

A popular packer used in many malware variants is the `Ultimate Packer for Executables (UPX)`.

Let's first see what happens when we run the `strings` command on a UPX-packed malware sample named `credential_stealer.exe` residing in the `C:\Samples\MalwareAnalysis\packed` directory of this section's target.

```
C:\Users\htb-student> strings
C:\Samples\MalwareAnalysis\packed\credential_stealer.exe

Strings v2.54 - Search for ANSI and Unicode strings in binary images.
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Sysinternals - www.sysinternals.com

!This program cannot be run in DOS mode.
UPX0
UPX1
UPX2
3.96
UPX!
ff.
8MZu
HcP<H
tY)
L~o
tK1
7c0
VDgxt
amE
8#v
$ /uX
OAUATUWVSH
Z6L
```

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```
<=h
%0rv
o?H9
7sk
3H{
HZu
'.}
c|/
c`fG
Iq%
[^_]A\A]
> -P
fo{Wnl
c9"^$!=
;\V
%&m
')A
v/7>
07ZC
_L$AAl
mug.%(
t%n
#8%,X
e]'^
(hk
Dks
zC:
Vj<
w~5
m<6
|$PD
c(t
\3_
---SNIP---
```

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Observe the strings that include `UPX`, and take note that the remainder of the output doesn't yield any valuable information regarding the functionality of the malware.

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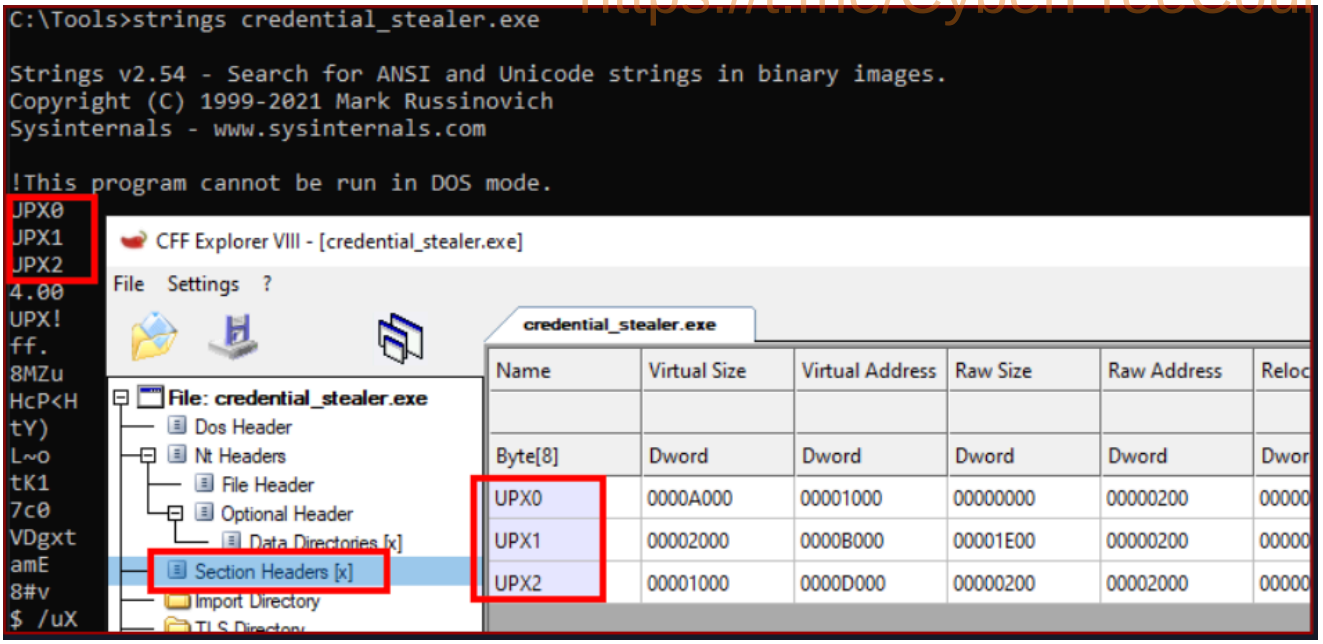

We can unpack the malware using the `UPX` tool (available at `C:\Tools\upx\upx-4.0.2-win64`) with the following command.

```
C:\Tools\upx\upx-4.0.2-win64> upx -d -o unpacked_credential_stealer.exe
C:\Samples\MalwareAnalysis\packed\credential_stealer.exe
                       Ultimate Packer for eXecutables
                          Copyright (C) 1996 - 2023
UPX 4.0.2       Markus Oberhumer, Laszlo Molnar & John Reiser   Jan 30th
2023

        File size         Ratio      Format      Name
   --------------------   ------   -----------   -----------
     16896 <-      8704   51.52%    win64/pe
unpacked_credential_stealer.exe

Unpacked 1 file.
```

Let's now run the `strings` command on the unpacked sample.

```
C:\Tools\upx\upx-4.0.2-win64> strings unpacked_credential_stealer.exe

Strings v2.54 - Search for ANSI and Unicode strings in binary images.
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Sysinternals - www.sysinternals.com

!This program cannot be run in DOS mode.
.text
P`.data
.rdata
`@.pdata
[email protected]
```

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```
[email protected]
.idata
.CRT
.tls
ff.
8MZu
HcP<H
---SNIP---
D$(
D$
D$0
D$(
D$
t'H
%5T
@A\A]A^
SeDebugPrivilege
SE Debug Privilege is adjusted
lsass.exe
Searching lsass PID
Lsass PID is: %lu
Error is - %lu
lsassmem.dmp
LSASS Memory is dumped successfully
Err 2: %lu
@u@
`p@
Unknown error
Argument domain error (DOMAIN)
Overflow range error (OVERFLOW)
Partial loss of significance (PLOSS)
Total loss of significance (TLOSS)
The result is too small to be represented (UNDERFLOW)
Argument singularity (SIGN)
_matherr(): %s in %s(%g, %g)  (retval=%g)
Mingw-w64 runtime failure:
Address %p has no image-section
  VirtualQuery failed for %d bytes at address %p
  VirtualProtect failed with code 0x%x
  Unknown pseudo relocation protocol version %d.
  Unknown pseudo relocation bit size %d.
.pdata
 0@
00@
`E@
`E@
@v@
hy@
`y@
@p@
```

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```
0v@
Pp@
AdjustTokenPrivileges
LookupPrivilegeValueA
OpenProcessToken
MiniDumpWriteDump
CloseHandle
CreateFileA
CreateToolhelp32Snapshot
DeleteCriticalSection
EnterCriticalSection
GetCurrentProcess
GetCurrentProcessId
GetCurrentThreadId
GetLastError
GetStartupInfoA
GetSystemTimeAsFileTime
GetTickCount
InitializeCriticalSection
LeaveCriticalSection
OpenProcess
Process32First
Process32Next
QueryPerformanceCounter
RtlAddFunctionTable
RtlCaptureContext
RtlLookupFunctionEntry
RtlVirtualUnwind
SetUnhandledExceptionFilter
Sleep
TerminateProcess
TlsGetValue
UnhandledExceptionFilter
VirtualProtect
VirtualQuery
__C_specific_handler
__getmainargs
__initenv
__iob_func
__lconv_init
__set_app_type
__setusermatherr
_acmdln
_amsg_exit
_cexit
_fmode
_initterm
_onexit
abort
calloc
```

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```
exit
fprintf
free
fwrite
malloc
memcpy
printf
puts
signal
strcmp
strlen
strncmp
vfprintf
ADVAPI32.dll
dbghelp.dll
KERNEL32.DLL
msvcrt.dll
```

Now, we observe a more comprehensible output that includes the actual strings present in the sample.

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Dynamic Analysis

When it comes to the domain of malware analysis, dynamic or behavioral analysis represents an indispensable approach in our investigative arsenal. In dynamic analysis, we observe and interpret the behavior of the malware while it is running, or in action. This is a critical contrast to static analysis, where we dissect the malware's properties and contents without executing it. The primary goal of dynamic analysis is to document and understand the real-world impact of the malware on its host environment, making it an integral part of comprehensive malware analysis.

In executing dynamic analysis, we encapsulate the malware within a tightly controlled, monitored, and usually isolated environment to prevent any unintentional spread or damage. This environment is typically a virtual machine (VM) to which the malware is oblivious. It believes it is interacting with a genuine system, while we, as researchers, have full control over its interactions and can document its behavior thoroughly.

Our dynamic analysis procedure can be broken down into the following steps:

- `Environment Setup`: We first establish a secure and controlled environment, typically a `VM`, isolated from the rest of the network to prevent inadvertent contamination or propagation of the malware. The VM setup should mimic a real-world system, complete with software, applications, and network configurations that an actual user might have.
- `Baseline Capture`: After the environment is set up, we capture a snapshot of the system's clean state. This includes `system files`, `registry states`, `running`

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`processes`, `network configuration`, and more. This baseline serves as a reference point to identify changes made by the malware post-execution.

- `Tool Deployment (Pre-Execution)`: To capture the activities of the malware effectively, we deploy various monitoring and logging tools. Tools such as `Process Monitor (Procmon)` from Sysinternals Suite are used to log system calls, file system activity, registry operations, etc. We can also employ utilities like `Wireshark`, `tcpdump`, and `Fiddler` for capturing network traffic, and `Regshot` to take before-and-after snapshots of the system registry. Finally, tools such as `INetSim`, `FakeDNS`, and `FakeNet-NG` are used to simulate internet services.
- `Malware Execution`: With our tools running and ready, we proceed to execute the malware sample in the isolated environment. During execution, the monitoring tools capture and log all activities, including process creation, file and registry modifications, network traffic, etc.
- `Observation and Logging`: The malware sample is allowed to execute for a sufficient duration. All the while, our monitoring tools are diligently recording its every move, which will provide us with comprehensive insight into its behavior and modus operandi.
- `Analysis of Collected Data`: After the malware has run its course, we halt its execution and stop the monitoring tools. We now examine the logs and data collected, comparing the system's state to our initial baseline to identify the changes introduced by the malware.

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In some cases, when the malware is particularly evasive or complex, we might employ sandboxed environments for dynamic analysis. Sandboxes, such as `Cuckoo Sandbox`, `Joe Sandbox`, or `FireEye's Dynamic Threat Intelligence cloud`, provide an automated, safe, and highly controlled environment for malware execution. They come equipped with numerous features for in-depth behavioral analysis and generate detailed reports regarding the malware's network behavior, file system interaction, memory footprint, and more.

However, it's important to remember that while sandbox environments are valuable tools, they are not foolproof. Some advanced malware can detect sandbox environments and alter their behavior accordingly, making it harder for researchers to ascertain their true nature.

Let's now navigate to the bottom of this section and click on "Click here to spawn the target system!". Then, let's RDP into the Target IP using the provided credentials. The vast majority of the actions/commands covered from this point up to end of this section can be replicated inside the target, offering a more comprehensive grasp of the topics presented.

```
xfreerdp /u:htb-student /p:'HTB_@cademy_stdnt!' /v:[Target IP] /dynamic-resolution
```

Dynamic Analysis With Noriben

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Noriben is a powerful tool in our dynamic analysis toolkit, essentially acting as a Python wrapper for Sysinternals `ProcMon`, a comprehensive system monitoring utility. It orchestrates the operation of `ProcMon`, refines the output, and adds a layer of malware-specific intelligence to the process. Leveraging `Noriben`, we can capture malware behaviors more conveniently and understand them more precisely.

To understand how `Noriben` empowers our dynamic analysis efforts, let's first quickly review `ProcMon`. This tool, from `Sysinternals Suite`, monitors real-time file system, Registry, and process/thread activity. It combines the features of utilities like `Filemon`, `Regmon`, and advanced features like filtering, advanced highlighting, and extensive event properties, making it a powerful system monitoring tool for malware analysis.

However, the volume and breadth of information that `ProcMon` collects can be overwhelming. Without proper filtering and contextual analysis, sifting through this raw data becomes a considerable challenge. This is where Noriben steps in. It uses `ProcMon` to capture system events but then filters and analyzes this data to extract meaningful information and pinpoint malicious activities.

In our dynamic malware analysis process, here's how we employ Noriben:

- `Setting Up Noriben`: We initiate `Noriben` by launching it from the command line. The tool supports numerous command-line arguments to customize its operation. For instance, we can define the duration of data collection, specify a custom malware sample for execution, or select a personalized `ProcMon` configuration file.
- `Launching ProcMon`: Upon initiation, `Noriben` starts `ProcMon` with a predefined configuration. This configuration contains a set of filters designed to exclude normal system activity and focus on potential indicators of malicious actions.
- `Executing the Malware Sample`: With `ProcMon` running, `Noriben` executes the selected malware sample. During this phase, `ProcMon` captures all system activities, including process operations, file system changes, and registry modifications.
- `Monitoring and Logging`: `Noriben` controls the duration of monitoring, and once it concludes, it commands `ProcMon` to save the collected data to a CSV file and then terminates ProcMon.
- `Data Analysis and Reporting`: This is where `Noriben` shines. It processes the CSV file generated by `ProcMon`, applying additional filters and performing contextual analysis. `Noriben` identifies potentially suspicious activities and organizes them into different categories, such as file system activity, process operations, and network connections. This process results in a clear, readable report in HTML or TXT format, highlighting the behavioral traits of the analyzed malware.

Noriben's integration with YARA rules is another notable feature. We can leverage YARA rules to enhance our data filtering capabilities, allowing us to identify patterns of interest more efficiently.

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For demonstration purposes, we'll conduct dynamic analysis on a malware specimen named `shell.exe`, found in the `C:\Samples\MalwareAnalysis` directory on this section's target machine. Follow these steps:

- Launch a new Command Line interface and make your way to the `C:\Tools\Noriben-master` directory.
- Initiate Noriben as indicated.

```
C:\Tools\Noriben-master> python .\Noriben.py
[*] Using filter file: ProcmonConfiguration.PMC
[*] Using procmon EXE: C:\ProgramData\chocolatey\bin\procmon.exe
[*] Procmon session saved to: Noriben_27_Jul_23__23_40_319983.pml
[*] Launching Procmon ...
[*] Procmon is running. Run your executable now.
[*] When runtime is complete, press CTRL+C to stop logging.
```

- Upon seeing the `User Account Control` prompt, select `Yes`.
- Proceed to `C:\Samples\MalwareAnalysis` and activate `shell.exe` by double-clicking.
- `shell.exe` will identify it is running within a sandbox. Close the window it created.
- Terminate `ProcMon`.
- In the Command Prompt running Noriben, use the `Ctrl+C` command to cease its operation.

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```
C:\Tools\Noriben-master> python .\Noriben.py
[*] Using filter file: ProcmonConfiguration.PMC
[*] Using procmon EXE: C:\ProgramData\chocolatey\bin\procmon.exe
[*] Procmon session saved to: Noriben_27_Jul_23__23_40_319983.pml
[*] Launching Procmon ...
[*] Procmon is running. Run your executable now.
[*] When runtime is complete, press CTRL+C to stop logging.

[*] Termination of Procmon commencing... please wait
[*] Procmon terminated
[*] Saving report to: Noriben_27_Jul_23__23_42_335666.txt
[*] Saving timeline to: Noriben_27_Jul_23__23_42_335666_timeline.csv
[*] Exiting with error code: 0: Normal exit
```

You'll observe that Noriben generates a `.txt` report inside it's directory, compiling all the behavioral information it managed to gather.

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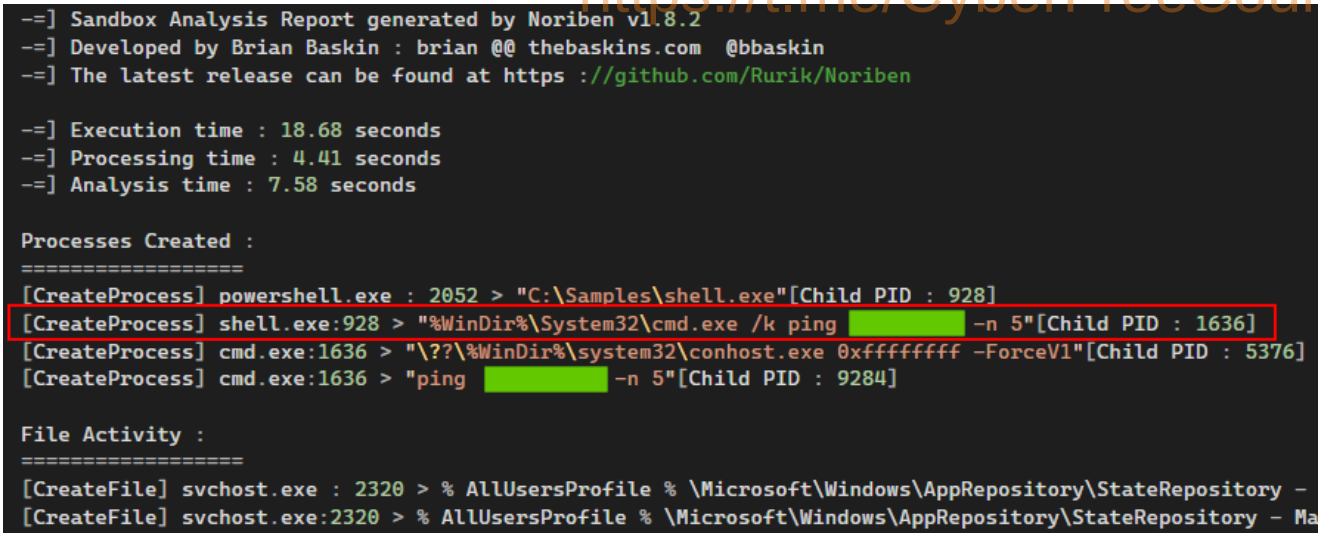

As discussed, `Noriben` uses `ProcMon` to capture system events but then filters and analyzes this data to extract meaningful information and pinpoint malicious activities.

`Noriben` might filter out some potentially valuable information. For instance, we don't receive any insightful data from Noriben's report about how `shell.exe` recognized that it was functioning within a sandbox or virtual machine.

Let's take a different approach and manually launch `ProcMon` (available at `C:\Tools\sysinternals`) using its default, more inclusive, configuration. Following this, let's re-run `shell.exe`. This might give us insights into how `shell.exe` detects the presence of a sandbox or virtual machine.

Then, let's configure the filter (`Ctrl+L`) as follows and press `Apply`.

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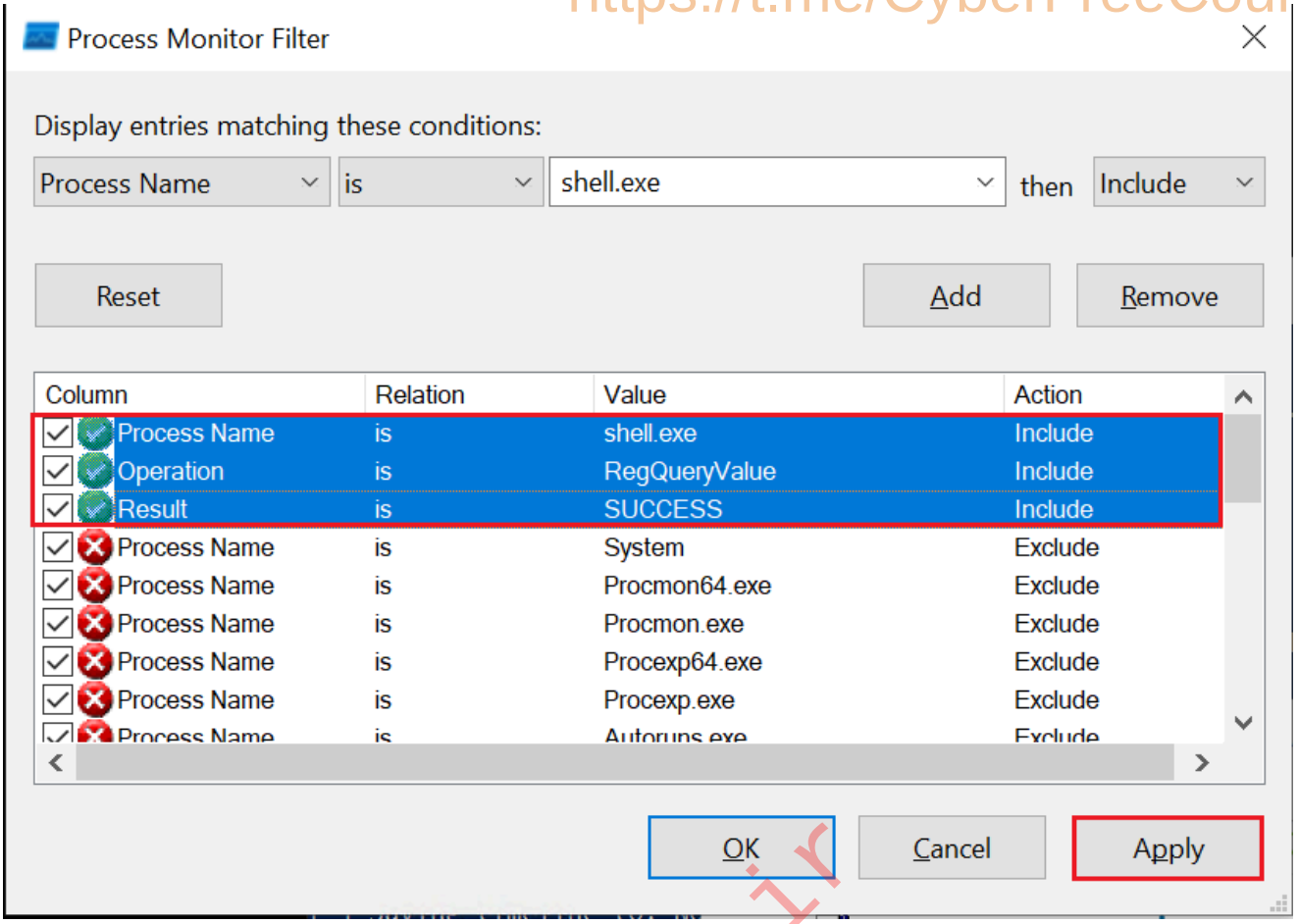
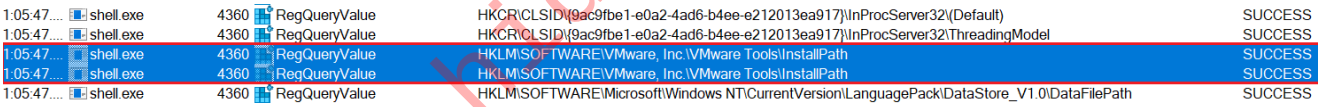


Finally, let's navigate to the end of the results. There can observe that `shell.exe` conducts sandbox or virtual machine detection by querying the registry for the presence of `VMware Tools`.



Code Analysis

Reverse Engineering & Code Analysis

`Reverse engineering` is a process that takes us beneath the surface of executable files or compiled machine code, enabling us to decode their functionality, behavioral traits, and structure. With the absence of source code, we turn to the analysis of disassembled code instructions, also known as `assembly code analysis`. This deeper level of understanding helps us to uncover obscured or elusive functionalities that remain hidden even after static and dynamic analysis.

To untangle the complex web of machine code, we turn to a duo of powerful tools: `Disassemblers` and `Debuggers`.

- A `Disassembler` is our tool of choice when we wish to conduct a static analysis of the code, meaning that we need not execute the code. This type of analysis is invaluable as it helps us to understand the structure and logic of the code without activating

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potentially harmful functionalities. Some prime examples of disassemblers include `IDA`, `Cutter`, and `Ghidra`.

- A `Debugger`, on the other hand, serves a dual purpose. Like a disassembler, it decodes machine code into assembly instructions. Additionally, it allows us to execute code in a controlled manner, proceeding instruction by instruction, skipping to specific locations, or halting the execution flow at designated points using breakpoints. Examples of debuggers include `x32dbg`, `x64dbg`, `IDA`, and `OllyDbg`.

Let's take a step back and understand the challenge before us. The journey of code from human-readable high-level languages, such as C or C++, to `machine code` is a one-way ticket, guided by the compiler. `Machine code`, a binary language that computers process directly, is a cryptic narrative for human analysts. Here's where the assembly language comes into play, acting as a bridge between us and the machine code, enabling us to decode the latter's story.

A disassembler transforms machine code back into assembly language, presenting us with a readable sequence of instructions. Understanding assembly and its mnemonics is pivotal in dissecting the functionality of malware.

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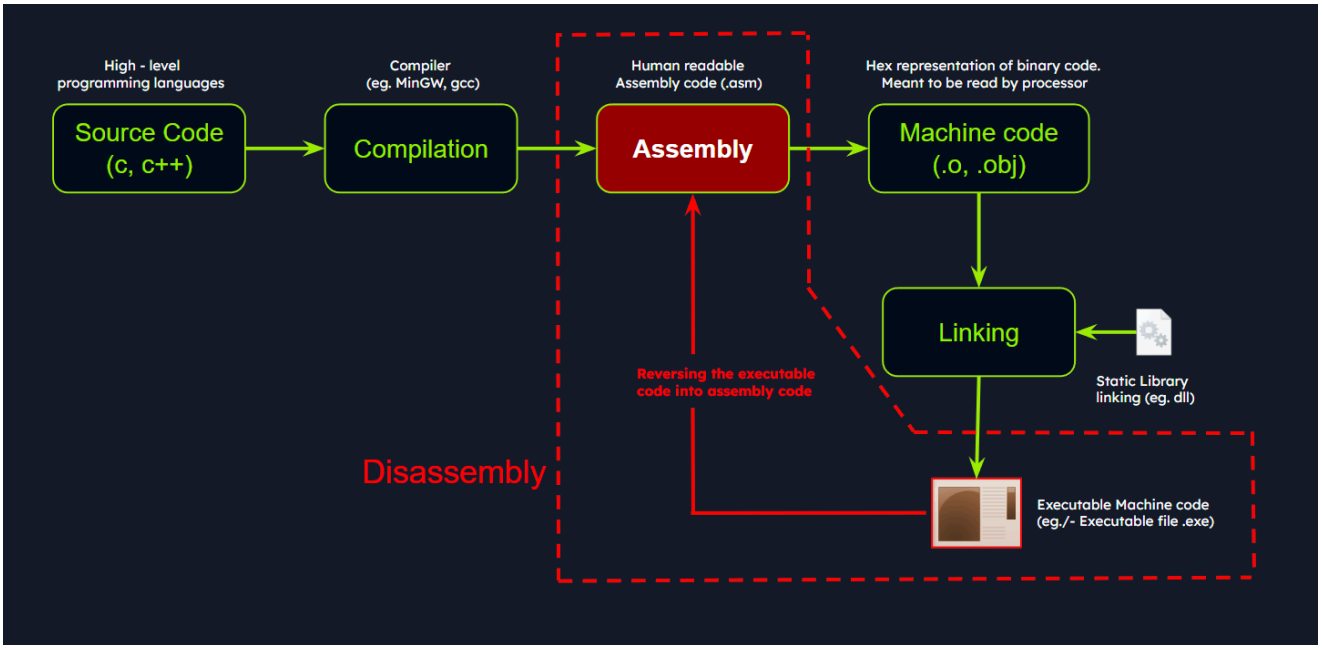
`Code analysis` is the process of scrutinizing and deciphering the behavior and functionality of a compiled program or binary. This involves analyzing the instructions, control flow, and data structures within the code, ultimately shedding light on the purpose, functionality, and potential `indicators of compromise (IOCs)`.

Understanding a program or a piece of malware often requires us to reverse the compilation process. This is where `Disassembly` comes into the picture. By converting machine code back into assembly language instructions, we end up with a set of instructions that are symbolic and mnemonic, enabling us to decode the logic and workings of the program.



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Disassemblers are our allies in this process. These specialized tools take the binary code, generate the corresponding assembly instructions, and often supplement them with additional context such as memory addresses, function names, and control flow analysis. One such powerful tool is IDA, a widely used disassembler and debugger revered for its advanced analysis features. It supports multiple executable file formats and architectures, presenting a comprehensive disassembly view and potent analysis capabilities.

Let's now navigate to the bottom of this section and click on "Click here to spawn the target system!". Then, let's RDP into the Target IP using the provided credentials. The vast majority of the actions/commands covered from this point up to end of this section can be replicated inside the target, offering a more comprehensive grasp of the topics presented.

```
xfreerdp /u:htb-student /p:'HTB_@cademy_stdnt!' /v:[Target IP] /dynamic-resolution
```

Code Analysis Example: shell.exe

Let's persist with the analysis of the `shell.exe` malware sample residing in the `C:\Samples\MalwareAnalysis` directory of this section's target. Up until this point, we've discovered that it conducts `sandbox detection`, and that it includes a possible sleep mechanism - a `5-second ping` delay - before executing its intended operations.

Importing a Malware Sample into the Disassembler - IDA

For the next stage in our investigation, we must scrutinize the code in `IDA` to ascertain its further actions and discover how to circumvent the sandbox check employed by the malware sample.

We can initiate `IDA` either by double-clicking the `IDA` shortcut that is placed on the Desktop or by right-clicking it and selecting `Run as administrator` to ensure proper access rights. At first, it will display the license information and subsequently prompt us to open a new executable for analysis.

Next, opt for `New` and select the `shell.exe` sample residing in the `C:\Samples\MalwareAnalysis` directory of this section's target to dissect.

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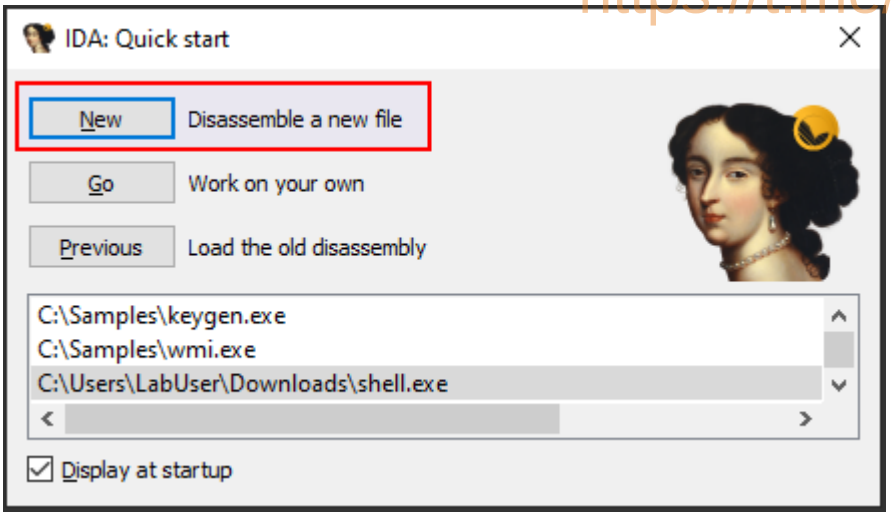
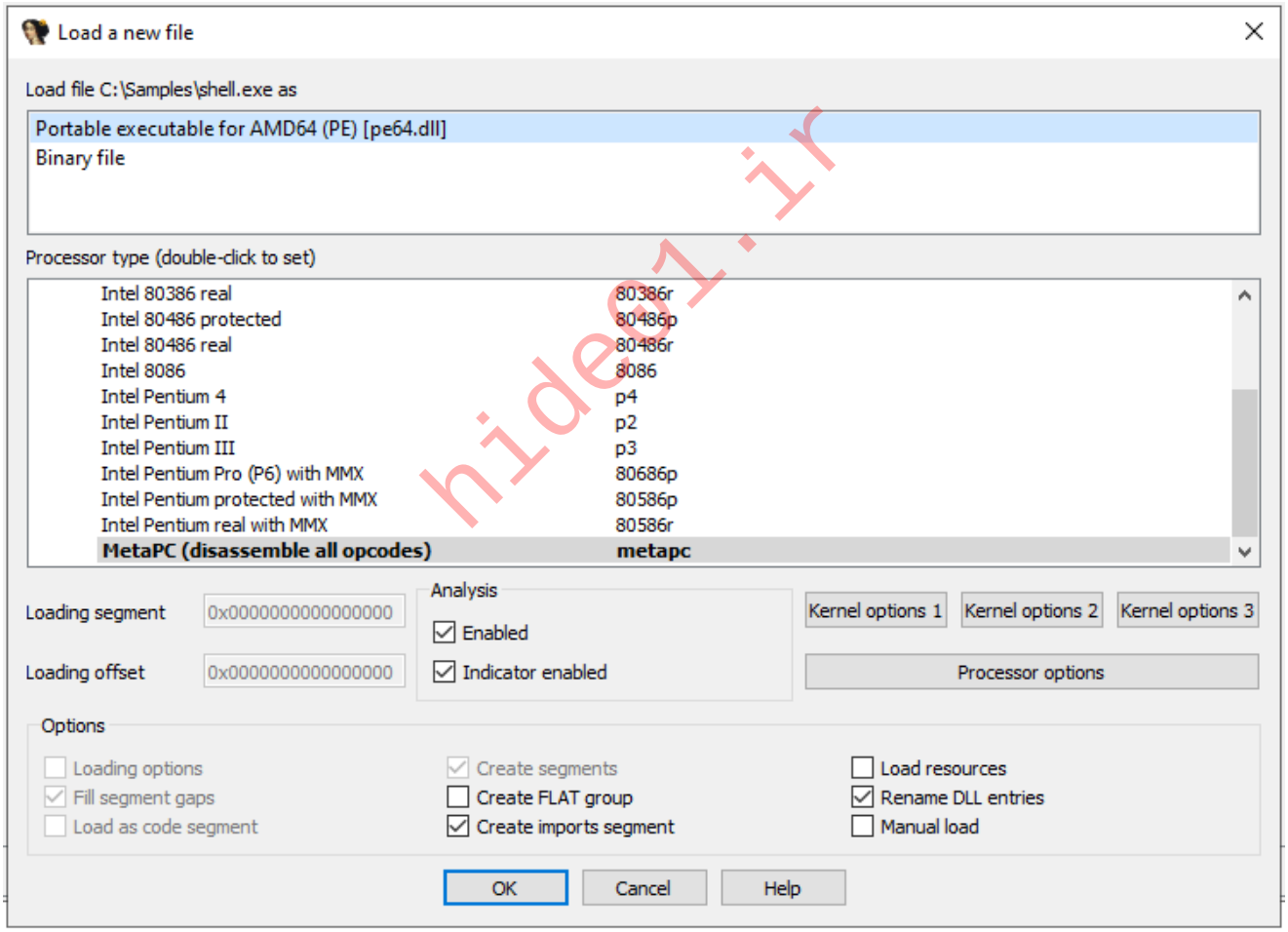


The `Load a new file` dialog box that pops up next is where we can select the processor architecture. Choose the correct one and click `OK`. By default, `IDA` determines the appropriate processor type.



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After we hit `OK`, `IDA` will load the executable file into memory and disassemble the machine code to render the disassembled output for us. The screenshot below illustrates the different views in `IDA`.

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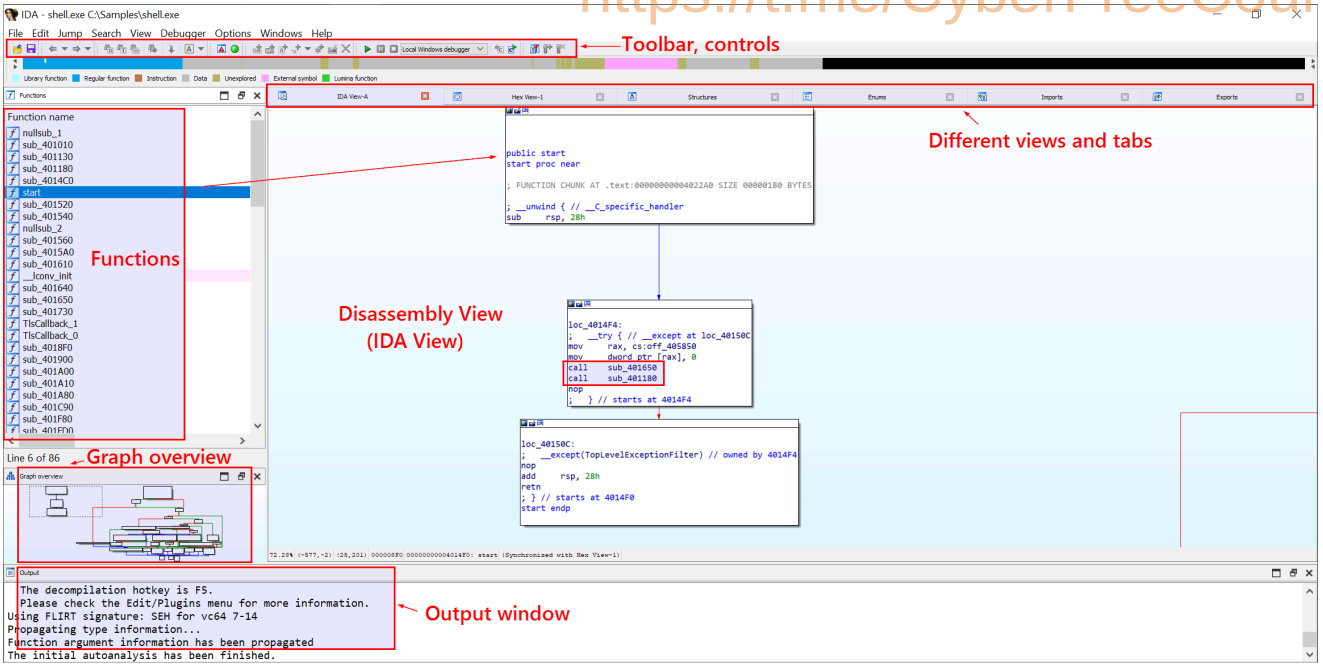

Once the executable is loaded and the analysis completes, the disassembled code of the sample `shell.exe` will be exhibited in the main `IDA-View` window. We can traverse through the code using the cursor keys or the scroll bar and zoom in or out using the mouse wheel or the zoom controls.

Text and Graph Views

The disassembled code is presented in two modes, namely the `Graph view` and the `Text view`. The default view is the `Graph view`, which provides a graphic illustration of the function's basic blocks and their interconnections. Basic blocks are instruction sequences with a single entry and exit point. These basic blocks are symbolized as nodes in the graph view, with the connections between them as edges.

To toggle between the graph and text views, simply press the `spacebar` button.

- The `Graph view` offers a pictorial representation of the program's control flow, facilitating a better understanding of execution flow, identification of loops, conditionals, and jumps, and a visualization of how the program branches or cycles through different code paths.

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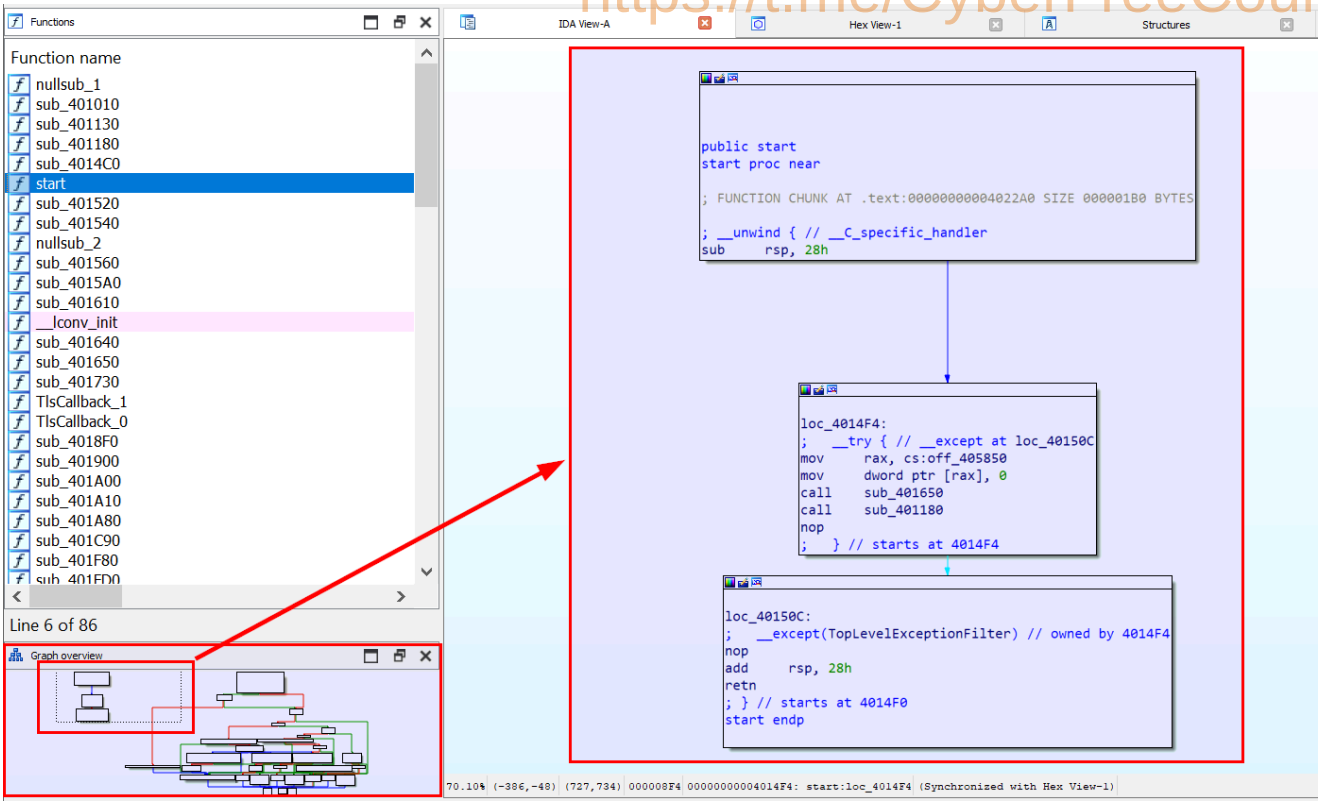

The functions are displayed as `nodes` in the `Graph view`. Each function is depicted as a distinct node with a unique identifier and additional details such as the `function name`, `address`, and `size`.

- The `Text view` displays the assembly instructions along with their corresponding memory addresses. Each line in the `Text view` represents an `instruction or a data element` in the code, beginning with the `section name:virtual address` format (for example, `.text:00000000004014F0`, where the section name is `.text` and the virtual address is `00000000004014F0`).

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```
text:00000000004014F0 ; =============== S U B R O U T I N E
=======================================
text:00000000004014F0
text:00000000004014F0
text:00000000004014F0                 public start
text:00000000004014F0 start           proc near               ; DATA XREF:
.pdata:000000000040603C↓o
text:00000000004014F0
text:00000000004014F0 ; FUNCTION CHUNK AT
.text:00000000004022A0 SIZE 000001B0 BYTES
text:00000000004014F0
text:00000000004014F0 ; __unwind { // __C_specific_handler
text:00000000004014F0                 sub     rsp, 28h
text:00000000004014F4
text:00000000004014F4 loc_4014F4:                             ; DATA XREF:
.xdata:0000000000407058↓o
text:00000000004014F4 ;   __try { // __except at loc_40150C
text:00000000004014F4                 mov     rax, cs:off_405850
```

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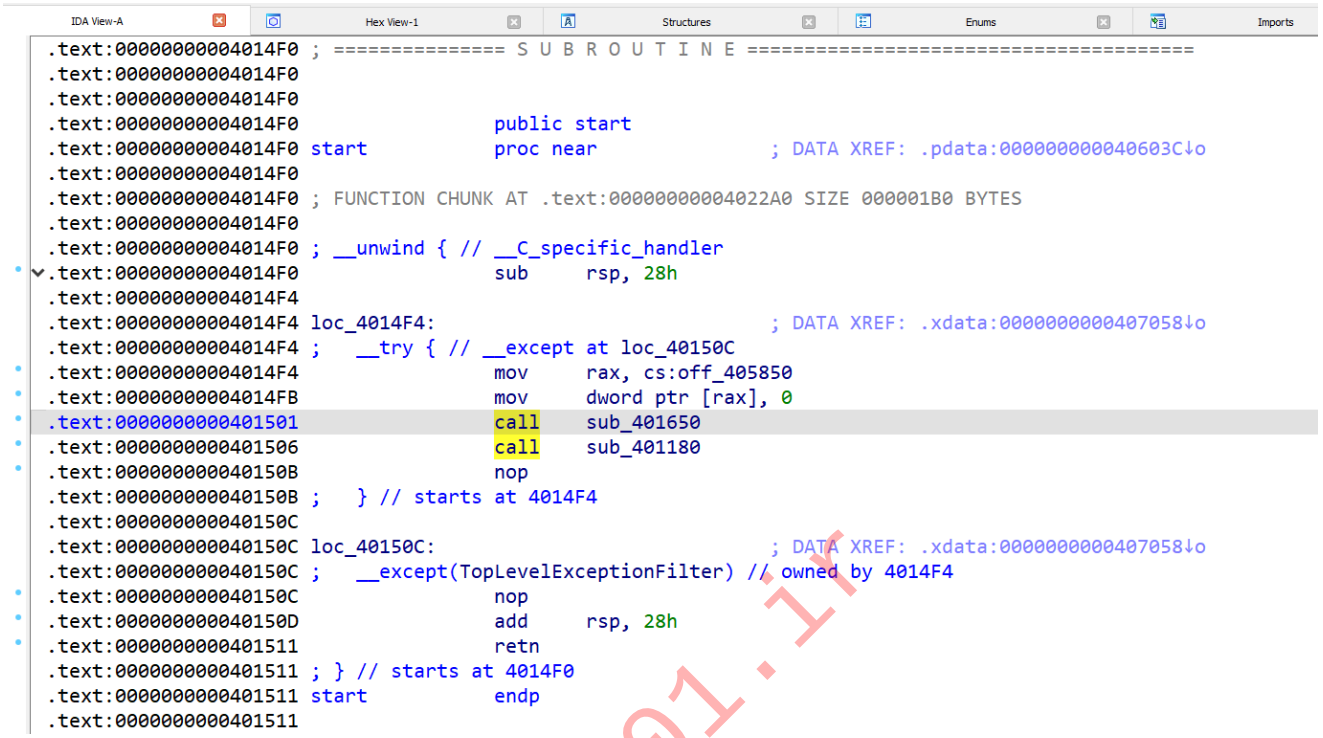
```
text:00000000004014FB                   mov     dword ptr [rax], 0
text:0000000000401501                   call    sub_401650
text:0000000000401506                   call    sub_401180
text:000000000040150B                   nop
text:000000000040150B ;   } // starts at 4014F4
```



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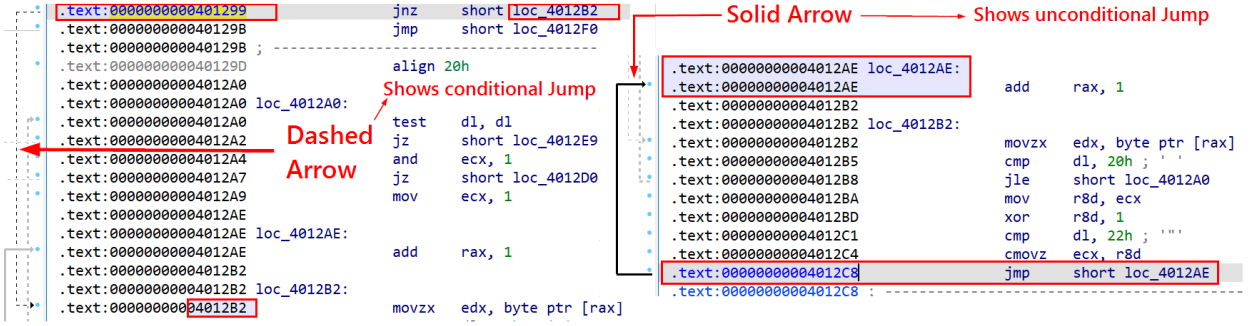
`IDA`'s `Text view` employs arrows to signify different types of control flow instructions and jumps. Here are some commonly seen arrows and their interpretations:

- `Solid Arrow (→)`: A solid arrow denotes a direct jump or branch instruction, indicating an unconditional shift in the program's flow where execution moves from one location to another. This occurs when a jump or branch instruction like `jmp` or `call` is encountered.
- `Dashed Arrow (----→)`: A dashed arrow represents a conditional jump or branch instruction, suggesting that the program's flow might change based on a specific condition. The destination of the jump depends on the condition's outcome. For instance, a `jz` (jump if zero) instruction will trigger a jump only if a previous comparison yielded a zero value.



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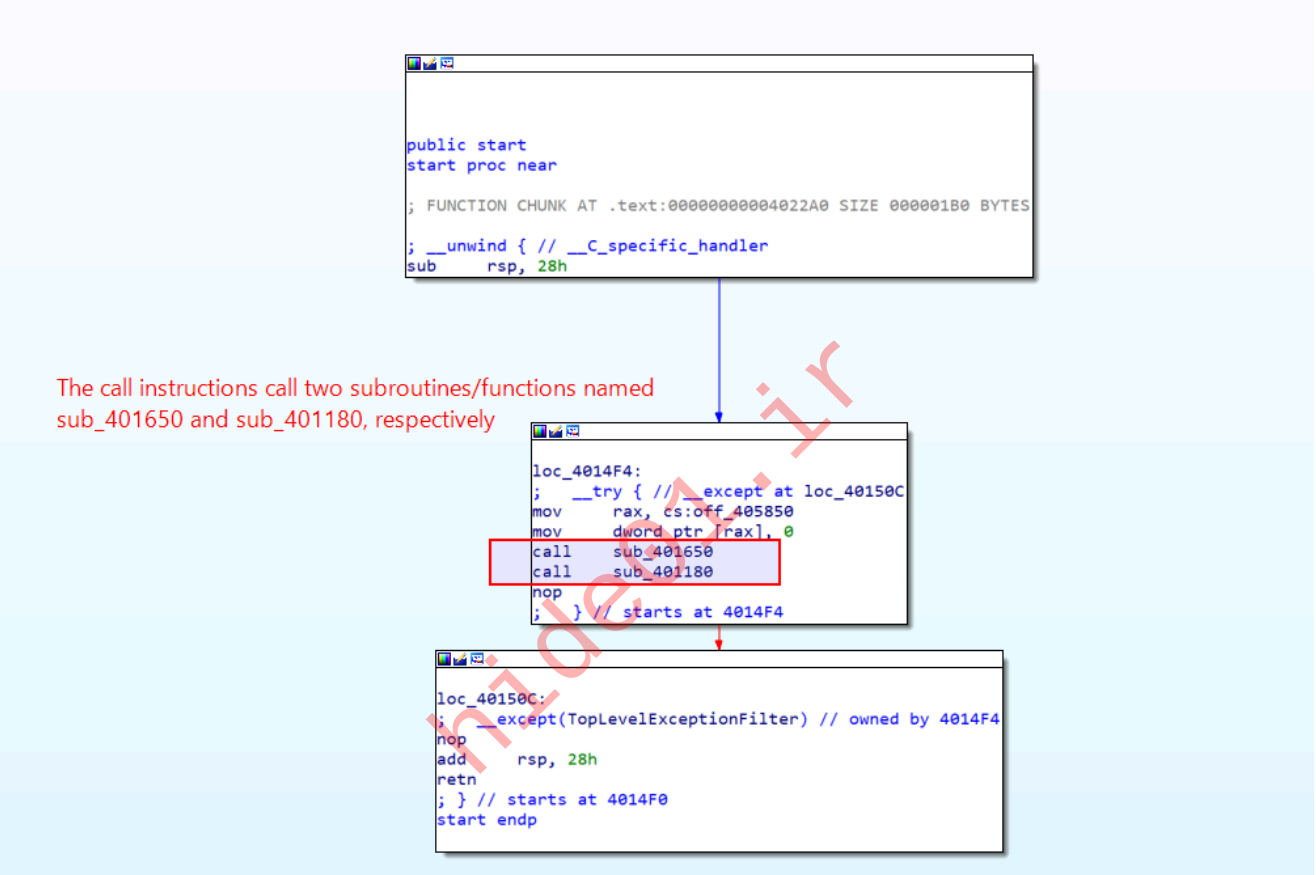
By default, IDA initially exhibits the main function or the function at the program's designated entry point. However, we have the liberty to explore and examine other functions in the graph view.

Recognizing the Main Function in IDA

The following screenshot demonstrates the `start` function, which is the program's entry point and is generally responsible for setting up the runtime environment before invoking the actual `main` function. This is the initial `start` function shown by IDA after the executable is loaded.



Our objective is to locate the actual main function, which necessitates further exploration of the disassembly. We will search for function calls or jumps that lead to other functions, as one of them is likely to be the main function. `IDA`'s graph view, cross-references, or function list can aid in navigating through the disassembly and identifying the `main` function.

However, to reach the `main` function, we first need to understand the function of this `start` function. This function primarily consists of some initialization code, exception handling, and function calls. It eventually jumps to the `loc_40150C` label, which is an exception handler. Therefore, we can infer that this is not the actual main function where the program logic typically resides. We will inspect the other function calls to identify the `main` function.

The code commences by subtracting `0x28` (40 in decimal) from the `rsp` (stack pointer) register, effectively creating space on the stack for local variables and preserving the previous stack contents.

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```
public start
start proc near

; FUNCTION CHUNK AT .text:00000000004022A0 SIZE 000001B0 BYTES

; __unwind { // __C_specific_handler
sub     rsp, 28h
```

The middle block in the screenshot above represents an exception handling mechanism that uses `structured exception handling (SEH)` in the code. The `__try` and `__except` keywords suggest the setup of an exception handling block. Within this, the subsequent `call` instructions call two subroutines (functions) named `sub_401650` and `sub_401180`, respectively. These are placeholder names automatically generated by IDA to denote subroutines, program locations, and data. The autogenerated names usually bear one of the following prefixes followed by their corresponding virtual addresses: `sub_<virtual_address>` or `loc_<virtual_address>` etc.

```
loc_4014F4:
;   __try { // __except at loc_40150C
mov     rax, cs:off_405850
mov     dword ptr [rax], 0
call    sub_401650          ; Will inspect this function
call    sub_401180          ; Will inspect this function
nop
;   } // starts at 4014F4

---------------------------------------------

loc_40150C:
;   __except(TopLevelExceptionFilter) // owned by 4014F4
nop
add     rsp, 28h
retn
; } // starts at 4014F0
start endp
```

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Navigating Through Functions in IDA

Let's inspect the contents of these two functions `sub_401650` and `sub_401180` by navigating within each function to peruse the disassembled code.

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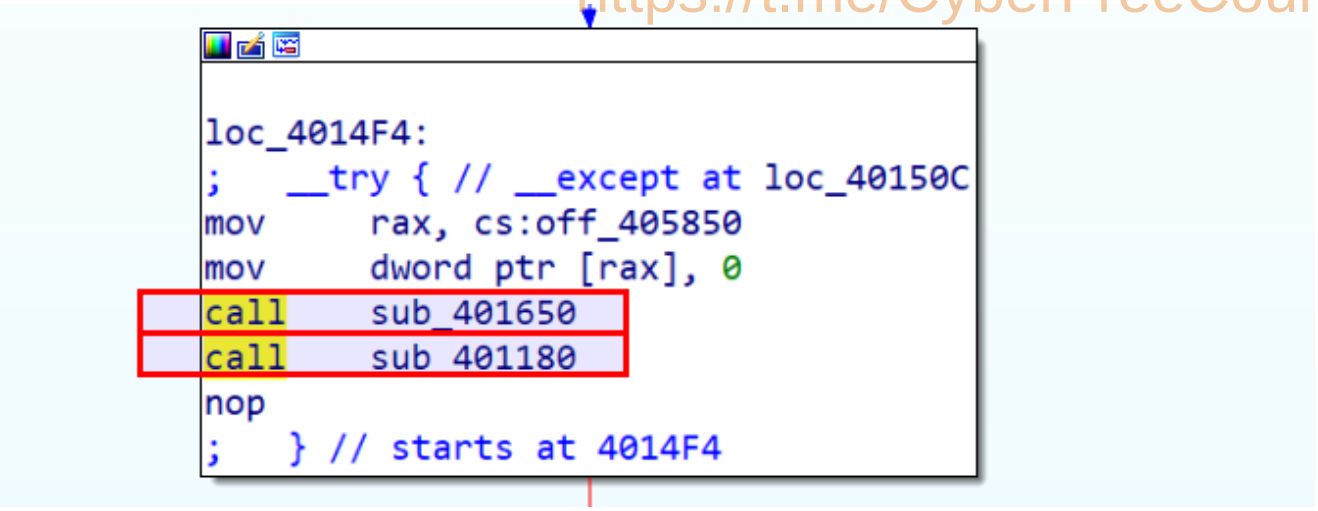
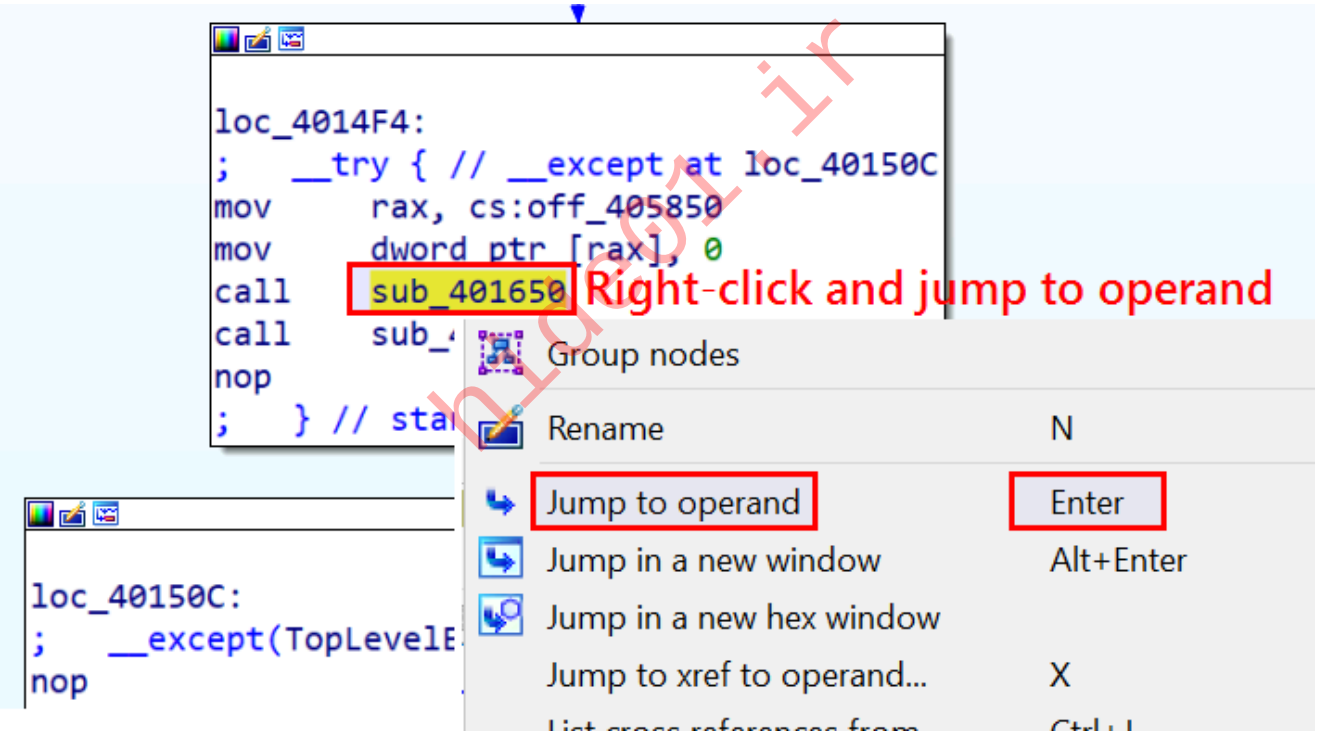


We will initially open the first function/subroutine `sub_401650`. To enter a function in `IDA`'s disassembly view, place the cursor on the instruction that represents the function call (or jump instruction) we want to follow, then right-click on the instruction and select `Jump to Operand` from the context menu. Alternatively, we can press the `Enter` key on our keyboard.



Then, `IDA` will guide us to the target location of the jump or function call, taking us to the start of the called function or the destination of the jump.

Now that we're inside the first function/subroutine `sub_401650`, let's strive to understand it in order to determine if it's the `main` function. If not, we'll navigate through other functions and discern the call to the `main` function.

In this subroutine `sub_401650`, we can see call instructions to the functions such as `GetSystemTimeAsFileTime`, `GetCurrentProcessId`, `GetCurrentThreadId`, `GetTickCount`, and `QueryPerformanceCounter`. This pattern is frequently observed at the

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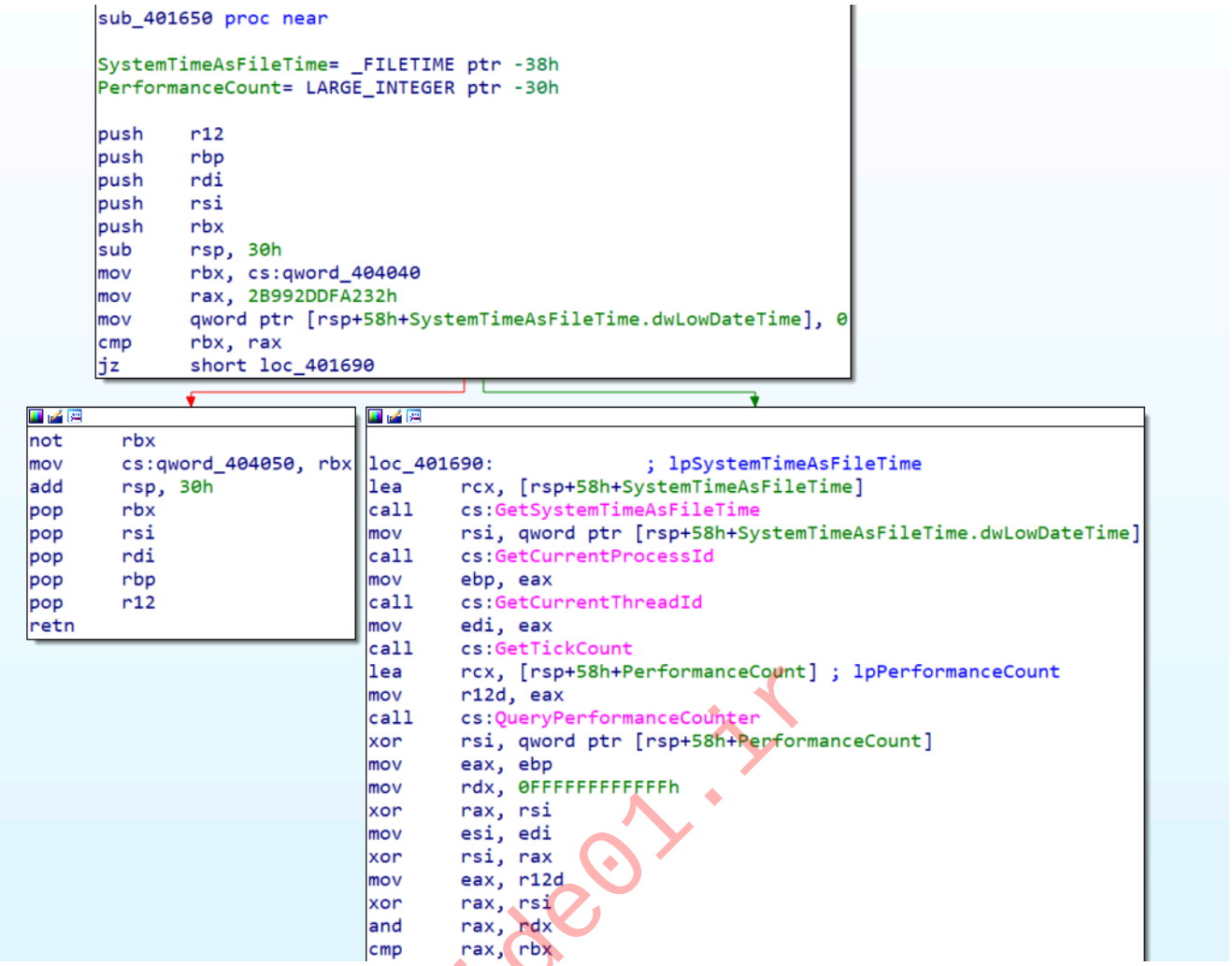
beginning of disassembled executable code and typically consists of setting up the initial stack frame and carrying out some system-related initialization tasks.



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The type of instructions detailed here are typically found in the executable code produced by compilers targeting the x86/x64 architecture. When an executable is loaded and run by the operating system, it falls to the operating system to ready the execution environment for the program. This process involves tasks such as stack setup, register initialization, and preparation of system-relevant data structures.

Broadly speaking, this section of code is part of the initial execution environment setup, carrying out necessary system-related initialization tasks before the program's main logic executes. The goal here is to guarantee that the program launches in a consistent state, with access to necessary system resources and information. To clarify, this isn't where the program's main logic resides, and so we need to explore other function calls to pinpoint the `main` function.

Let's return to and open the second subroutine, `sub_401180`, to examine its contents.

To backtrack to the previous function we were scrutinizing, we can press the `Esc` key on our keyboard, or alternatively, we can click the `Jump Back` button in the toolbar.

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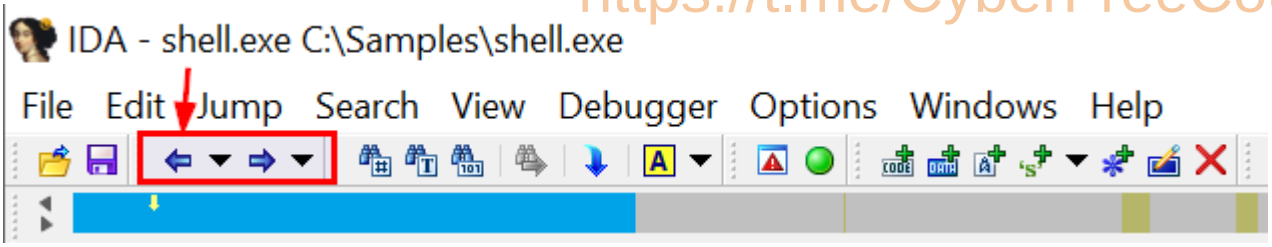
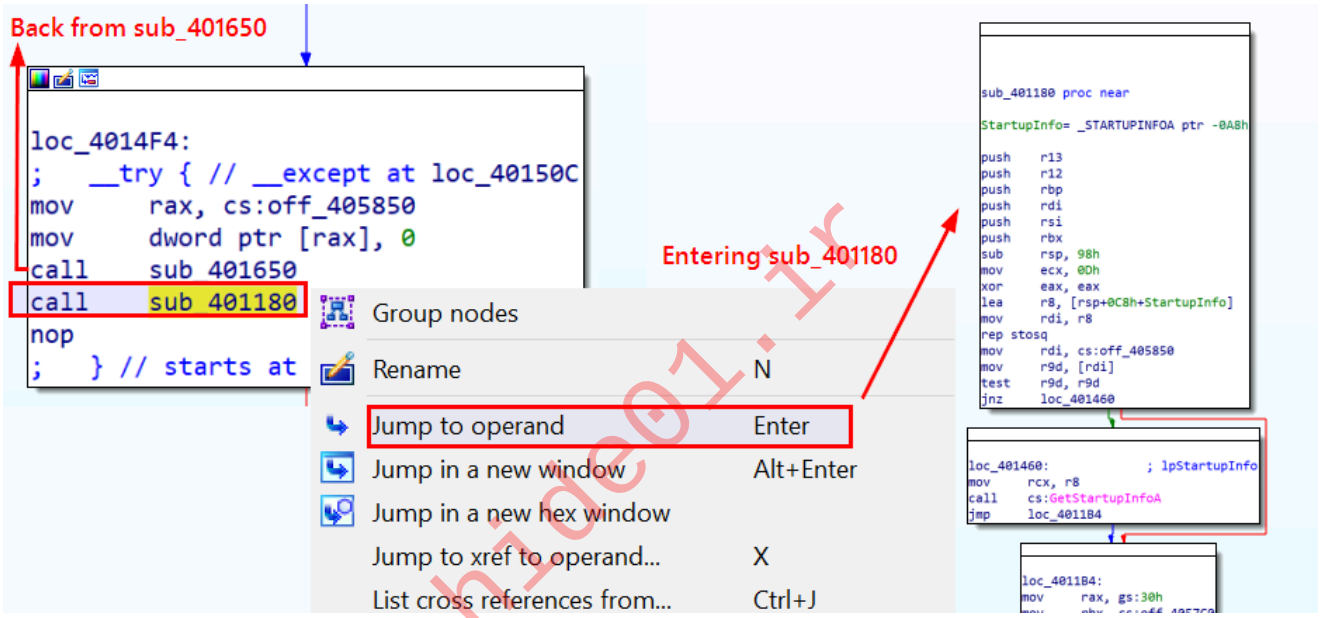


`IDA` will transport us back to the previous function we were inspecting (`loc_4014F4`), taking us to where we were prior to shifting to the current function or location. We're now back at the preceding location, which contains the call instructions to the current function, `sub_401650`, as well as another function, `sub_401180`.

From here, we can position the cursor on the instruction to call `sub_401180` and press `Enter`.



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This will guide us into the function `sub_401180`, where we will endeavor to identify the `main` function in which the program logic is situated.

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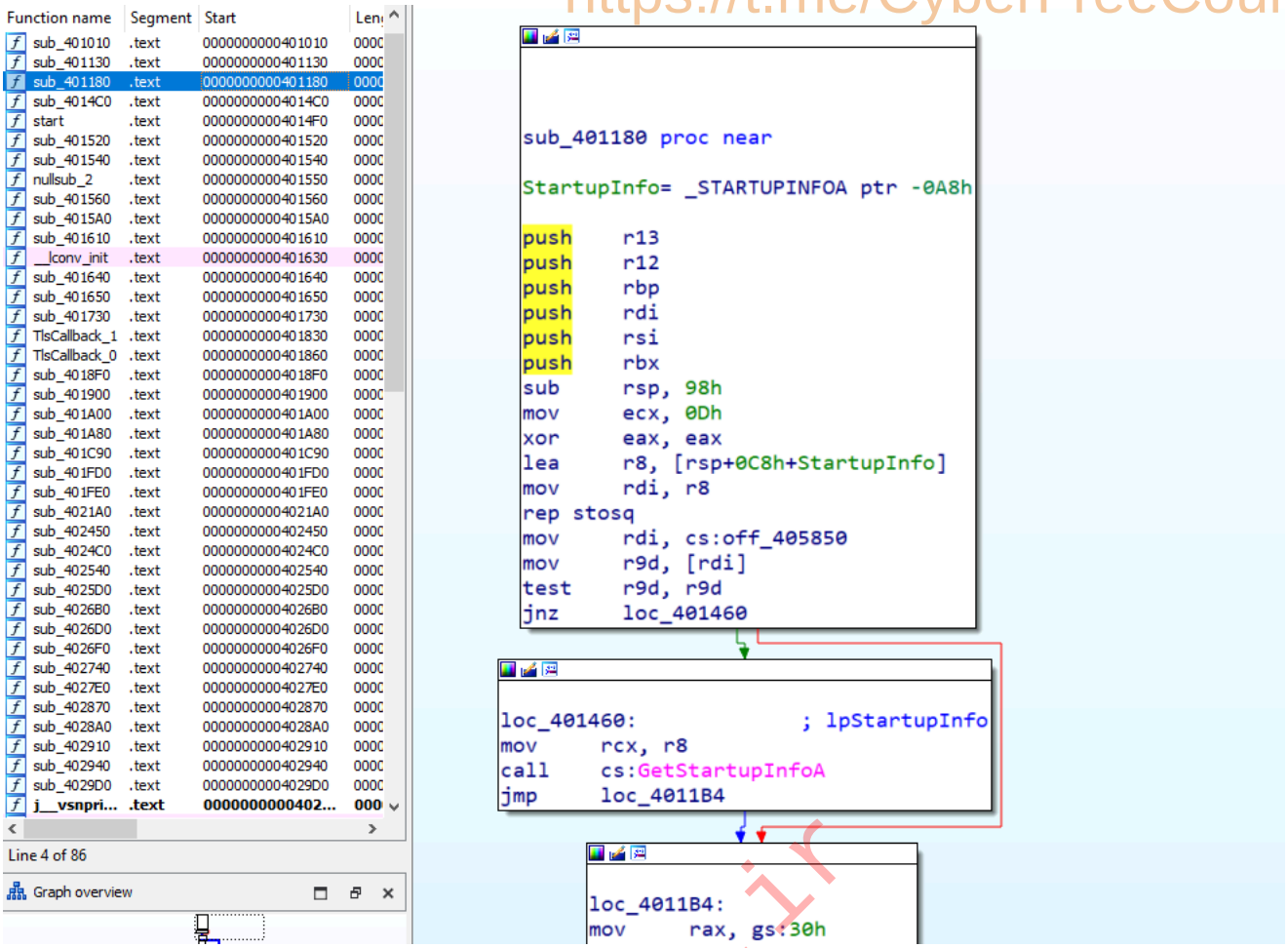

Upon examination, we can observe that this function seems to be implicated in initializing the `StartupInfo` structure and performing certain checks relative to its value. The `rep stosq` instruction nullifies a block of memory, while subsequent instructions modify the contents of registers and execute conditional jumps based on register values. This does not seem to be the `main` function in which the program logic resides, but it does contain a few `call` instructions which could potentially lead us to the `main` function. We will investigate all the `call` instructions prior to the return of this function.

We need to scroll to this function's endpoint and begin searching for `call` instructions from the bottommost one.

On scrolling upwards from the endpoint of this block (where the function returns), we observe a call to another subroutine, `sub_403250`, prior to this function's return.

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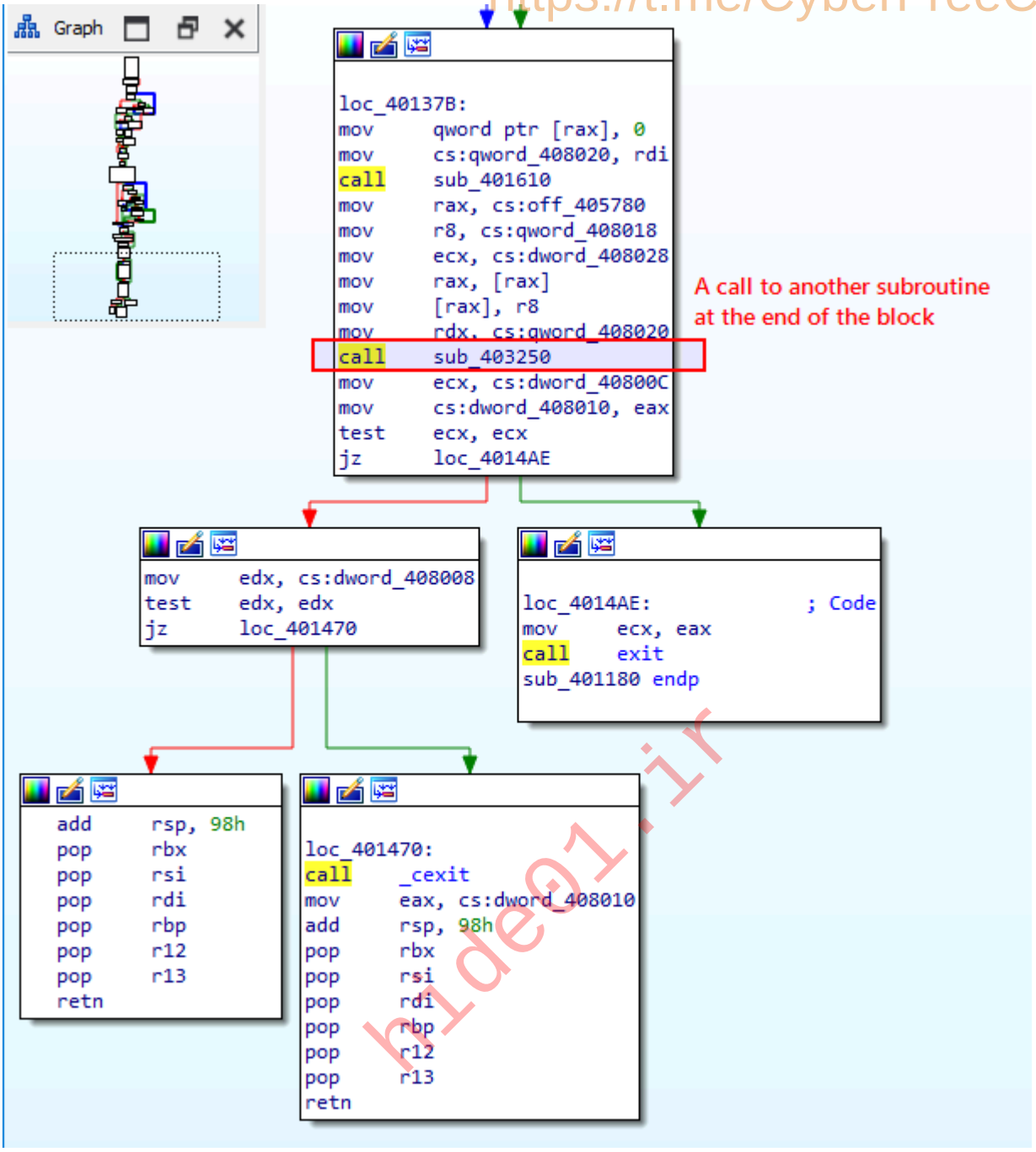

Our objective is to traverse the function calls preceding the program's exit in order to locate the main function, which might contain the initial code for registry check (sandbox detection) we witnessed in process monitor and strings.

We must now navigate to the function `sub_403250` to investigate its contents. To enter this function, we should position the cursor on the call instruction below:

```
call    sub_403250
```

We can right-click on the instruction and select `Jump to Operand` from the context menu, or alternatively, we can press the `Enter` key. This action will reveal the disassembled function for `sub_403250`.

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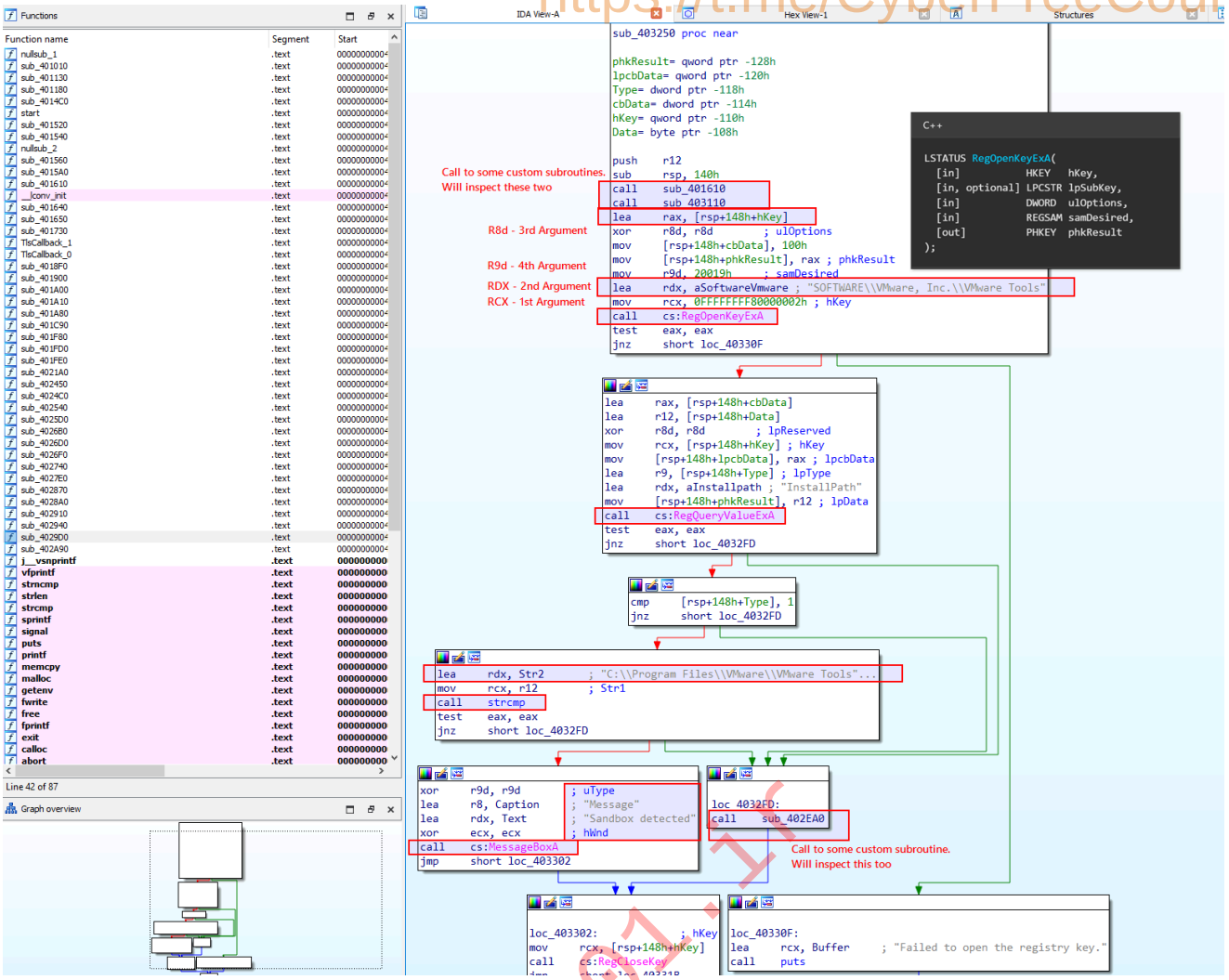

Upon reviewing the instructions, it appears that the function is querying the registry for the value associated with the `SOFTWARE\\VMware, Inc.\\VMware Tools` path and performing a comparison to discern whether VMWare Tools is installed on the machine. Generally speaking, it seems probable that this is the `main` function, which was referenced in the process monitor and strings.

We can observe that the registry query is performed using the function `RegOpenKeyExA`, as shown in the instruction `call cs:RegOpenKeyExA` in the disassembled code that follows:

```
xor     r8d, r8d        ; ulOptions
mov     [rsp+148h+cbData], 100h
mov     [rsp+148h+phkResult], rax ; phkResult
mov     r9d, 20019h     ; samDesired
lea     rdx, aSoftwareVmware ; "SOFTWARE\\VMware, Inc.\\VMware Tools"
mov     rcx, 0FFFFFFFF80000002h ; hKey
call    cs:RegOpenKeyExA
```

In the code block above, the final instruction, `call cs:RegOpenKeyExA`, is presumably a representation of the `RegOpenKeyExA` function call, prefaced by `cs`. The function `RegOpenKeyExA` is a part of the Windows Registry API and is utilized to open a handle to a specified registry key. This function enables access to the Windows registry. The `A` in the

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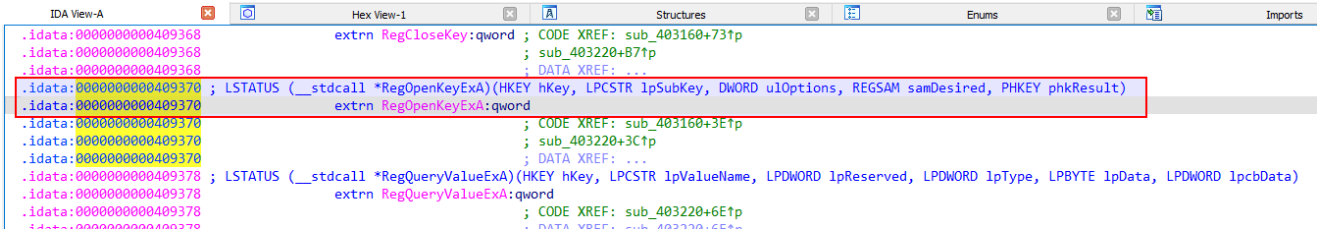
function name signifies that it is the `ANSI version` of the function, which operates on ANSI-encoded strings.

In `IDA`, `cs` is a segment register that usually refers to the code segment. When we click on `cs:RegOpenKeyExA` and press `Enter`, this action takes us to the `.idata` section, which includes import-related data and the import address of the function `RegOpenKeyExA`. In this scenario, the `RegOpenKeyExA` function is imported from an external library (advapi32.dll), with its address stored in the `.idata` section for future use.




```
.idata:0000000000409370 ; LSTATUS (__stdcall *RegOpenKeyExA)(HKEY hKey,
LPCSTR lpSubKey, DWORD ulOptions, REGSAM samDesired, PHKEY phkResult)
.idata:0000000000409370                 extrn RegOpenKeyExA:qword
.idata:0000000000409370                                         ; CODE
XREF: sub_403160+3E↑p
.idata:0000000000409370                                         ;
sub_403220+3C↑p
.idata:0000000000409370                                         ; DATA
XREF: ...
```

hide01.ir

This is not the actual address of the `RegOpenKeyExA` function, but rather the address of the entry in the `IAT (Import Address Table)` for `RegOpenKeyExA`. The IAT entry houses the address that will be dynamically resolved at runtime to point to the actual function implementation in the respective DLL (in this case, advapi32.dll).

The line `extrn RegOpenKeyExA:qword` indicates that `RegOpenKeyExA` is an external symbol to be resolved at runtime. This alerts the assembler that the function is defined in another module or library, and the linker will handle the resolution of its address during the linking process.

Reference: https://learn.microsoft.com/en-us/windows/win32/debug/pe-format#import-address-table

In actuality, `cs:RegOpenKeyExA` is a means of accessing the `IAT` entry for `RegOpenKeyExA` in the code segment using a relative reference. The actual address of `RegOpenKeyExA` will be resolved and stored in the IAT during runtime by the operating system's dynamic linker/loader.

Based on the overall structure of this function, we can conjecture that this is the possible `main` function. Let's rename it to `assumed_Main` for easy recollection in the event we come

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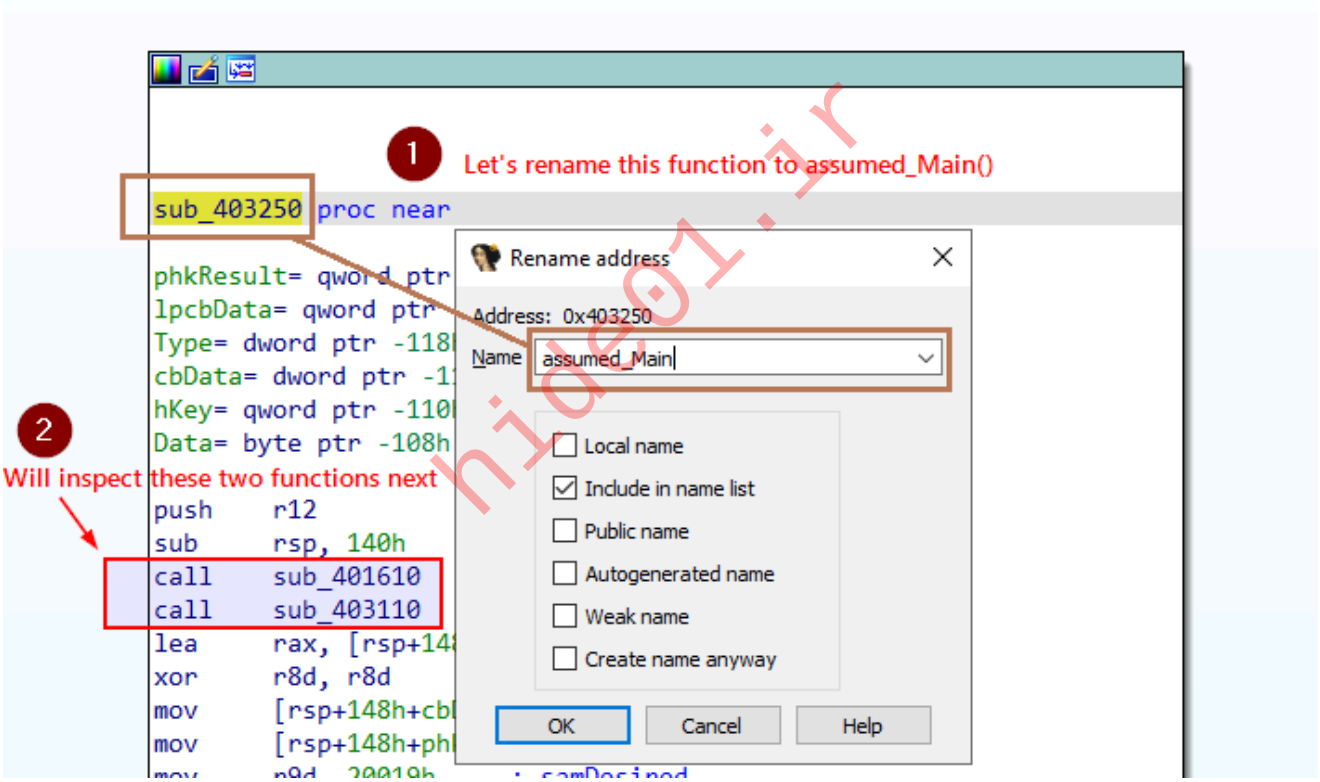
across references to this function in the future.

To rename a function in `IDA`, we should proceed as follows:

- Position the cursor on the function name (`sub_403250`) or the line containing the function definition. Then, press the `N` key on the keyboard, or right-click and select `Rename` from the context menu.
- Input the new name for the function and press `Enter`.

IDA will update the function name throughout the disassembly view and any references to the function within the binary.

Note: Renaming a function in `IDA` does not modify the actual binary file. It only alters the representation within `IDA`'s analysis.



Let's now delve into the instructions present in this block of code.

We can identify two function calls emanating from this function (`sub_401610` and `sub_403110`) prior to calling the Windows API function `RegOpenKeyExA`. Let's examine both of these before we advance to the WINAPI functions.

Let's delve into these functions by directing the cursor to their respective `call` instructions and tapping `Enter` to glimpse within.

Begin by examining the disassembled code for the first subroutine `sub_401610`. Initiate the journey into the subroutine by pressing `Enter` on the call instruction for `sub_401610`.

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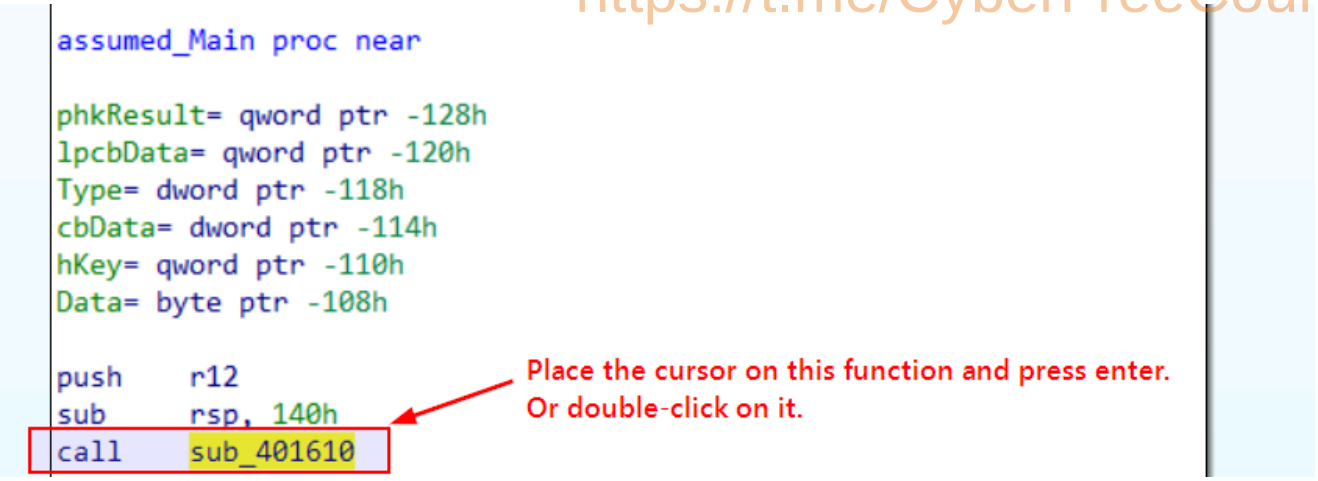
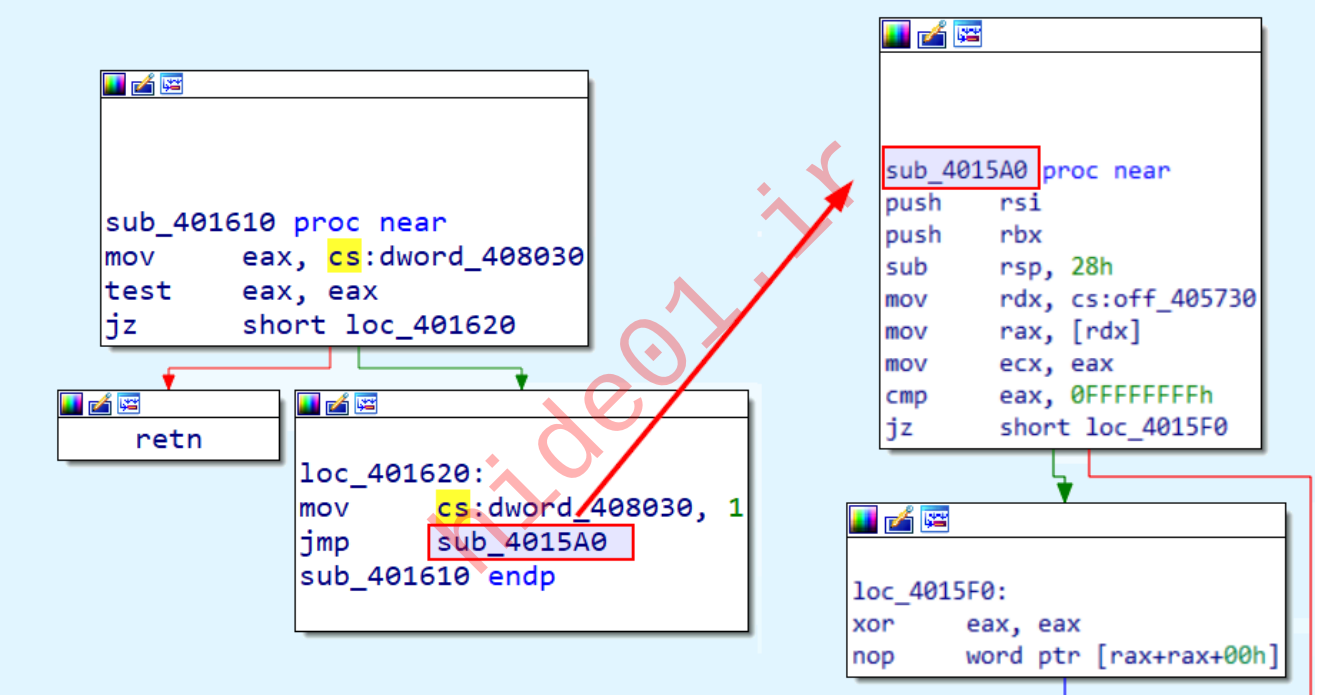


We find ourselves in the first subroutine `sub_401610`, which examines the value of a variable (`cs:dword_408030`). If its value is zero, it is redefined as one. It subsequently redirects to `sub_4015A0`.



The following instructions detail `sub_401610`. Let's strive to comprehend its nuances.

```
sub_401610 proc near

mov     eax, cs:dword_408030
test    eax, eax
jz      short loc_401620

loc_401620:
mov     cs:dword_408030, 1
jmp     sub_4015A0
sub_401610 endp
```

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It initiates by transferring the value of the variable `dword_408030` into the `eax` register. It then conducts a `bitwise AND` operation with `eax` and itself, essentially evaluating whether the value is `zero`. If the result of the preceding test instruction deems `eax` as `zero`, it redirects to `sub_4015A0`. Let's dissect its code further.

```
sub_4015A0 proc near

push    rsi
push    rbx
sub     rsp, 28h
mov     rdx, cs:off_405730
mov     rax, [rdx]
mov     ecx, eax
cmp     eax, 0FFFFFFFFh
jz      short loc_4015F0
```

By pressing `Enter` while the cursor is on the function name `sub_4015A0`, we navigate to the disassembled code, revealing that the function commences by pushing the values of the `rsi` and `rbx` registers onto the stack, preserving the register values. Subsequently, it allots space on the stack by subtracting `28h (40 decimal)` bytes from the stack pointer (`rsp`). It then retrieves a function pointer from the address encapsulated in `off_405730` and stashes it in the `rax` register.

In essence, they seem to execute initialization checks and operations related to function pointers before the program proceeds to call the second subroutine `sub_403110` and the WINAPI function for registry operations. This isn't the actual main function hosting the program logic, so we'll scrutinize other function calls to pinpoint the `main` function.

We can rename this function as `initCheck` for our remembrance by pressing `N` and typing in the new function name.

At this point, we either press the `Esc` key or select the `Jump Back` button in the toolbar to revert to the second subroutine `sub_403110` and explore its inner workings.

Once we've navigated back to the previous function (`assumed_Main`), we should position the cursor on the `call sub_403110` instruction and hit `Enter`.

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```
assumed_Main proc near

phkResult= qword ptr -128h
lpcbData= qword ptr -120h
Type= dword ptr -118h
cbData= dword ptr -114h
hKey= qword ptr -110h
Data= byte ptr -108h

push    r12
sub     rsp, 140h
call    sub_401610
call    sub_403110
lea     rax, [rsp+148h+hKey]
xor     r8d, r8d        ; ulOptions
mov     [rsp+148h+cbData], 100h
mov     [rsp+148h+phkResult], rax ; phkResult
mov     r9d, 20019h     ; samDesired
lea     rdx, aSoftwareVmware ; "SOFTWARE\\VMware, Inc.\\VMware Tools"
mov     rcx, 0FFFFFFFF80000002h ; hKey
call    cs:RegOpenKeyExA
```

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This transition lands us in the disassembled code for this function. Let's examine it to determine its operation.

```
.rdata:0000000000405266 ; const CHAR Operation[]
.rdata:0000000000405266 Operation       db 'open',0             ; DATA XREF: sub_403110+14to
.rdata:0000000000405266                                         ; sub_403150+B1o
.rdata:00000000004052A8 ; const CHAR Parameters[]
.rdata:00000000004052A8 Parameters      db '/k ping 127.0.0.1 -n 5',0
.rdata:00000000004052A8                                         ; DATA XREF: sub_403110+4to
.rdata:00000000004052BF ; const CHAR File[]
.rdata:00000000004052BF File            db 'C:\Windows\System32\cmd.exe',0
```

```
sub_403110 proc near

lpDirectory= qword ptr -18h
nShowCmd= dword ptr -10h

sub     rsp, 38h
lea     r9, Parameters  ; "/k ping 127.0.0.1 -n 5"
lea     r8, File        ; "C:\\Windows\\System32\\cmd.exe"
xor     ecx, ecx        ; hwnd
lea     rdx, Operation  ; "open"
mov     [rsp+38h+nShowCmd], 0 ; nShowCmd
mov     [rsp+38h+lpDirectory], 0 ; lpDirectory
call    cs:ShellExecuteA
nop
add     rsp, 38h
retn
sub_403110 endp
```

Loading addresses of strings parameters stored from .rdata section

```
C++

HINSTANCE ShellExecuteA(
  [in, optional] HWND   hwnd,
  [in, optional] LPCSTR lpOperation,
  [in]           LPCSTR lpFile,
  [in, optional] LPCSTR lpParameters,
  [in, optional] LPCSTR lpDirectory,
  [in]           INT    nShowCmd
);
```

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The variables `Parameters`, `File` and `Operation` are string variables stowed in the `.rdata` section of the executable. The `lea` instructions are utilized to obtain the memory addresses of these strings, which are subsequently passed as arguments to the `ShellExecuteA` function. This block of code is accountable for a `sleep` duration of `5 seconds`. Following that, it reverts to the preceding function. Having understood the code, we can rename this function as `pingSleep` by right-clicking and choosing rename.

Now that we've encountered some references for Windows API functions, let's elucidate how WINAPI functions are interpreted in the disassembled code.

After investigating the operations within the two function calls (`sub_401610` and `sub_403110`) from this function and before invoking the Windows API function `RegOpenKeyExA`, let's inspect the calls made to WINAPI function `RegOpenKeyExA`. In this `IDA` disassembly view, the arguments passed to the WINAPI function call are depicted above the `call` instruction. This standard convention in disassemblers offers a lucid representation of the function call along with its corresponding arguments.

The Windows API function, `RegOpenKeyExA`, is utilized here to unlock a registry key. The syntax of this function, as per Microsoft documentation, is presented below.

```
LSTATUS RegOpenKeyExA(
  [in]           HKEY   hKey,
  [in, optional] LPCSTR lpSubKey,
  [in]           DWORD  ulOptions,
  [in]           REGSAM samDesired,
  [out]          PHKEY  phkResult
);
```

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C++ Copy

```
LSTATUS RegOpenKeyExA(
  [in]           HKEY   hKey,
  [in, optional] LPCSTR lpSubKey,
  [in]           DWORD  ulOptions,
  [in]           REGSAM samDesired,
  [out]          PHKEY  phkResult
);
```

Let's deconstruct the code for this function as it appears in the `IDA` disassembled view.

```
lea     rax, [rsp+148h+hKey]      ; Calculate the address of hKey
xor     r8d, r8d                  ; Clear r8d register (ulOptions)
mov     [rsp+148h+phkResult], rax ; Store the calculated address of hKey
in phkResult
mov     r9d, 20019h               ; Set samDesired to 0x20019h (which is
```

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```
KEY_READ in MS-DOCS)
lea     rdx, aSoftwareVmware      ; Load address of string
"SOFTWARE\\VMware, Inc.\\VMware Tools"
mov     rcx, 0FFFFFFFF80000002h   ; Set hKey to 0xFFFFFFFF80000002h
(HKEY_LOCAL_MACHINE)
call    cs:RegOpenKeyExA          ; Call the RegOpenKeyExA function
test    eax, eax                  ; Check the return value
jnz     short loc_40330F          ; Jump if the return value is not zero
(error condition)
```

The `lea` instruction calculates the address of the `hKey` variable, presumably a handle to a registry key. Then, `mov rcx, 0FFFFFFFF80000002h` pushes `HKEY_LOCAL_MACHINE` as the first argument (`rcx`) to the function. The `lea rdx, aSoftwareVmware` instruction employs the `load effective address (LEA)` operation to calculate the effective address of the memory location storing the string `Software\\VMware, Inc.\\VMware Tools`. This calculated address is then stowed in the `rdx` register, the function's second argument.

The third argument to this function is passed to the `r8d` register via the instruction `xor r8d, r8d` which empties the `r8d` register by implementing an `XOR` operation with itself, effectively resetting it to zero. In the context of this code, it indicates that the third argument (`ulOptions`) passed to the `RegOpenKeyExA` function bears a value of `0`.

The fourth argument is `mov r9d, 20019h`, corresponding to `KEY_READ` in MS-DOCS.

The fifth argument, `phkResult`, is on the stack. By adding `rsp+148h` to the base stack pointer `rsp`, the code accesses the memory location on the stack where the `phkResult` parameter resides. The `mov [rsp+148h+phkResult], rax` instruction duplicates the value of `rax` (which holds the address of `hKey`) to the memory location pointed to by `phkResult`, essentially storing the address of `hKey` in `phkResult` (which is passed to the next function as the first argument).

From this point onward, whenever we stumble upon a WINAPI function reference in the code, we'll resort to the Microsoft documentation for that function to grasp its syntax, parameters, and the return value. This will assist us in understanding the probable values in the registers when these functions are invoked.

Should we scroll down the graph view, we encounter the next WINAPI function `RegQueryValueExA` which retrieves the type and data for the specified value name associated with an open registry key. The key data is compared, and upon a match, a message box stating `Sandbox Detected` is displayed. If it does not match, then it redirects to another subroutine `sub_402EA0`. We'll also rectify this sandbox detection in the debugger later. The image below outlines the overall flow of this operation.

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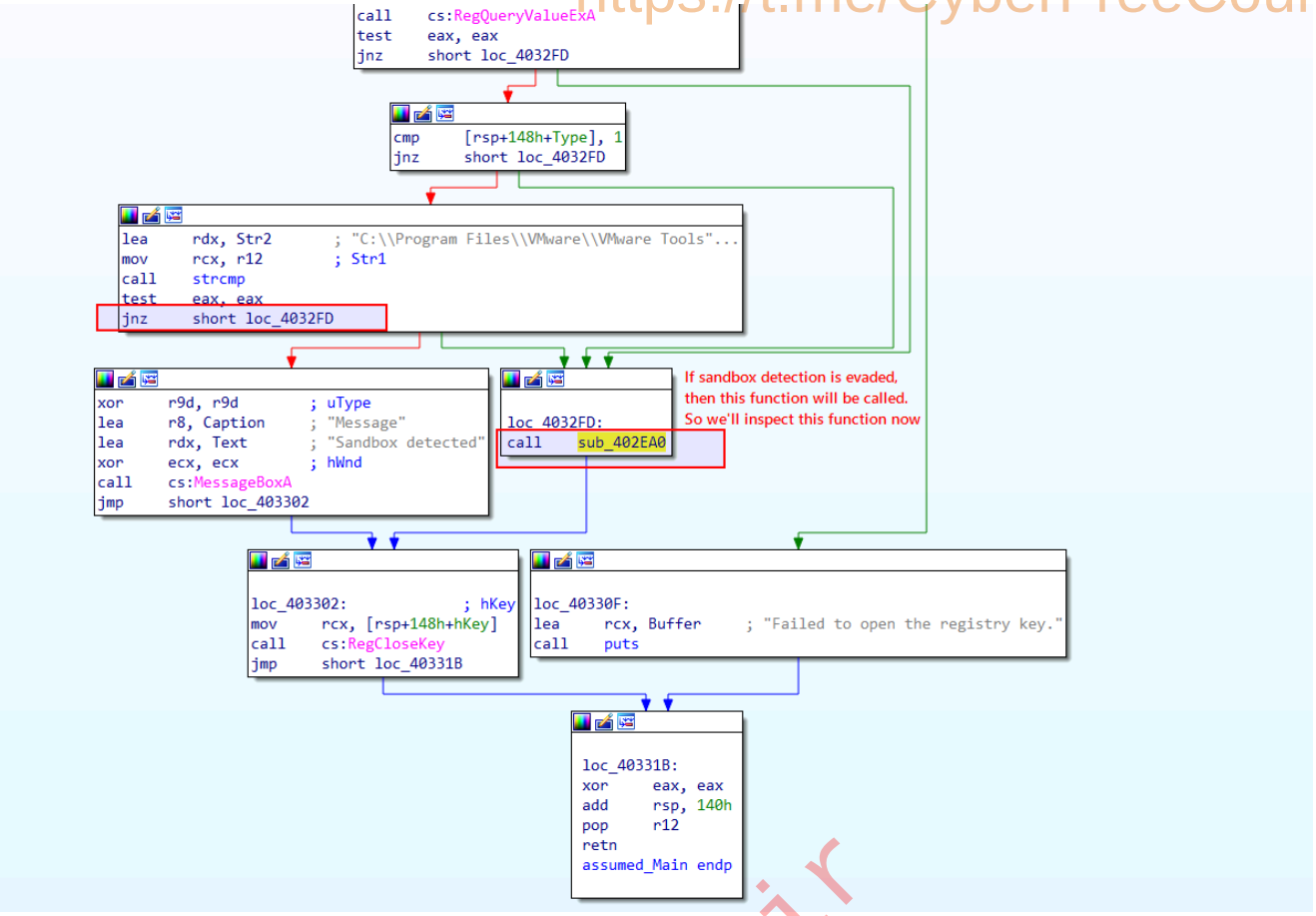

Let's press `Enter` on the upcoming call instruction for the function `sub_402EA0` to enable us to scrutinize this subroutine and figure out its operations.

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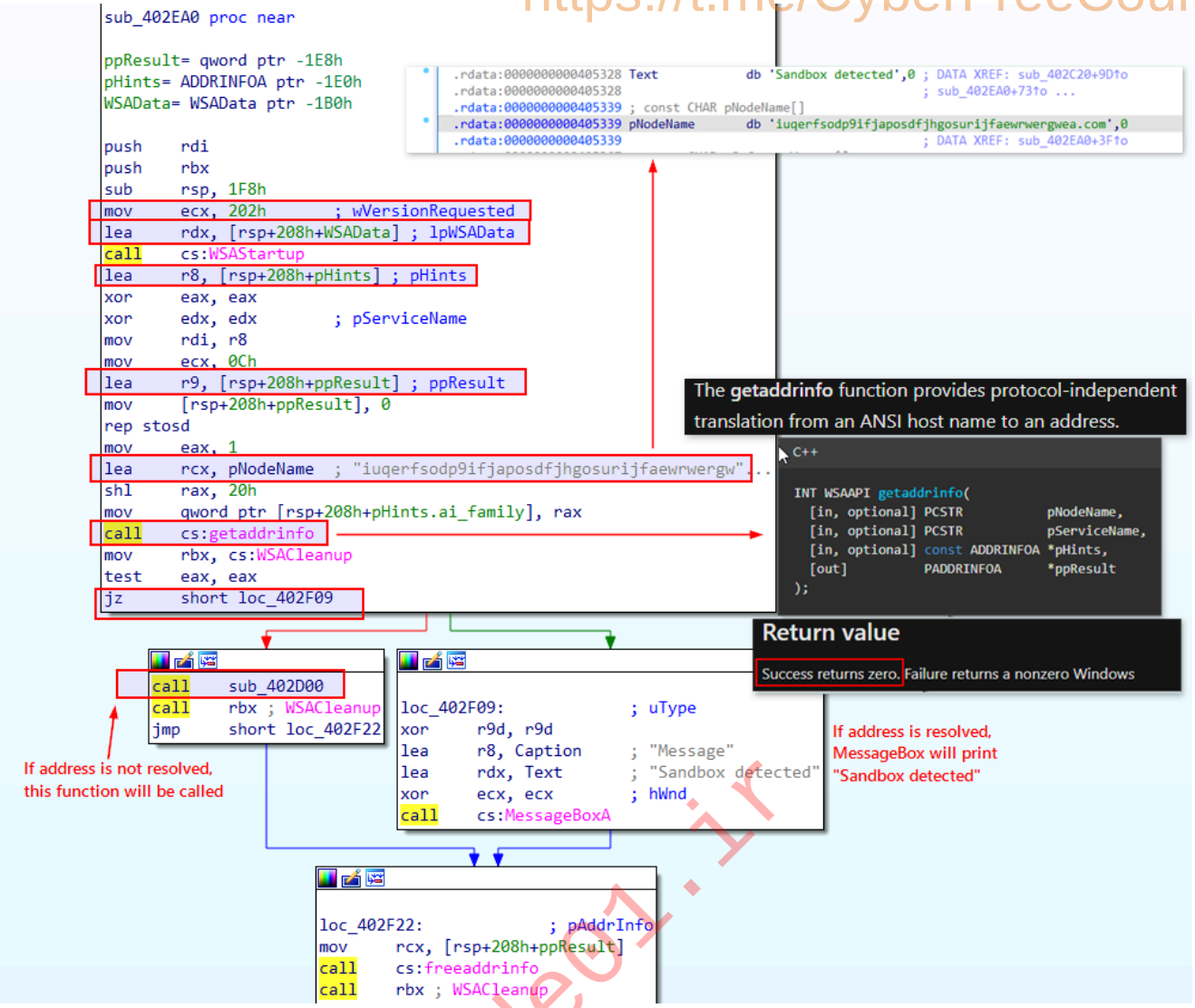

Upon pressing `Enter`, we uncover its functionality. This subroutine seems to execute network-related operations using the `Windows Sockets API (Winsock)`. It initially invokes the `WSAStartup` function to set up the `Winsock` library, then it calls the `WSAAPI` function `getaddrinfo` which is used to fetch address information for the specified node name (`pNodeName`) based on the provided hints `pHints`. The subroutine verifies the success of the address resolution using the `getaddrinfo` function.

If the `getaddrinfo` function yields a return value of `zero` (indicating success), this implies that the address has been successfully resolved to an IP. Following this event, if indeed successful, the sequence jumps to a MessageBox which displays `Sandbox detected`. If not, it directs the flow to the subroutine `sub_402D00`.

Subsequently, it prompts the invocation of the `WSACleanup` function. This action initiates the cleanup of resources related to `Winsock`, irrespective of whether the address resolution process was successful or unsuccessful. For the sake of clarity, we'll christen this function as `DomainSandboxCheck`.

Possible IOC: Kindly note the domain name `iuqerfsodp9ifjaposdfjhgosurijfaewrwergwea[.]com` as a component of potential `IOC`s.

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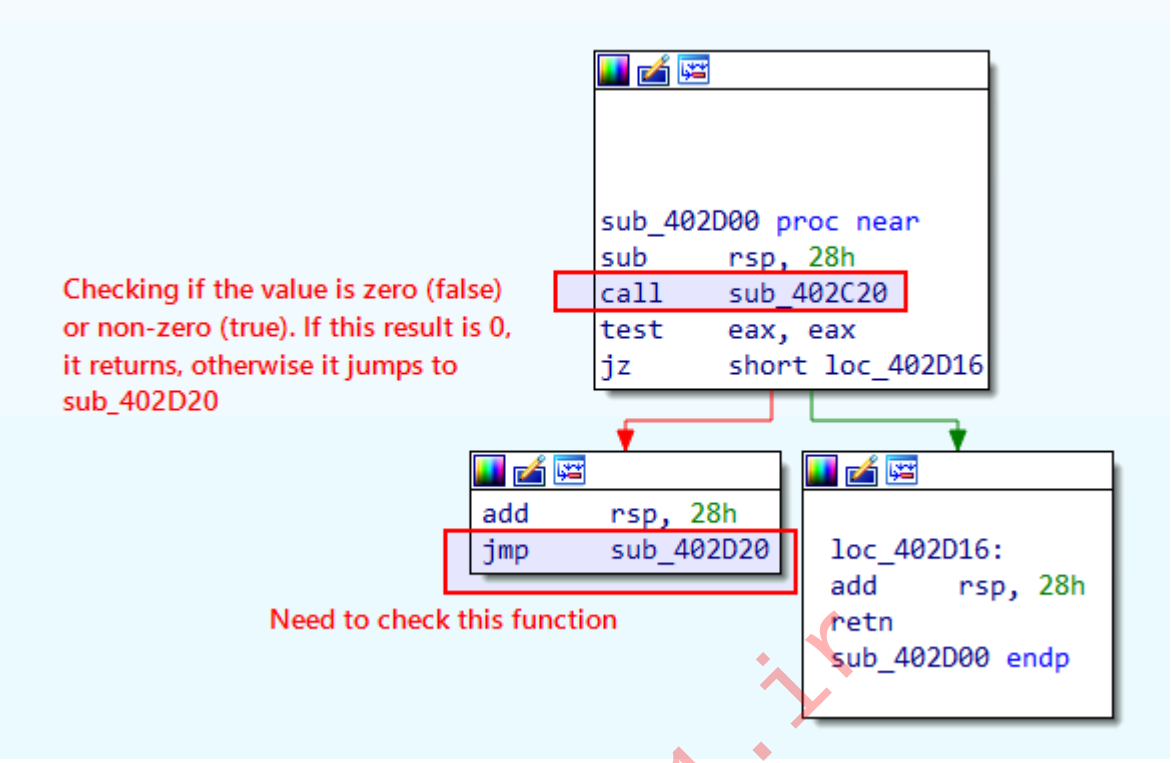
To explore the consequences of bypassing the sandbox check, we'll delve into the subroutine `sub_402D00`. We can scrutinize this subroutine by hitting `Enter` on the ensuing `call` instruction related to the `sub_402D00` function. An image attached below displays the disassembled code for this function.



This function first reserves space on the stack for local variables before calling `sub_402C20`, a distinct function. The output of this function is then stored within the `eax` register. Depending on the results derived from the `sub_402C20` function, the sequence either returns (`retn`) or leaps to `sub_402D20`.

Consequently, we'll select the first highlighted function, `sub_402C20`, by pressing `Enter` to examine its instructions. Upon thorough analysis of `sub_402C20`, we'll loop back to this block to evaluate the second highlighted function, `sub_402D20`.

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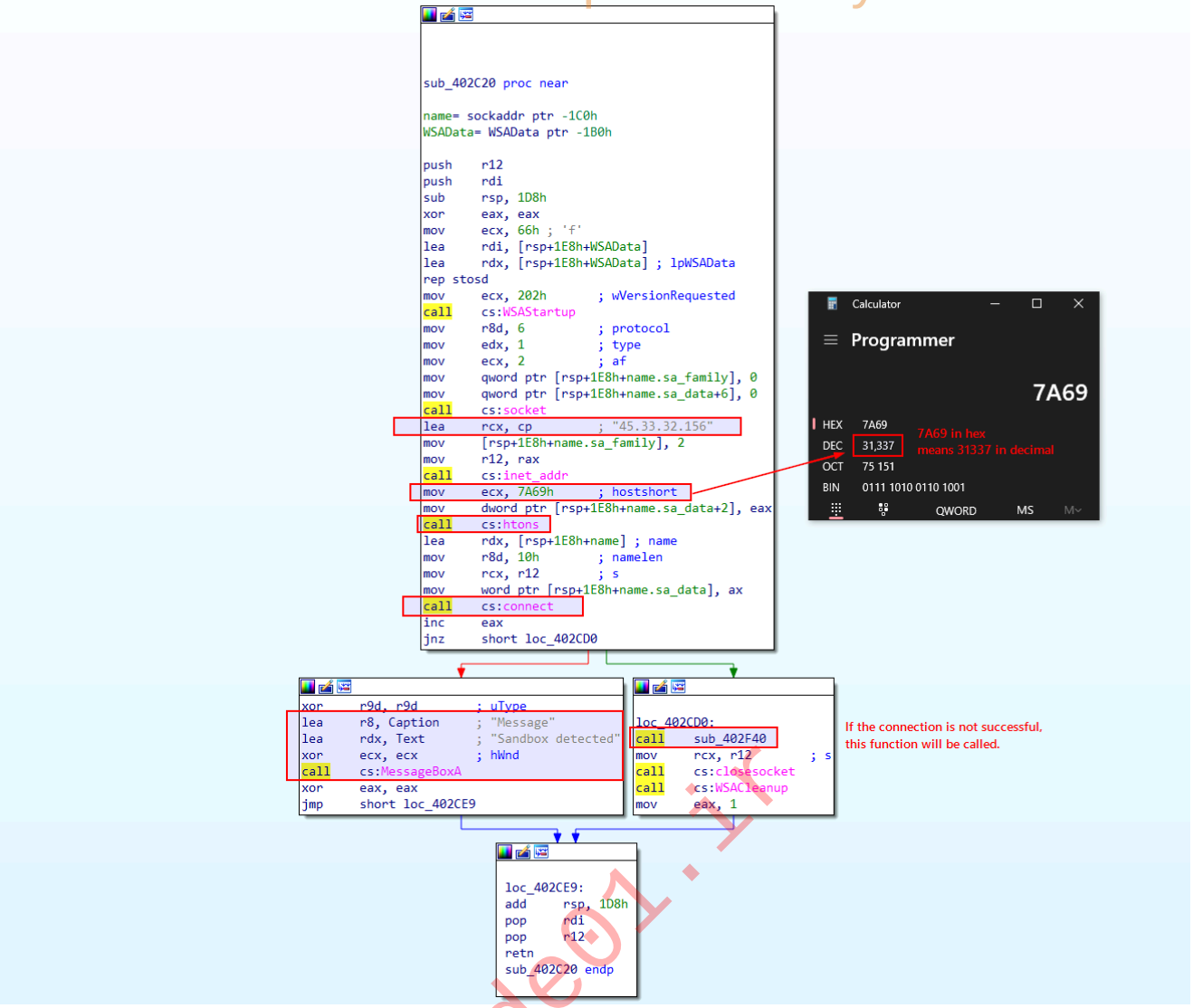

Upon hitting `Enter`, we are greeted with its instructions as portrayed in the image above. This function initiates the `Winsock` library, generates a socket, and connects to IP address `45.33.32.156` via port `31337`. It evaluates the return value (`eax`) to ascertain if the connection was successful. However, there is a twist; post-function invocation, the instruction `inc eax` increments the `eax` register's value by `1`. Subsequent to the `inc eax` instruction, the code appraises the value of `eax` using the `jnz (jump if not zero)` instruction.

Should the connection to the aforementioned port and IP address fail, this function should return `-1`, as specified in the documentation.

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Handling Winsock Errors

Article • 01/08/2021 • 3 contributors

Feedback

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Most Windows Sockets 2 functions do not return the specific cause of an error when the function returns. Some Winsock functions return a value of zero if successful. Otherwise, the value SOCKET_ERROR (-1) is returned and a specific error number can be retrieved by calling the WSAGetLastError function. For Winsock functions that return a handle, a return value of INVALID_SOCKET (0xffff) indicates an error and a specific error number can be retrieved by calling **WSAGetLastError**. For Winsock functions that return a pointer, a return value of **NULL** indicates an error and a specific error number can be retrieved by calling the **WSAGetLastError** function.

```
call    cs:connect
inc     eax
jnz     short loc_402CD0
```

Given that `eax` is incremented by `1` post-function call, this should reduce to `0`. Consequently, the `MessageBox` will print `Sandbox detected`. This implies that the function is examining the state of the internet connection.

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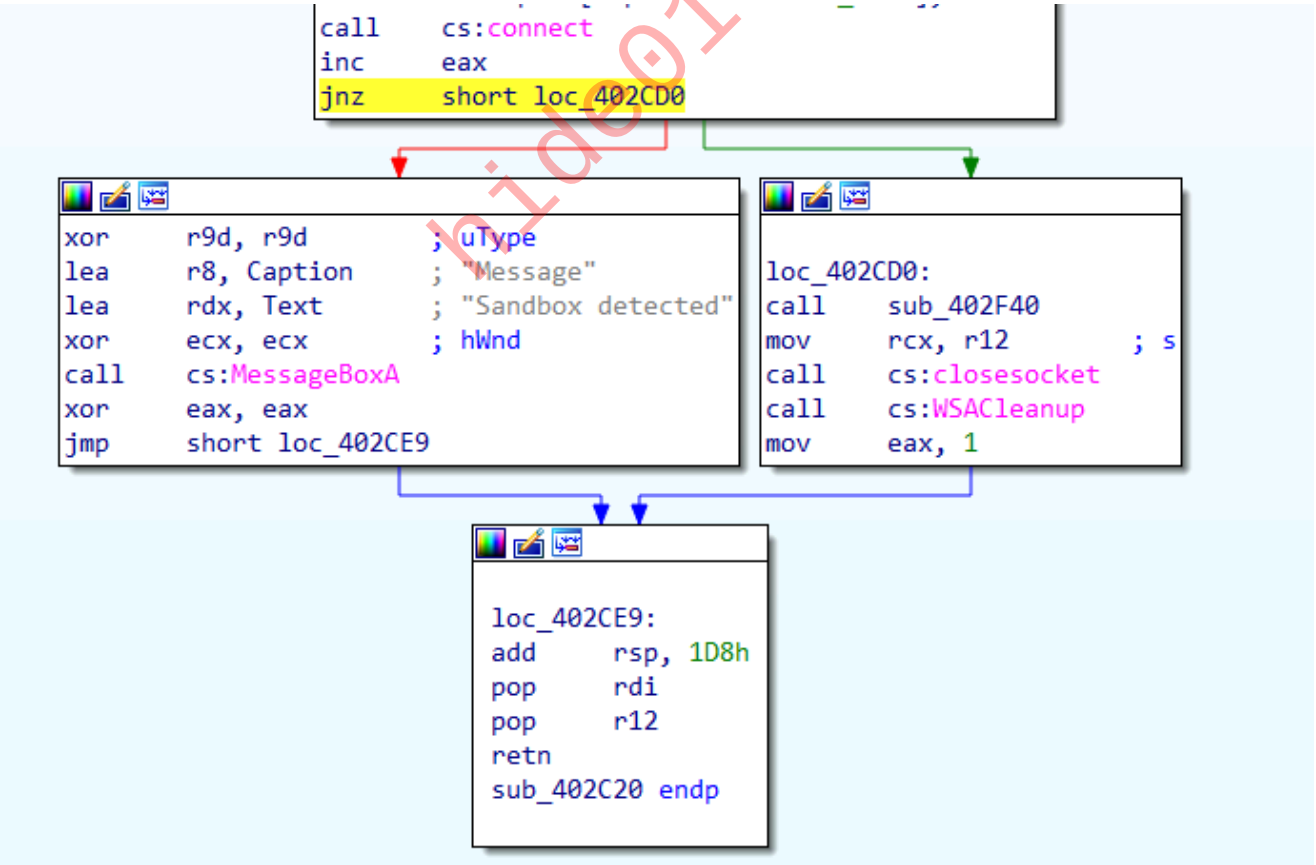

If, on the other hand, the connection is successful, it will produce a `non-zero` value, prompting the code to leap to `loc_402CD0`. This location houses a call to another function, `sub_402F40`. With a clear understanding of this function's operations, we'll rename it as `InternetSandboxCheck`.

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Possible IOC: Remember to note this IP address `45.33.32.156` and port `31337` as components of potential `IOC` s.

Next, we'll proceed to function `sub_402F40` to decipher its operations. We can do this by right-clicking and selecting `Jump to Operand`, or by pressing `Enter` on its `call` instruction.

This function calls upon the `getenv` function (with `rcx` acting as the argument passer for `TEMP`) and saves its result in the `eax` register. This action retrieves the `TEMP` environment variable's value.

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```
lea     rcx, VarName    ; "TEMP"
call    getenv
```

To verify the output, we can use powershell to print the `TEMP` environment variable's value.

```
PS C:\> Get-ChildItem env:TEMP

Name                           Value
----                           -----
TEMP                           C:\Users\htb-student\AppData\Local\Temp
```

It then employs the `sprintf` function to append the obtained `TEMP` path to the string `svchost.exe`, yielding a complete file path. Thereafter, the `GetComputerNameA` function is called to retrieve the computer's name, which is then stored in a buffer.

If the computer name is non-existent, it skips to the label `loc_4030F8` (which houses instructions for returning). Conversely, if the computer name is not empty (`non-zero` value), the code progresses to the subsequent instruction as displayed on the left side of the image.

In subsequent instructions, we find a call to the function `sub_403220`. We can access it by double-clicking on the function name.

The left side of the attached image above displays the function `sub_403220`, which formats a string housing a custom `user-agent` value with the string `Windows-Update/7.6.7600.256 %s`. The `%s` placeholder is replaced with the previously obtained computer name, which is transmitted to this function in the `rcx` register.

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```
sub_403220 proc near

var_10= qword ptr -10h
ArgList= byte ptr  20h

sub     rsp, 38h
lea     r8, aWindowsUpdate7 ; "Windows-Update/7.6.7600.256 %s"
mov     edx, 104h       ; BufferCount
mov     qword ptr [rsp+38h+ArgList], r9
lea     r9, [rsp+38h+ArgList] ; ArgList
mov     [rsp+38h+var_10], r9
call    j__vsnprintf
add     rsp, 38h
retn
sub_403220 endp
```

Now, the complete value reads `Windows-Update/7.6.7600.256 HOSTNAME`, where `HOSTNAME` is the result of `GetComputerNameA` (the computer's name).

It's crucial to note this unique custom `user-agent`, wherein the hostname is also transmitted in the request when the malware initiates a network connection.

Back to the previous function, it subsequently calls the `InternetOpenA` WINAPI function to commence an internet access session and configure the parameters for the `InternetOpenUrlA` function. It then proceeds to call the latter to open the URL `http://ms-windows-update.com/svchost.exe`.

Possible IOC: Do note this URL `http[:]//ms-windows-update[.]com/svchost[.]exe` as potential `IOC`. The malware is downloading an additional executable from this location.

If the URL opens successfully, the code leaps to the label `loc_40301E`. Let's probe the instructions at `loc_40301E` by double-clicking on it.

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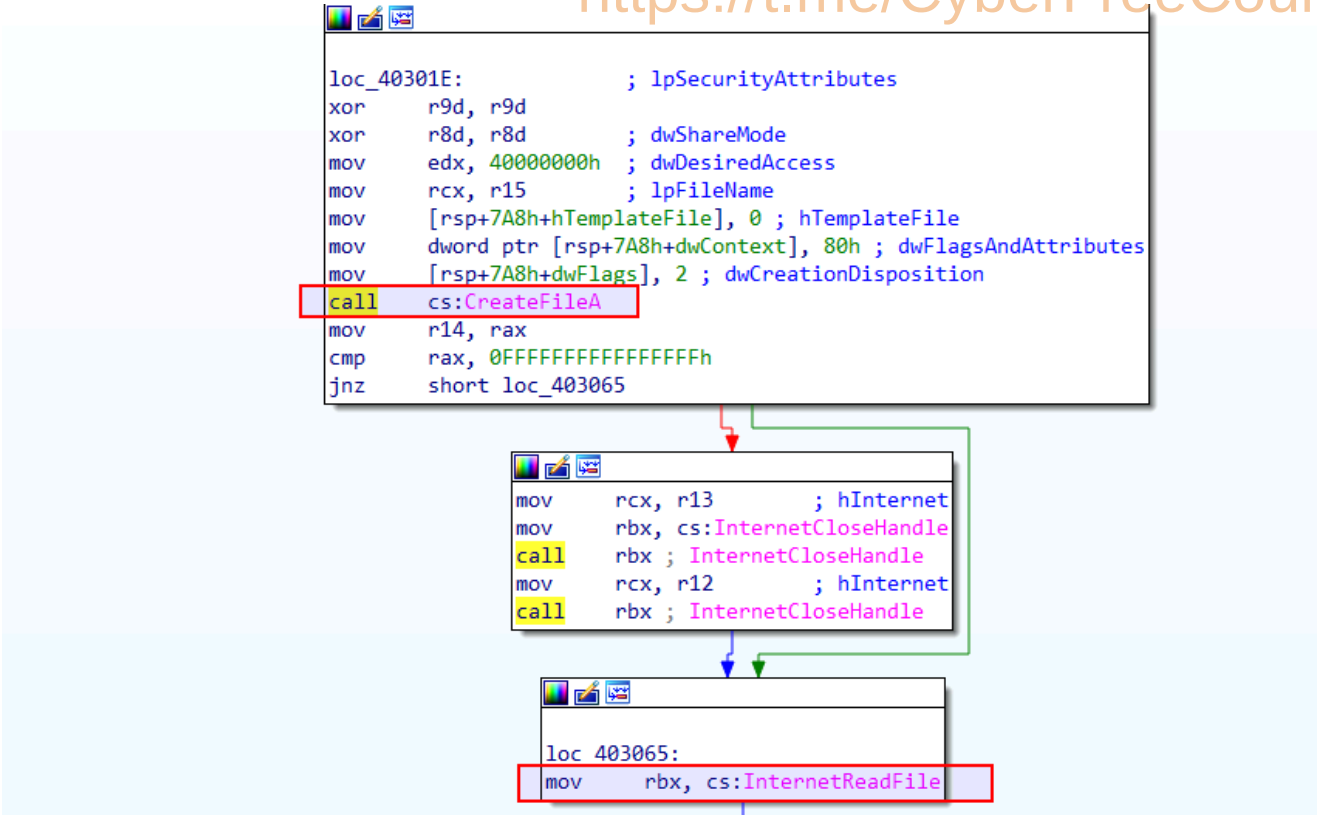

Upon opening the function, we observe a call to the Windows API function `CreateFileA`, which is used to generate a file on the local system, designating the previously obtained file path.

The code then enters a loop, repeatedly invoking the `InternetReadFile` function to pull data from the opened URL `http[:]//ms-windows-update[.]com/svchost[.]exe`. If the data reading operation proves successful, the code advances to write the received data to the created file (`svchost.exe` located in the `TEMP` directory) using the `WriteFile` function.

Note this unique technique, where the malware downloads and deposits an executable file `svchost.exe` in the `temp` directory.

The aforementioned loop is illustrated in the image below.

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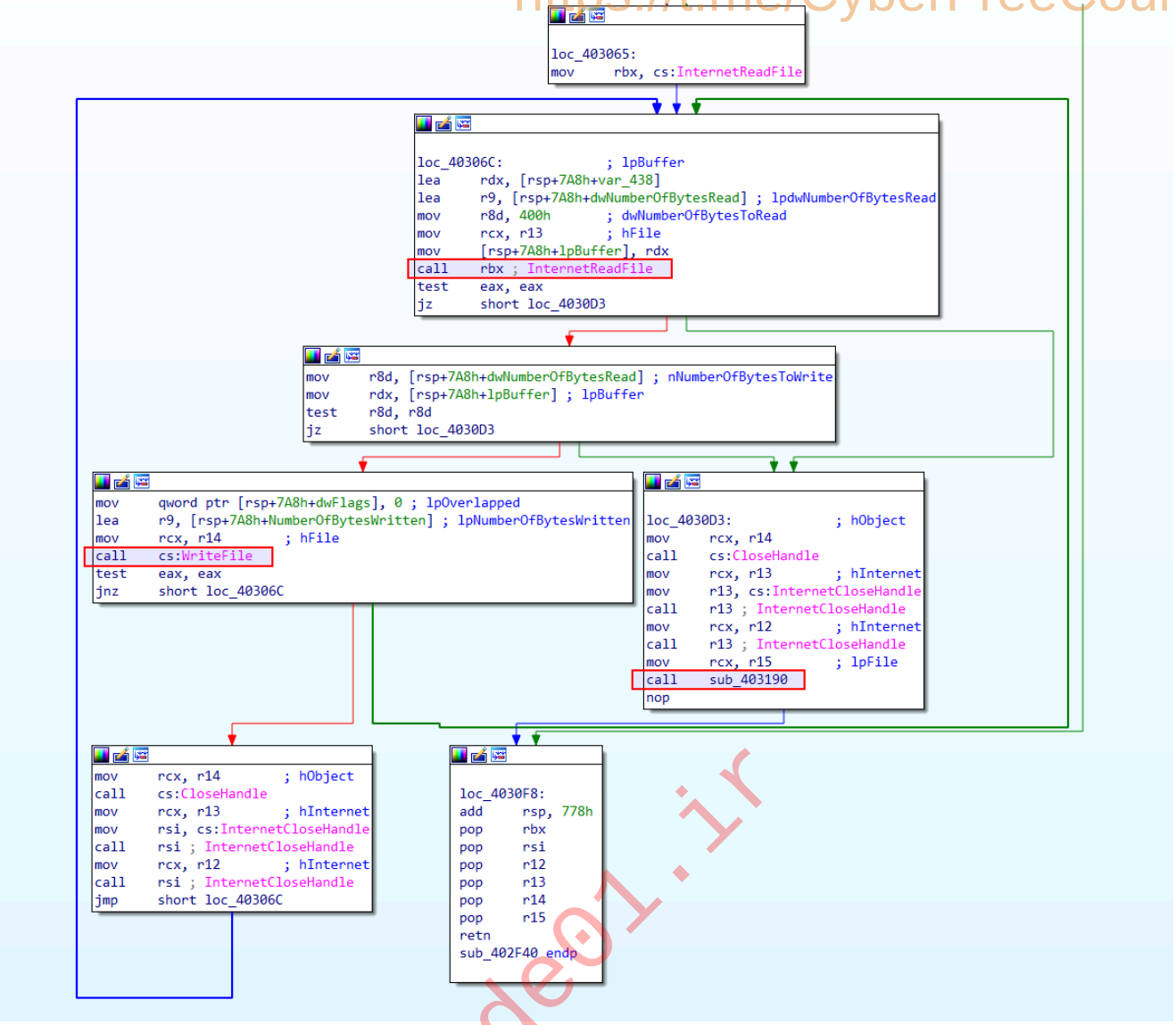

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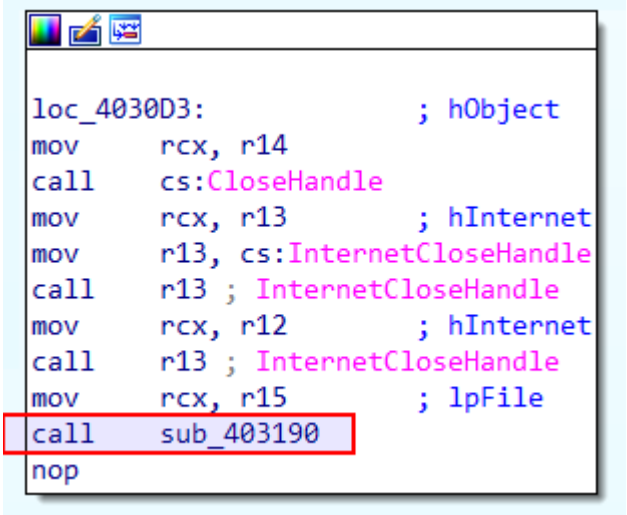
After the data writing operation, the code cycles back to read more data until the `InternetReadFile` function returns a value that indicates the end of the data stream. Once all data has been read and written, the opened file and the internet handles are closed using the appropriate functions (`CloseHandle` and `InternetCloseHandle`). Subsequently, the code leaps to `loc_4030D3` , where it calls upon the function `sub_403190` .

We'll double-click on `sub_403190` to unveil its contents.



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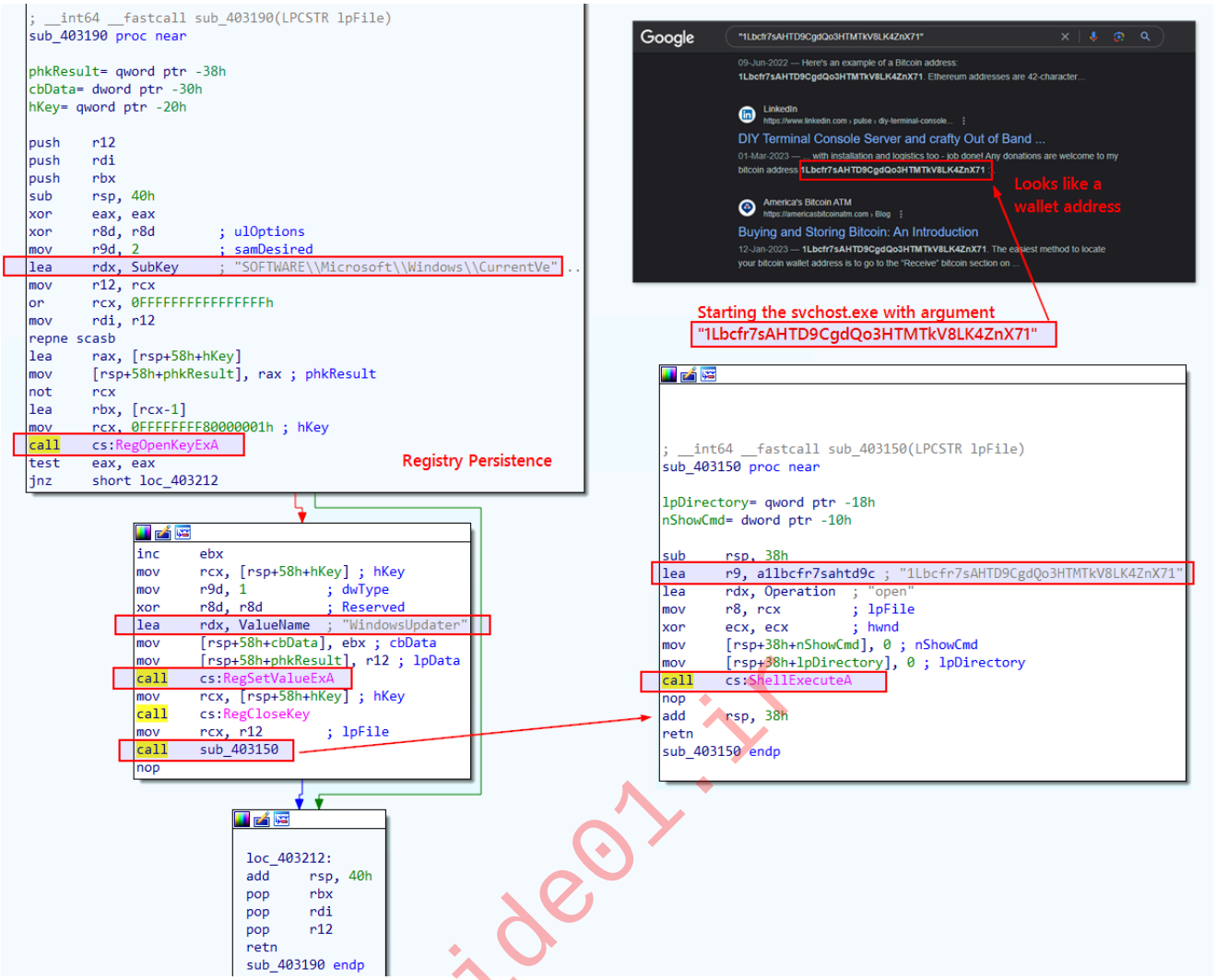
The function `sub_403190` is now exposed, revealing a series of WINAPI calls related to registry modifications, such as `RegOpenKeyExA` and `RegSetValueExA`.



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It appears that this function places the file (`svchost.exe` located in the `TEMP` directory) into the registry key path `SOFTWARE\Microsoft\Windows\CurrentVersion\Run` with the value name `WindowsUpdater`, then seals the registry key. This technique is frequently employed by both malware and legitimate applications to maintain their grip on the system across reboots, ensuring automatic operation each time the system initiates or a user logs in. We've taken the liberty of renaming this function in `IDA` to `persistence_registry` for the sake of clarity.

```
.rdata:000000000040526B ; const CHAR SubKey[]
.rdata:000000000040526B SubKey          db 'SOFTWARE\Microsoft\Windows\CurrentVersion\Run',0
.rdata:000000000040526B                                         ; DATA XREF: sub_403190+13↑o
.rdata:0000000000405299 ; const CHAR ValueName[]
.rdata:0000000000405299 ValueName       db 'WindowsUpdater',0   ; DATA XREF: sub_403190+58↑o
```

Possible IOC: Highlight this technique in which the malware modifies the registry to achieve persistence. It does so by adding an entry for `svchost.exe` under the `WindowsUpdater` name in the `SOFTWARE\Microsoft\Windows\CurrentVersion\Run` registry key.

Upon establishing the registry, it initiates another function, `sub_403150`, which sets in motion the dropped file `svchost.exe` and funnels an argument into it. A rudimentary Google

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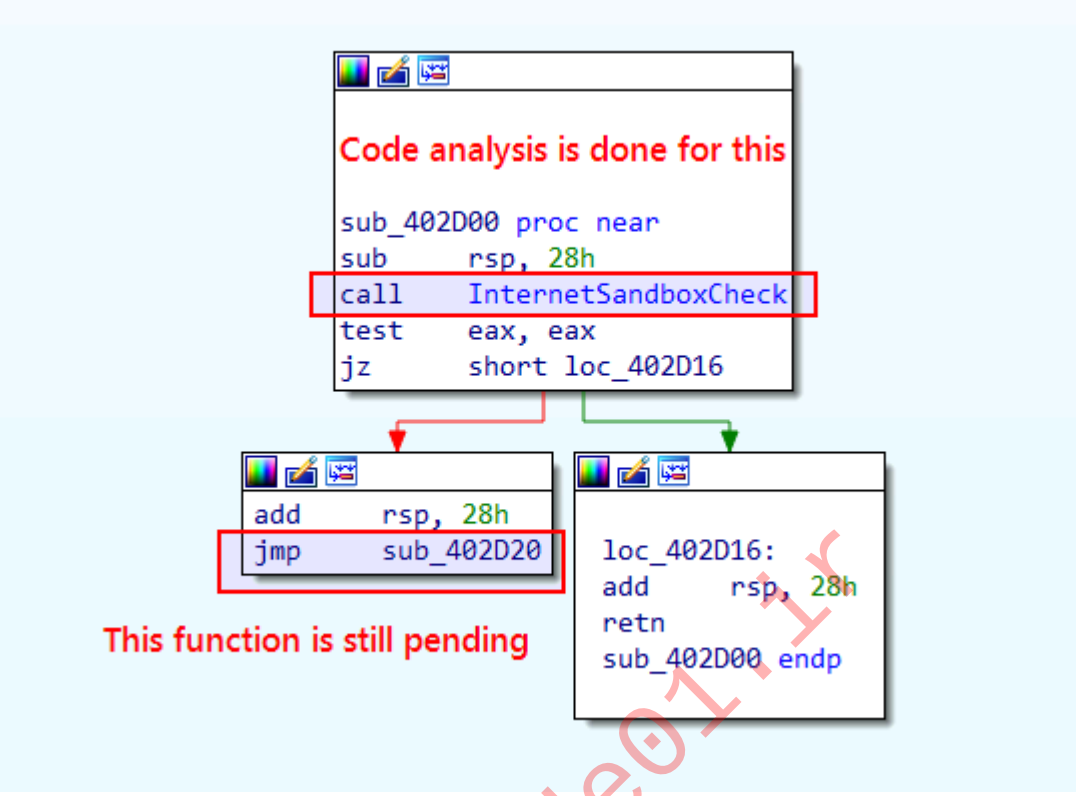
search suggests that this argument could potentially be a `Bitcoin wallet address`. Thus, it's reasonable to postulate that the dropped executable could be a coin miner.

By rewinding our steps and inspecting the functions systematically, we can identify any residual functions that we've not yet scrutinized. The `Esc` key or the `Jump Back` button in the toolbar facilitates this reverse tracking.



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After tracing back on the analysed code, we've reached this block, where a subroutine `sub_402D20` is pending for analysis. So let's double click to open it and see what's inside it.

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```
sub_402D20 proc near

bInheritHandles= dword ptr -2A8h
dwCreationFlags= dword ptr -2A0h
lpEnvironment= qword ptr -298h
lpCurrentDirectory= qword ptr -290h
lpStartupInfo= qword ptr -288h
lpProcessInformation= qword ptr -280h
ProcessInformation= _PROCESS_INFORMATION ptr -278h
StartupInfo= _STARTUPINFOA ptr -260h
Buffer= byte ptr -1F5h

push    r12
push    rdi
push    rsi
push    rbx
sub     rsp, 2A8h
xor     eax, eax
mov     ecx, 1Ah
lea     rsi, unk_405057
xor     r9d, r9d        ; lpThreadAttributes
xor     r8d, r8d        ; lpProcessAttributes
lea     rdx, CommandLine ; "C:\\Windows\\System32\\notepad.exe"
lea     rdi, [rsp+2C8h+StartupInfo]
rep stosd
lea     rdi, [rsp+2C8h+ProcessInformation]
mov     ecx, 6
mov     [rsp+2C8h+StartupInfo.cb], 68h ; 'h'
rep stosd
lea     rax, [rsp+2C8h+ProcessInformation]
lea     rdi, [rsp+2C8h+Buffer]
mov     ecx, 1CDh       ; lpApplicationName
rep movsb
mov     [rsp+2C8h+lpProcessInformation], rax ; lpProcessInformation
lea     rax, [rsp+2C8h+StartupInfo]
mov     [rsp+2C8h+lpStartupInfo], rax ; lpStartupInfo
mov     [rsp+2C8h+lpCurrentDirectory], 0 ; lpCurrentDirectory
mov     [rsp+2C8h+lpEnvironment], 0 ; lpEnvironment
mov     [rsp+2C8h+dwCreationFlags], 4 ; dwCreationFlags
mov     [rsp+2C8h+bInheritHandles], 0 ; bInheritHandles
call    cs:CreateProcessA
test    eax, eax
jz      loc_402E89
```

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Upon opening the subroutine, it's clear that it's setting up the necessary parameters for the `CreateProcessA` function to generate a new process. It then proceeds to instigate a new process, `notepad.exe`, situated in the `C:\Windows\System32` directory.

Here is the syntax for the CreateProcessA function.

```
BOOL CreateProcessA(
  [in, optional]      LPCSTR                lpApplicationName,
  [in, out, optional] LPSTR                 lpCommandLine,
  [in, optional]      LPSECURITY_ATTRIBUTES lpProcessAttributes,
  [in, optional]      LPSECURITY_ATTRIBUTES lpThreadAttributes,
  [in]                BOOL                  bInheritHandles,
  [in]                DWORD                 dwCreationFlags,
  [in, optional]      LPVOID                lpEnvironment,
  [in, optional]      LPCSTR                lpCurrentDirectory,
```

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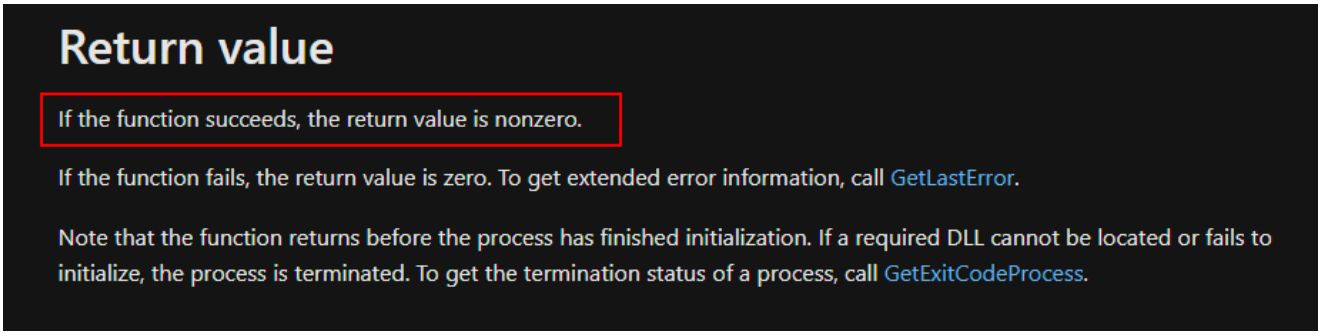
```
  [in]                LPSTARTUPINFOA        lpStartupInfo,
  [out]               LPPROCESS_INFORMATION lpProcessInformation
);
```

With `rdx` observed in the code, we see that the second argument to this function is pinpointed as `C:\\Windows\\System32\\notepad.exe`.



We note in the `CreateProcessA` function documentation that a `nonzero` return value indicates successful function execution. Consequently, if successful, it won't jump to `loc_402E89` but will continue to the next block of instructions.

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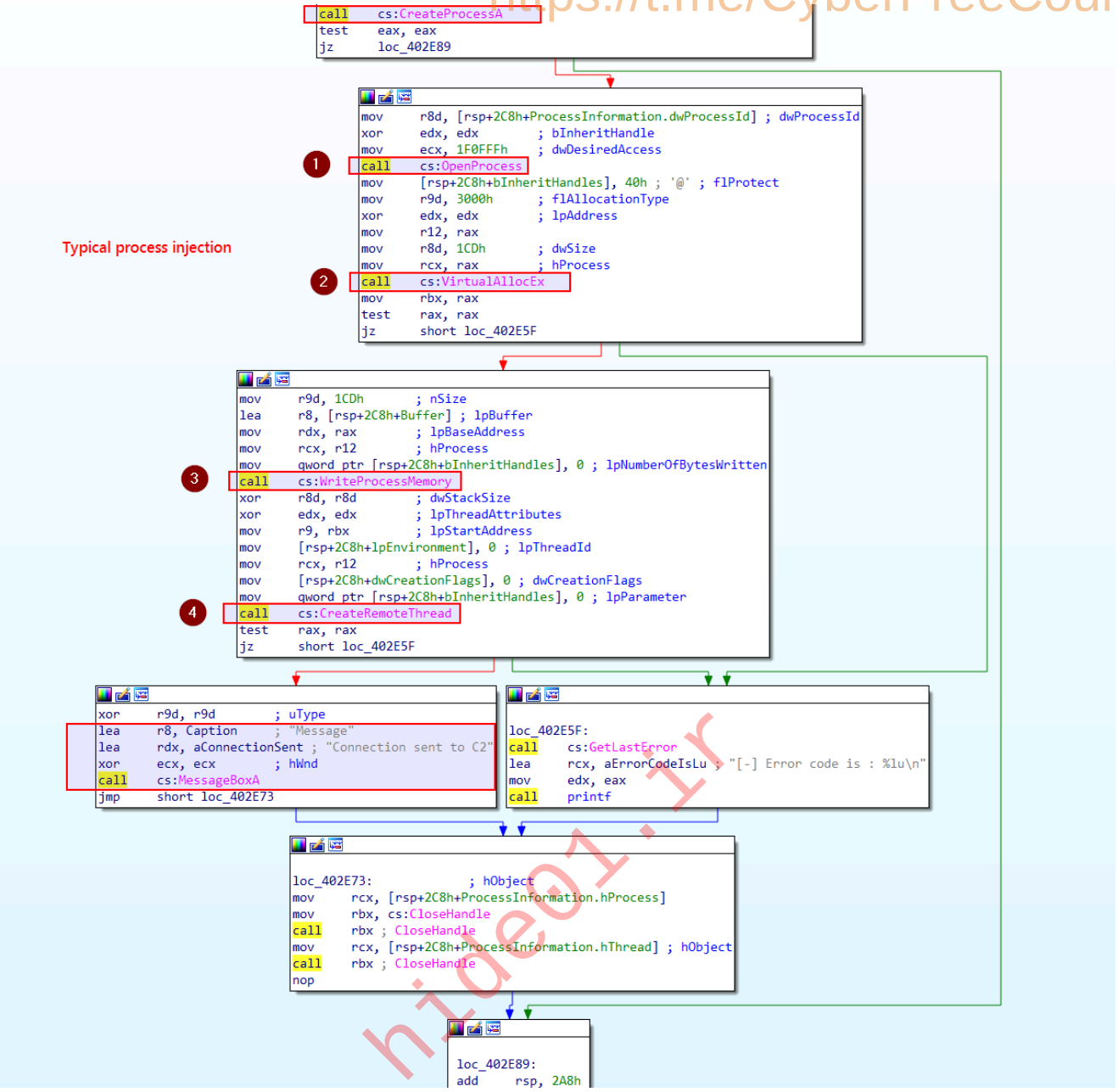

The subsequent block of instructions hints at a commonplace type of process injection, wherein `shellcode` is inserted into the newly created process using `VirtualAllocEx`, `WriteProcessMemory`, and `CreateRemoteThread` functions.

Let's decipher the process injection based on our observations of the code.

A fresh `notepad.exe` process is fabricated via the `CreateProcessA` function. Following this, memory is allocated within this process using `VirtualAllocEx`. The `shellcode` is then inscribed into the allocated memory of the remote process `notepad.exe` using the WINAPI function `WriteProcessMemory`. Lastly, a remote thread is established in `notepad.exe`, initiating the `shellcode` execution via the `CreateRemoteThread` function.

If the injection is triumphant, a message box manifests, declaring `Connection sent to C2`. Conversely, an error message surfaces in the event of failure.

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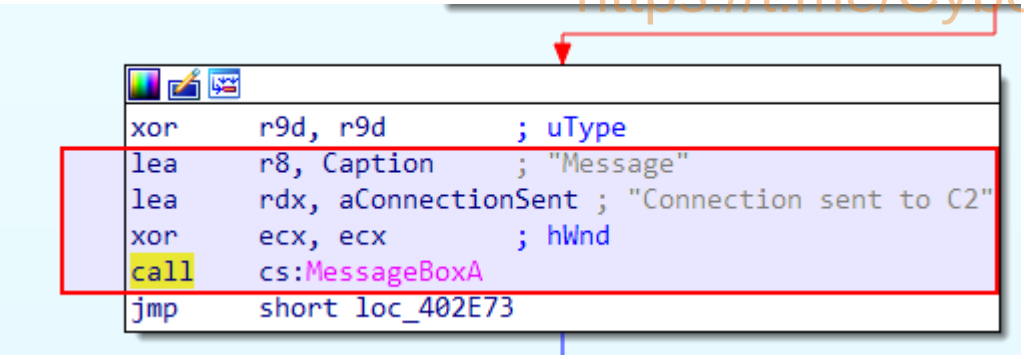

For the sake of ease, let's rename the function `sub_402D20` as `process_Injection`.

At the outset of this function, we can spot an unknown address `unk_405057`, the effective address of which is loaded into the `rsi` register via the instruction `lea rsi, unk_405057`. Executed prior to the WINAPI functions call for the process injection, the reason for loading the effective address into `rsi` could be manifold - it might function as a data-accessing pointer or as a function call argument. There is, however, the possibility that this address houses potential `shellcode`. We will verify this when `debugging` these WINAPI functions using a debugger like `x64dbg`.

Upon analyzing and renaming this process injection function, we will continue to retrace our steps to the preceding functions to ensure that no function has been overlooked.

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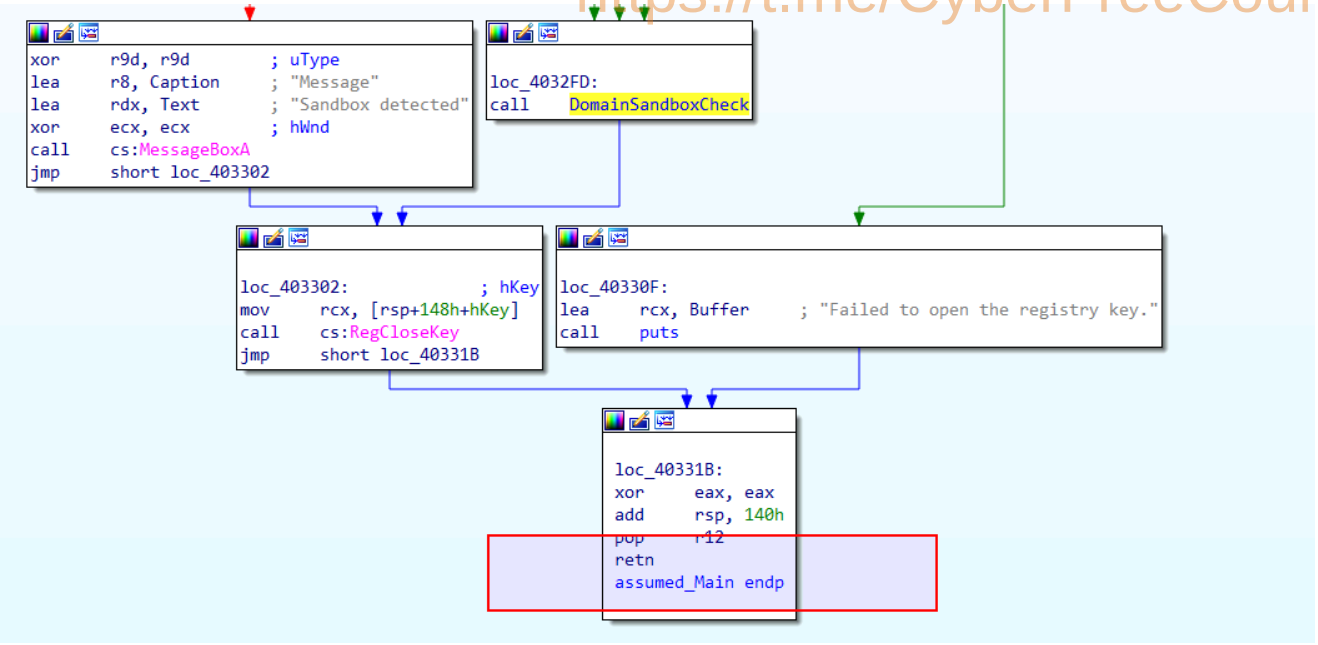

`IDA` also offers a feature that visualizes the execution flow between functions in an executable via a `call flow graph`. This potent visual tool aids analysts in navigating and understanding the control flow and the interactions among functions.

Here's how to generate and examine the graph to identify the links among different functions:

- Switch to the disassembly view.
- Locate the `View` menu at the top of the `IDA` interface.
- Hover over the `Graphs` option.
- From the submenu, choose `Function calls`.

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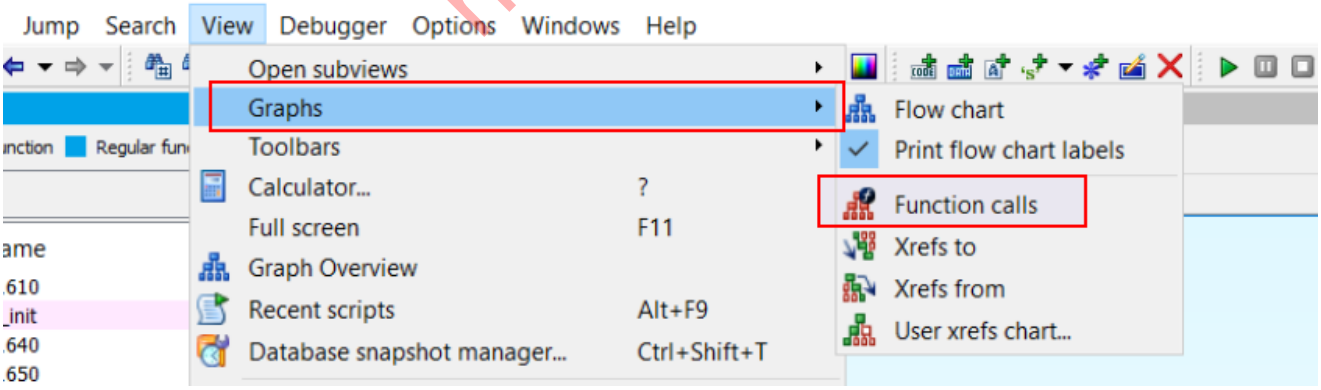

`IDA` will then forge the function calls flow graph for all functions in the binary and present it in a new window. This graph offers an overview of the calls made between the various functions in the program, enabling us to scrutinize the control flow and dependencies among functions. An example of how this graph appears is shown in the screenshot below.

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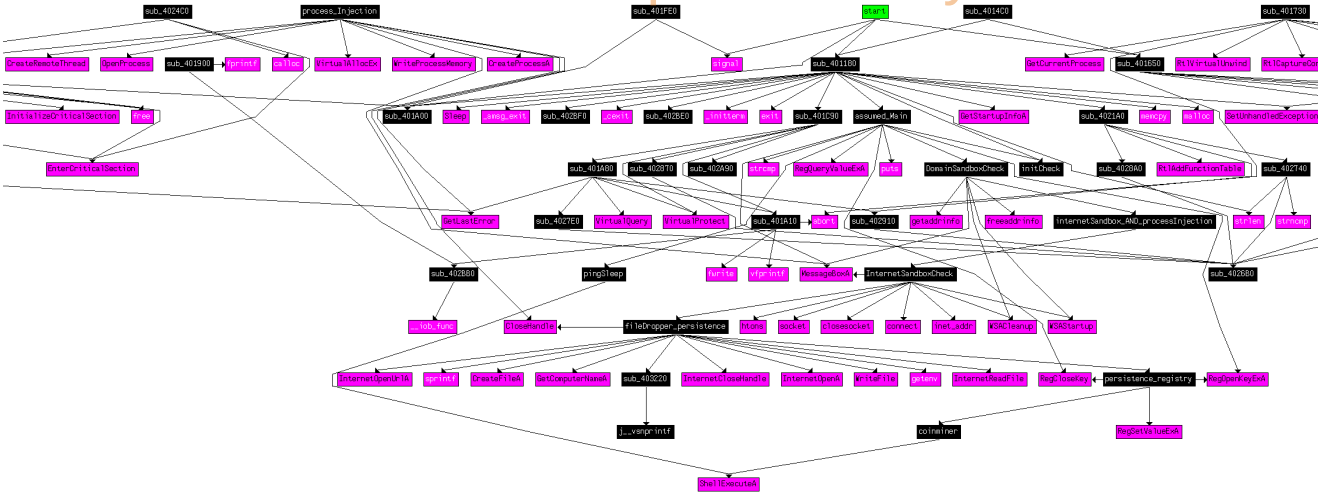

Contrary to viewing the relationship graph for all function calls, we can also focus on specific functions. To generate the reference graph for the function calls flow related to a specific function, these steps can be followed.

- Navigate to the function whose function call flow graph we wish to examine.
- To open the function in the disassembly view, either double-click the function name or press `Enter`.
- In the disassembly view, right-click anywhere and opt for either `Xrefs graph to...` or `Xrefs graph from...`, based on whether we want to observe the function calls made by the selected function or the function calls leading to the selected function.
- `IDA` will craft the function calls flow graph and exhibit it in a new window.

Looking ahead, we will delve into debugging in the subsequent section. There, we'll launch the executable within a debugger and establish breakpoints on the requisite instructions and select critical WINAPI functions. This strategy allows us to comprehend and manage the execution flow in real time as the program operates.

Debugging

Debugging adds a dynamic, interactive layer to code analysis, offering a real-time view of malware behavior. It empowers analysts to confirm their discoveries, witness runtime impacts, and deepen their comprehension of the program execution. Uniting code analysis and debugging allows for a comprehensive understanding of the malware, leading to the effective exposure of harmful behavior.

We could deploy a debugger like `x64dbg`, a user-friendly tool tailored for analyzing and debugging 64-bit Windows executables. It comes equipped with a graphical interface for visualizing disassembled code, implementing breakpoints, examining memory and registers, and controlling the execution of programs.

Let's now navigate to the bottom of this section and click on "Click here to spawn the target system!". Then, let's RDP into the Target IP using the provided credentials. The vast majority

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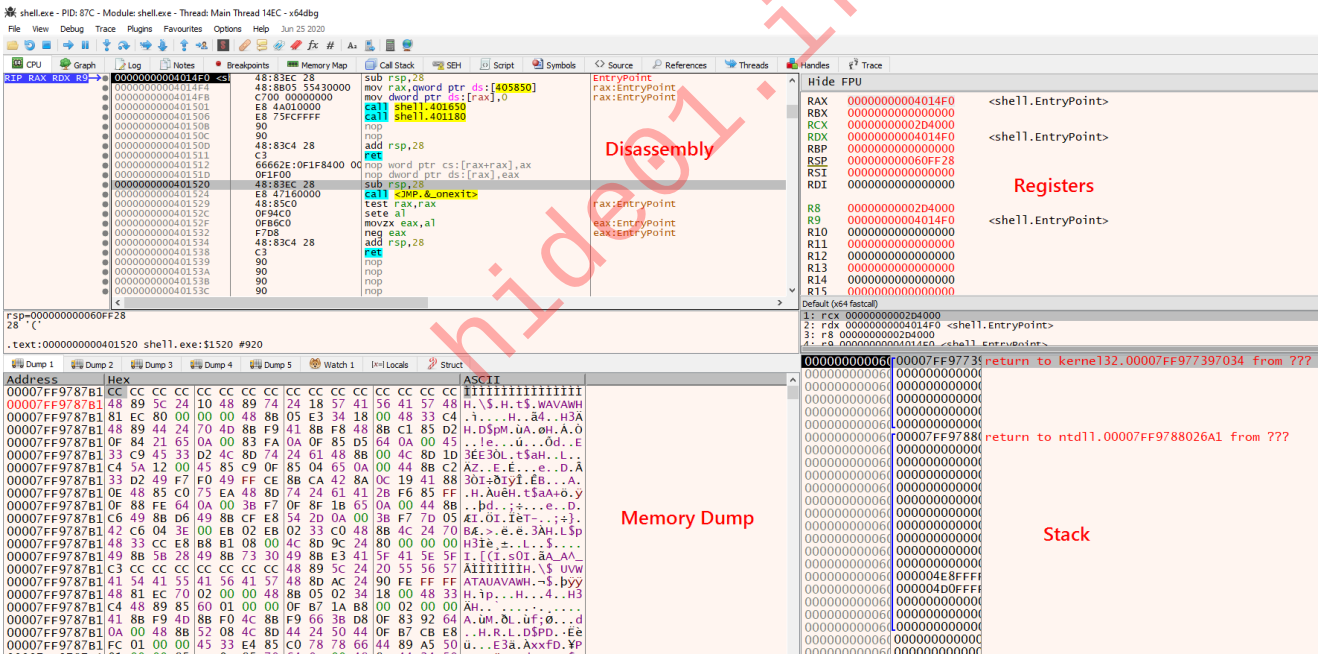
of the actions/commands covered from this point up to end of this section can be replicated inside the target, offering a more comprehensive grasp of the topics presented.

```
xfreerdp /u:htb-student /p:'HTB_@cademy_stdnt!' /v:[Target IP] /dynamic-resolution
```

Here's how to run a sample within `x64dbg` to familiarize with its operations.

- Launch `x64dbg`.
- At the top of the `x64dbg` interface, click the `File` menu.
- Select `Open` to choose the executable file we wish to debug.
- Browse to the directory containing the executable and select it.
- Optionally, command-line arguments or the working directory can be specified in the dialog box that appears.
- Click `OK` to load the executable into `x64dbg`.

Upon opening, the default window halts at a default breakpoint at the program's entry point.



Loading an executable into `x64dbg` reveals the disassembly view, showcasing the assembly instructions of the program, thereby aiding in understanding the code flow. To the right, the register window divulges the values of CPU registers, shedding light on the program's state. Beneath the register window, the stack view displays the current stack frame, enabling the inspection of function calls and local variables. Lastly, on the bottom left corner, we find the memory dump view, providing a pictorial representation of the program's memory, facilitating the analysis of data structures and variables.

Simulating Internet Services

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The role of `INetSim` in simulating typical internet services in our restricted testing environment is pivotal. It offers support for a multitude of services, encompassing `DNS`, `HTTP`, `FTP`, `SMTP`, among others. We can fine-tune it to reproduce specific responses, thereby enabling a more tailored examination of the malware's behavior. Our approach will involve keeping `InetSim` operational so that it can intercept any `DNS`, `HTTP`, or other requests emanating from the malware sample (`shell.exe`), thereby providing it with controlled, synthetic responses.

Note: It is highly recommended that we use your own VM/machine for running `InetSim`. Our VM/machine should be connected to VPN using the provided VPN config file that resides at the end of this section.

We should configure `INetSim` as follows.

```
sudo nano /etc/inetsim/inetsim.conf
```

The below need to be uncommented and specified.

```
service_bind_address <Our machine's/VM's TUN IP>
dns_default_ip <Our machine's/VM's TUN IP>
dns_default_hostname www
dns_default_domainname iuqerfsodp9ifjaposdfjhgosurijfaewrwergwea.com
```

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Initiating `INetSim` involves executing the following command.

```
sudo inetsim
INetSim 1.3.2 (2020-05-19) by Matthias Eckert & Thomas Hungenberg
Using log directory:      /var/log/inetsim/
Using data directory:     /var/lib/inetsim/
Using report directory:   /var/log/inetsim/report/
Using configuration file: /etc/inetsim/inetsim.conf
Parsing configuration file.
Configuration file parsed successfully.
=== INetSim main process started (PID 34711) ===
Session ID:     34711
Listening on:   0.0.0.0
Real Date/Time: 2023-06-11 00:18:44
Fake Date/Time: 2023-06-11 00:18:44 (Delta: 0 seconds)
 Forking services...
  * dns_53_tcp_udp - started (PID 34715)
  * smtps_465_tcp - started (PID 34719)
  * pop3_110_tcp - started (PID 34720)
  * smtp_25_tcp - started (PID 34718)
  * http_80_tcp - started (PID 34716)
```

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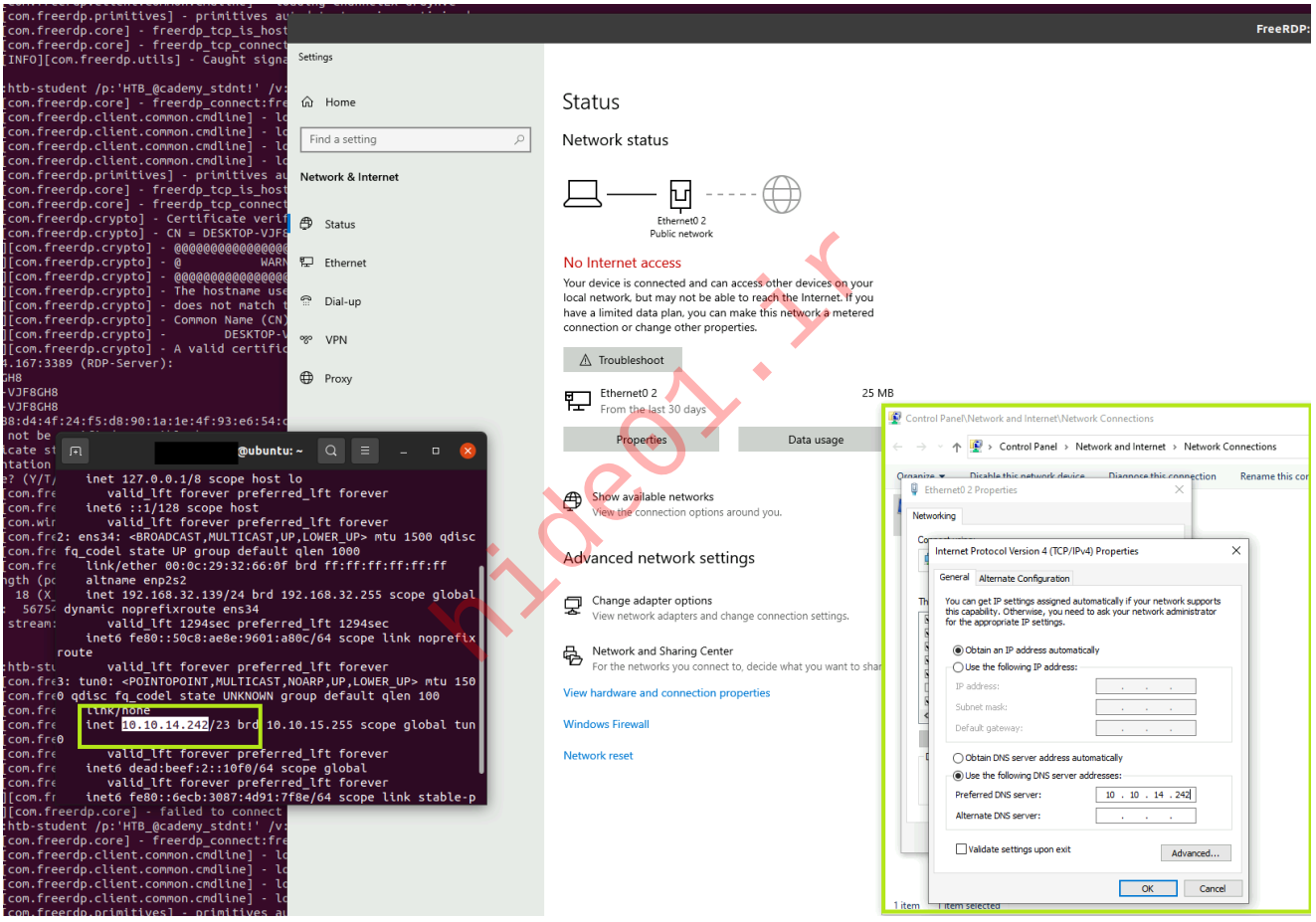
```
    * ftp_21_tcp - started (PID 34722)
    * https_443_tcp - started (PID 34717)
    * pop3s_995_tcp - started (PID 34721)
    * ftps_990_tcp - started (PID 34723)
  done.
Simulation running.
```

A more elaborate resource on configuring `INetSim` is the following: https://medium.com/@xNymia/malware-analysis-first-steps-creating-your-lab-21b769fb2a64

Finally, the spawned target's DNS should be pointed to the machine/VM where `INetSim` is running.



Applying the Patches to Bypass Sandbox Checks

Given that sandbox checks hinder the malware's direct execution on the machine, we need to patch these checks to circumvent the sandbox detection. Here's how we can dodge sandbox detection checks while debugging with `x64dbg`. Several methods can lead us to the instructions where sandbox detection is performed. We will discuss a few of these.

By Copying the Address from IDA

During code analysis, we observed the sandbox detection check related to the registry key. We can extract the address of the first `cmp` instruction directly from `IDA`.

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To find the address, let's revert to the IDA windows, open the first function we had renamed as `assumed_Main`, and look for the `cmp` instruction. To view the addresses, we can transition from graph view to text view by pressing the spacebar button.

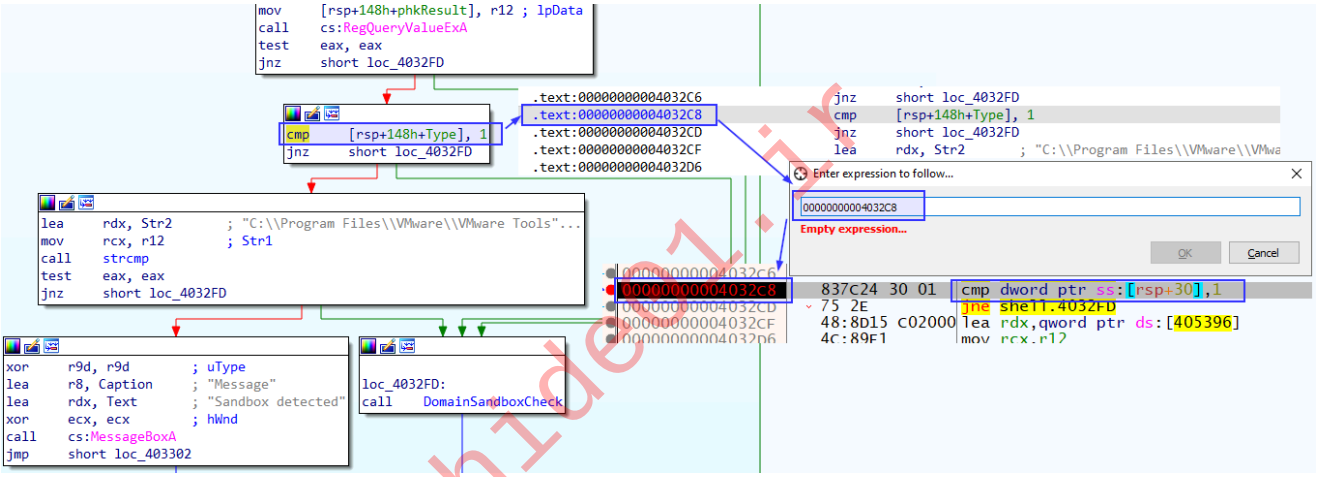
This exposes the address (as highlighted in the below screenshot)

We can copy the address `00000000004032C8` from `IDA`.

```
.text:00000000004032C8                  cmp     [rsp+148h+Type], 1
```

In `x64dbg`, we can right-click anywhere on the disassembly view (CPU) and select `Go to` > `Expression`. Alternatively, we can press `Ctrl+G` (go to expression) as a shortcut.

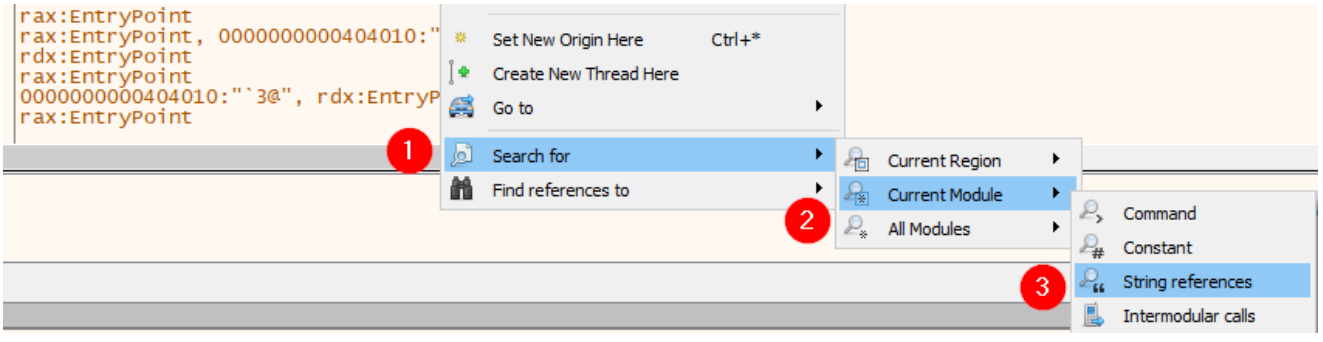
We can enter the copied address here, as shown in the screenshot. This navigates us to the comparison instruction where we can implement changes.



By Searching Through the Strings.

Let's look for `Sandbox detected` in the `String references`, and set a `breakpoint`, so that when we hit run, the execution should pause at this point.

To do this, first click on the `Run` button once and then right-click anywhere on the disassembly view, and choose `Search for` > `Current Module` > `String references`.



Next, we can add a breakpoint to mark the location, then study the instructions before this Sandbox `MessageBox` to discern how the jump was made to the instruction printing `Sandbox`

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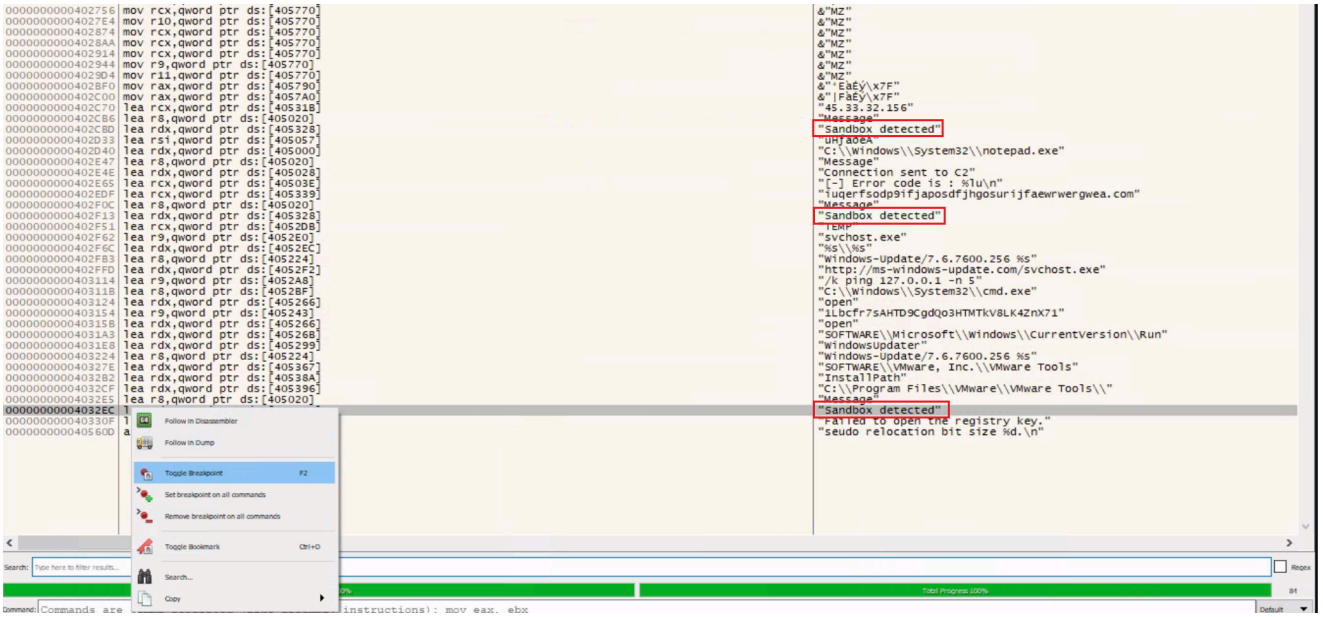
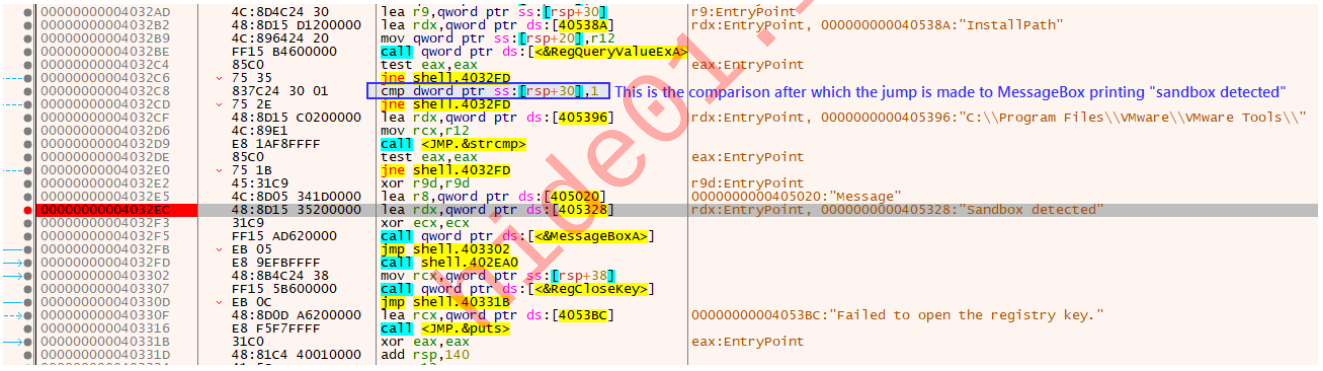
`detected`.

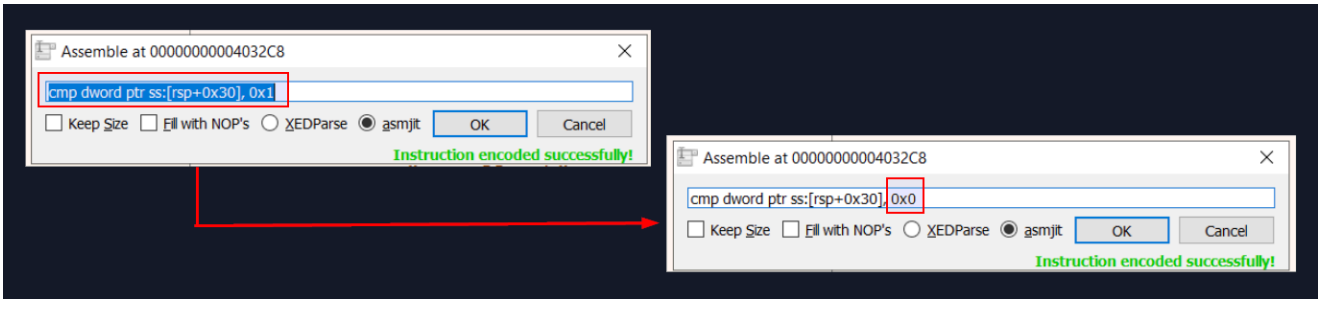
Let's start by adding a breakpoint at the last `Sandbox detected` string as follows.



We can then double-click on the string to go to the address where the instructions to print `Sandbox detected` are located.



As observed, a `cmp` instruction is present above this `MessageBox` which compares the value with `1` after a registry path comparison has been performed. Let's modify this comparison value to match with `0` instead. This can be done by placing the cursor on that instruction and pressing `Spacebar` on the keyboard. This allows us to edit the assembly code instructions.



We can change the comparison value of `0x1` to `0x0`. Changing the comparison to `0` may shift the control flow of the code, and it should not jump to the address where `MessageBox` is

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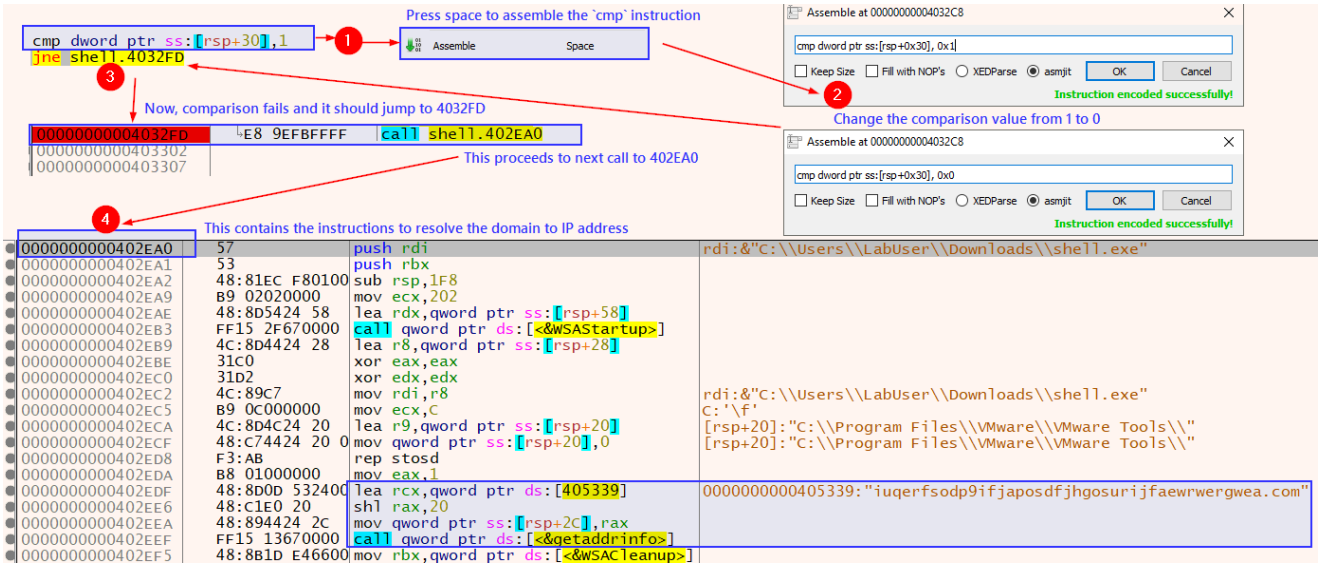
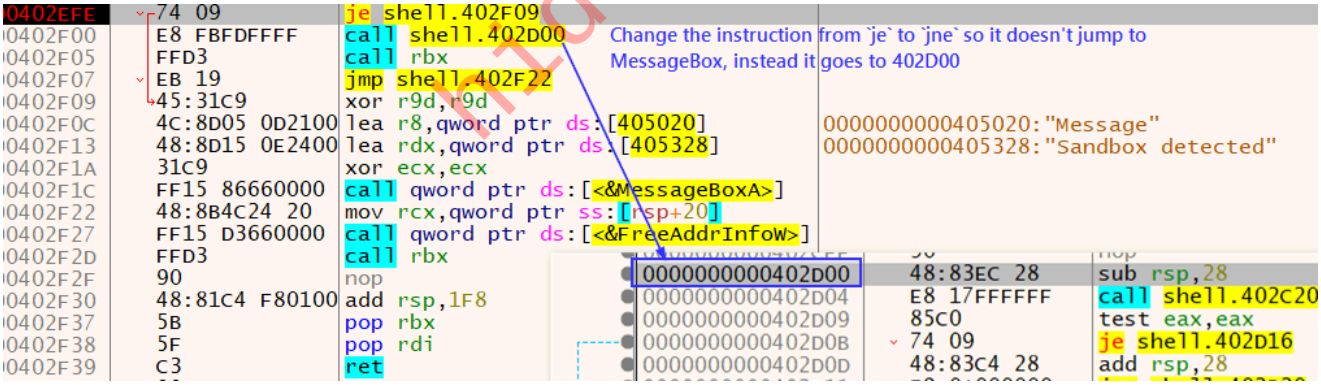
displayed.

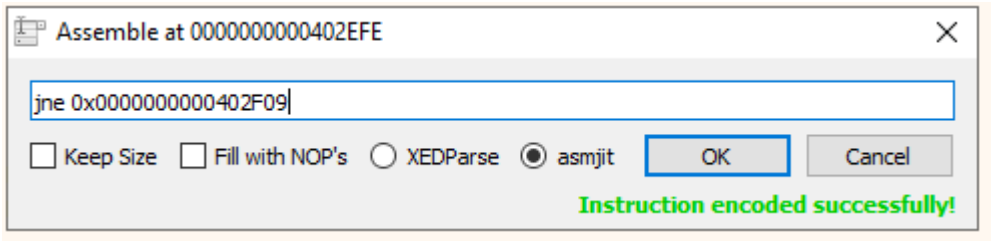


Upon clicking on `Run` in `x64dbg` or pressing `F9`, it won't hit the breakpoint for the first sandbox detection message code. This means that we successfully patched the instructions.

In a similar manner, we can add a breakpoint on the next sandbox detection function before it prints a `MessageBox` as well. To do that, the breakpoint should be placed at the `second to last Sandbox detected` string (`0000000000402F13`). If we double-click this string we will notice there's a `jump` instruction which we can skip, directing the execution flow to the next instruction that calls another function. That's exactly what we need – instead of the sandbox detection `MessageBox`, it jumps to another function.



We can alter the instruction from `je shell.402F09` to `jne shell.402F09`.



`shell.exe` performs sandbox detection by checking for internet connectivity. This section's target doesn't have internet connectivity. For this reason we should patch this sandbox

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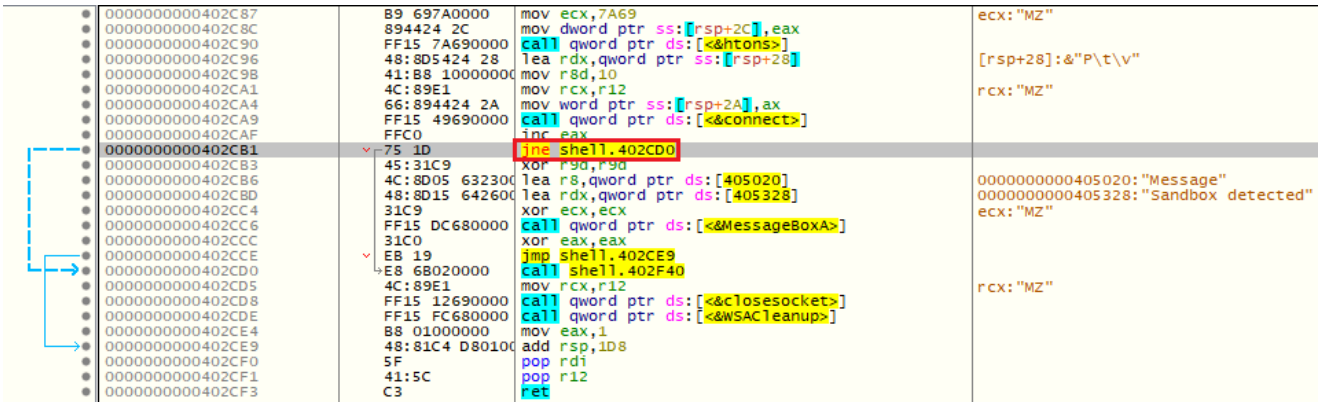
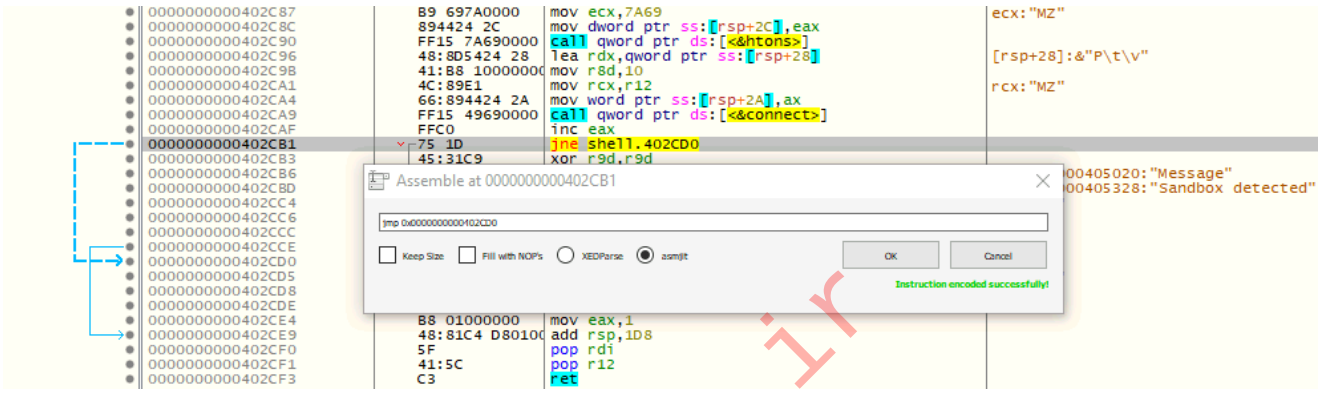
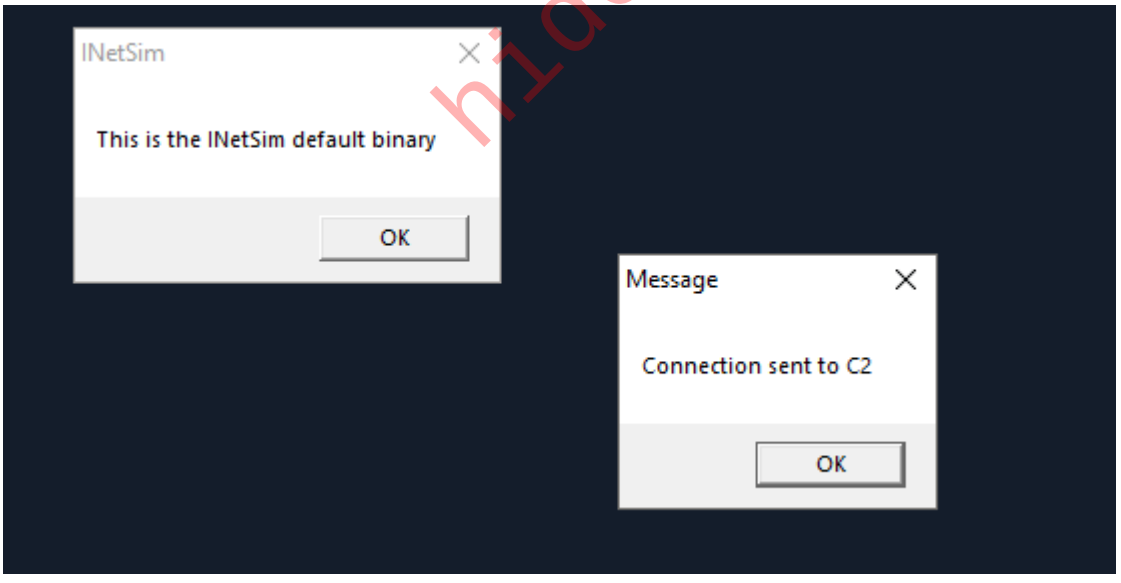
detection method as well. We can do that by clicking on the first `Sandbox detected` string (`0000000000402CBD`) and patching the following instruction.





Now, when we press `Run` , the patched `shell.exe` proceeds further, downloads the default executable from `INetSim` , and executes it.



With the sandbox checks bypassed, the actual functionality is unveiled. We can save the patched executable by pressing `Ctrl+P` and clicking on `Patch File` . This action stores the patched file, which skips the sandbox checks.

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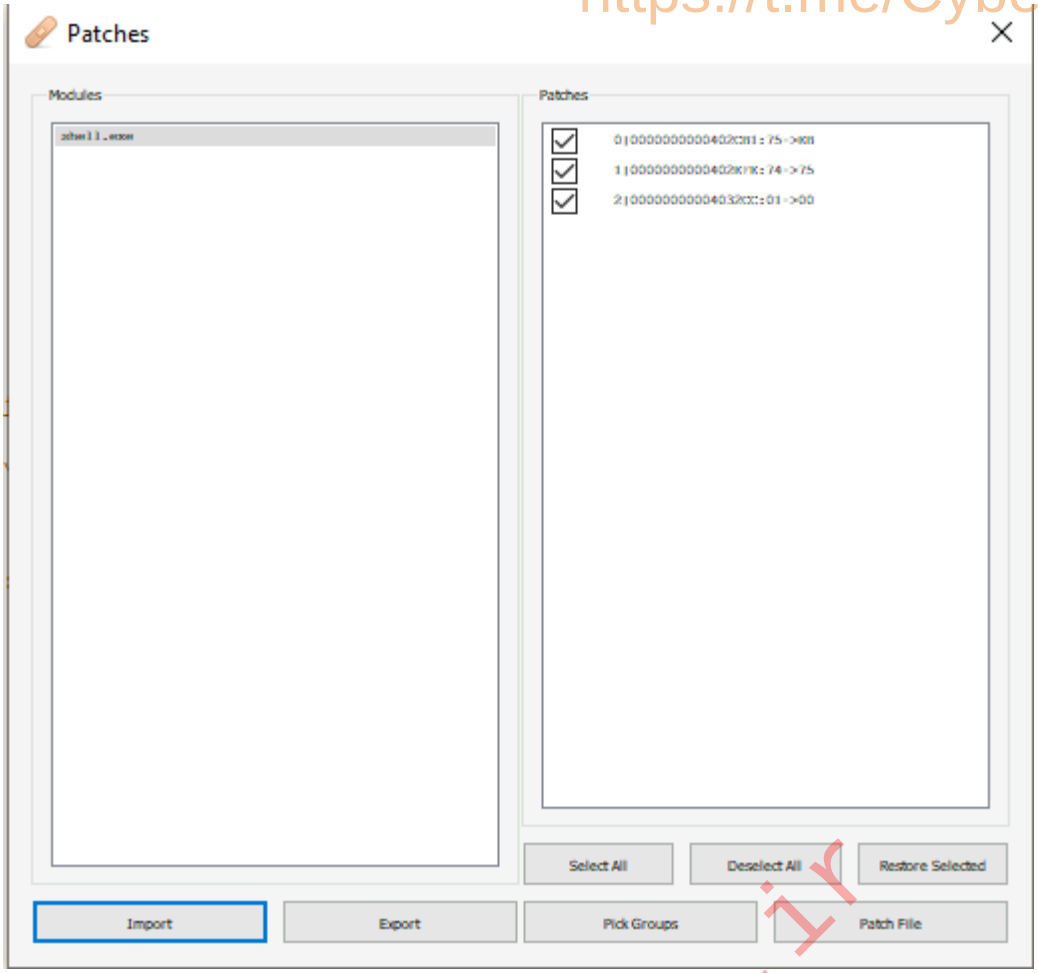

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We undertake this process to ensure that the next time we run the saved patched file, it executes directly without the sandbox checks, and we can observe all the events in `ProcessMonitor`.

Analyzing Malware Traffic

Keep in mind that traffic analysis not only can be, but ideally should be incorporated as an integral part of Dynamic Analysis.

Let's now employ `Wireshark`, to capture and examine the network traffic generated by the malware. Be mindful of the color-coded traffic: red corresponds to client-to-server traffic, while blue denotes the server-to-client exchanges.

Examining the HTTP Request reveals that the malware sample appends the computer hostname to the user agent field (in this case it was `RDSEMVM01`).

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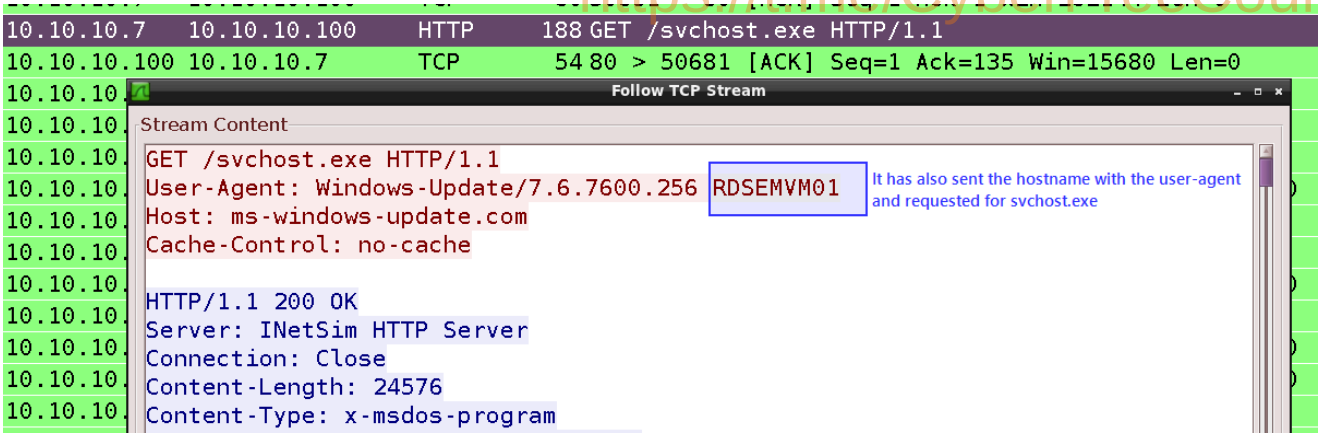
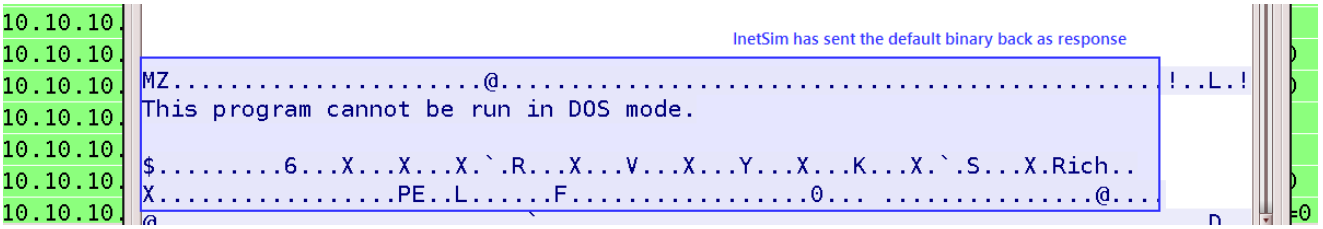
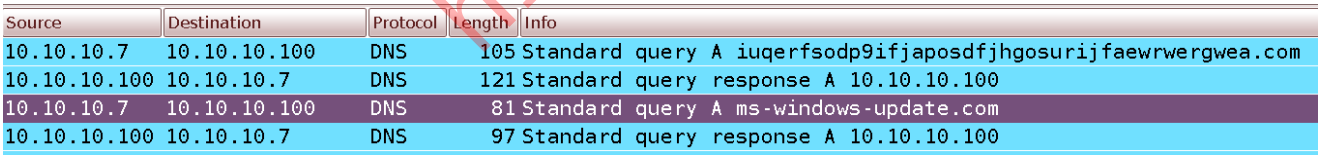


When inspecting the HTTP Response, it becomes evident that `InetSim` has returned its default binary as a response to the malware.



The malware's request for `svchost.exe` solicits the default binary from `InetSim`. This binary responds with a `MessageBox` featuring the message: `This is the INetSim default binary`.

Additionally, DNS requests for a random domain and the address `ms-windows-update[.]com` were sent by the malware, with `INetSim` responding with fake responses (in this case `INetSim` was running on `10.10.10.100`).



Source	Destination	Protocol	Length	Info
10.10.10.7	10.10.10.100	DNS	105	Standard query A iuqerfsodp9ifjaposdfjhgosurijfaewrwergwea.com
10.10.10.100	10.10.10.7	DNS	121	Standard query response A 10.10.10.100
10.10.10.7	10.10.10.100	DNS	81	Standard query A ms-windows-update.com
10.10.10.100	10.10.10.7	DNS	97	Standard query response A 10.10.10.100

Analyzing Process Injection & Memory Region

On the journey of code analysis, we discovered that our executable performs process injection on `notepad.exe` and displays a `MessageBox` stating `Connection sent to C2`.

To probe deeper into the process injection, we propose setting breakpoints at WINAPI functions `VirtualAllocEx`, `WriteProcessMemory`, and `CreateRemoteThread`. These breakpoints will allow us to scrutinize the content held in the registers during the process injection. Here's the procedure to set these breakpoints:

- Access the `x64dbg` interface and navigate to the `Symbols` tab, located at the top.
- In the symbol search box, search for the desired DLL name on the left and function names, such as `VirtualAllocEx`, `WriteProcessMemory`, and `CreateRemoteThread`, on the right within the `Kernel32.dll` DLL.

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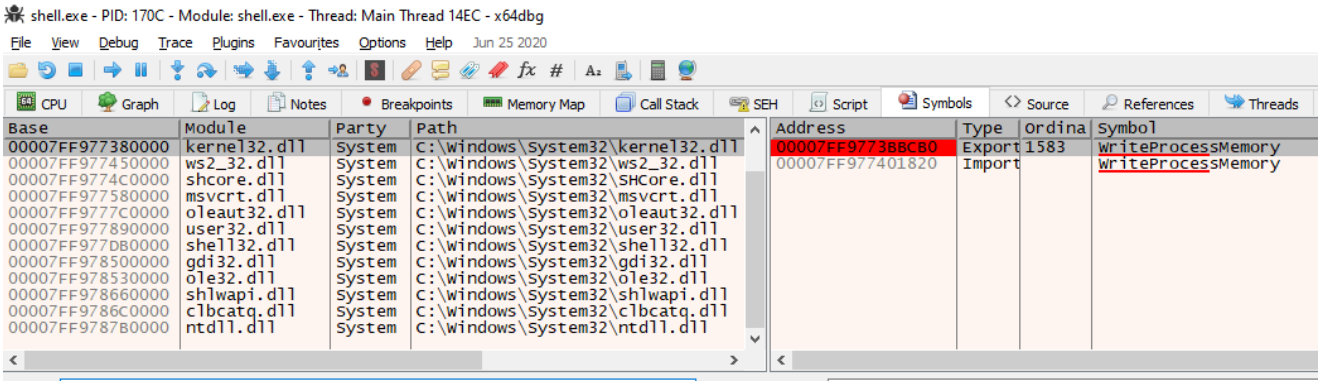
- As the function names materialize in the search results, right-click and select `Toggle breakpoint` from the context menu for each function. An alternative shortcut is to press `F2`.

Executing these steps sets a breakpoint at each function's entry point. We'll replicate these steps for all the functions we intend to scrutinize.



After setting breakpoints, we press `F9` or select `Run` from the toolbar until we reach the breakpoint for `WriteProcessMemory`. Up until this moment, `notepad` has been launched, but the `shellcode` has not yet been written into notepad's memory.

Attaching Another Running Process In x64dbg

In order to delve further, let's open another instance of `x64dbg` and attach it to `notepad.exe`.

- Start a new instance of `x64dbg`.
- Navigate to the `File` menu and select `Attach` or use the `Alt + A` keyboard shortcut.
- In the `Attach` dialog box, a list of running processes will appear. Choose `notepad.exe` from the list.
- Click the `Attach` button to begin the attachment process.

Once the attachment is successful, `x64dbg` initiates the debugging of the target process, and the main window displays the assembly code along with other debugging information.

Now, we can establish breakpoints, step through the code, inspect registers and memory, and study the behavior of the attached notepad.exe process using `x64dbg`.

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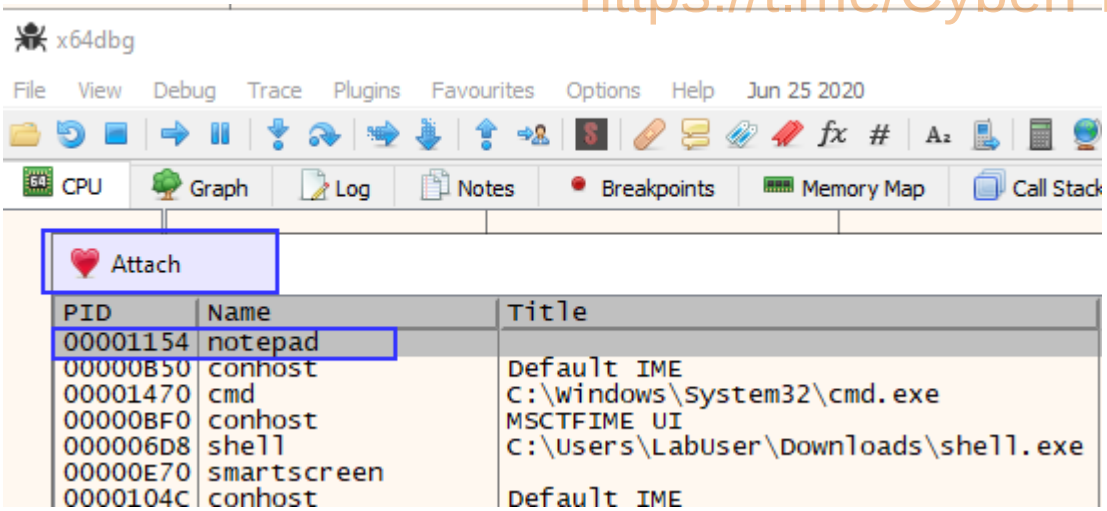

The 2nd argument of `WriteProcessMemory` is `lpBaseAddress` which contains a pointer to the base address in the specified process to which data is written. In our case, it should be in the `RDX` register.

C++ Copy

```
BOOL WriteProcessMemory(
  [in]  HANDLE  hProcess,
  [in]  LPVOID  lpBaseAddress,
  [in]  LPCVOID lpBuffer,
  [in]  SIZE_T  nSize,
  [out] SIZE_T  *lpNumberOfBytesWritten
);
```

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Parameters

`[in] hProcess`

A handle to the process memory to be modified. The handle must have PROCESS_VM_WRITE and PROCESS_VM_OPERATION access to the process.

`[in] lpBaseAddress`

A pointer to the base address in the specified process to which data is written. Before data transfer occurs, the system verifies that all data in the base address and memory of the specified size is accessible for write access, and if it is not accessible, the function fails.

When invoking the `WriteProcessMemory` function, the `rdx` register holds the `lpBaseAddress` parameter. This parameter represents the address within the target process's address space where the data will be written.

We aim to examine the registers when the `WriteProcessMemory` function is invoked in the `x64dbg` instance running the `shell.exe` process. This will reveal the address within `notepad.exe` where the shellcode will be written.

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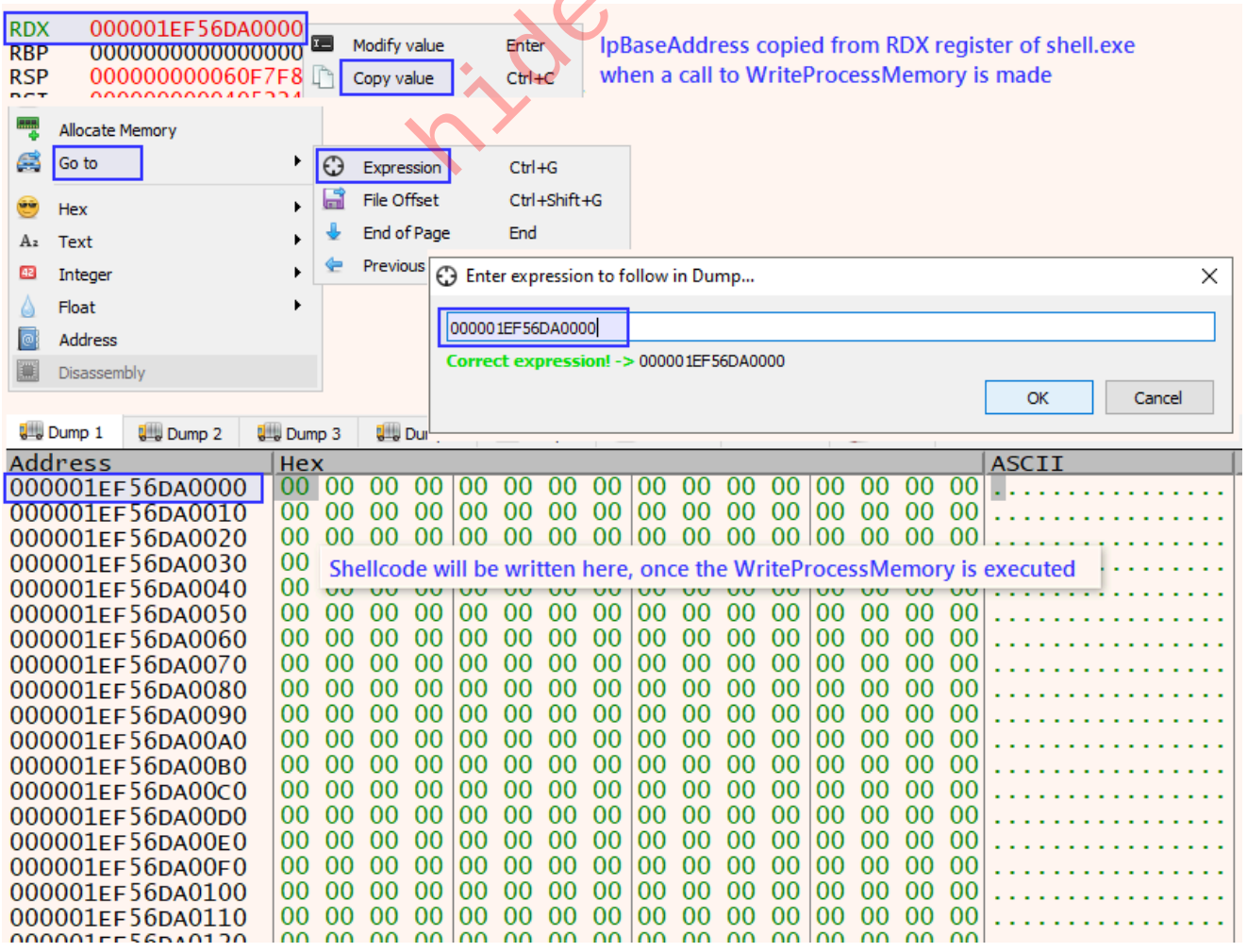
```
Hide FPU
RAX     000001EF56DA0000
RBX     000001EF56DA0000
RCX     0000000000000648    L'ٔ'
RDX     000001EF56DA0000
RBP     0000000000000000
RSP     000000000060F7F8
RSI     0000000000405224    "Windows-Update/7.6.7600.256 %s"
RDI     000000000060FAA0

R8      000000000060F8D3
R9      00000000000001CD    L'Ă'
R10     0000000000000000
R11     0000000000000246    L'Ɇ'
R12     0000000000000648    L'ٔ'
R13     0000000000B617A0    &"C:\\Users\\LabUser\\Downloads\\shell.exe"
R14     0000000000000000
R15     0000000000000000

RIP     00007FF9773BBCB0    <kernel32.WriteProcessMemory>
```

We copy this address to examine its content in the memory dump of the attached `notepad.exe` process in the second `x64dbg` instance.

We now select `Go to` > `Expression` by right-clicking anywhere on the memory dump in the second `x64dbg` instance running `notepad.exe`.

With the copied address entered, the content at this address is displayed (by right-clicking on the address and choosing `Follow in Dump` > `Selected Address`), which currently is empty.



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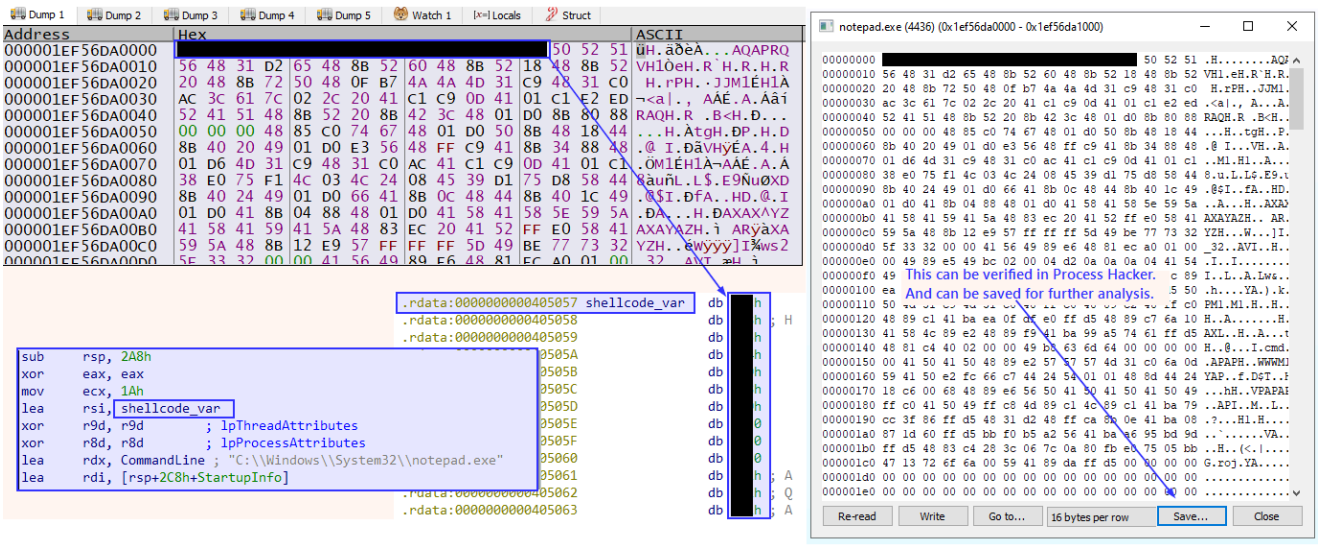
Next, we execute shell.exe in the first `x64dbg` instance by clicking on the `Run` button. We observe what is inscribed into this memory region of `notepad.exe`.



Following its execution, we identify the injected `shellcode`, which aligns with what we discovered earlier during code analysis. We can verify this in `Process Hacker` and save it to a file for subsequent examination.

Creating Detection Rules

Having now uncovered the Tactics, Techniques, and Procedures (TTPs) employed by this malware, we can proceed to design detection rules, such as `Yara` and `Sigma` rules.

While we will begin to delve into the concepts of Yara and Sigma rule development in this section, we'll only scratch the surface. These are extensive topics with a lot of depth, necessitating a comprehensive study. Hence, we will be dedicating a complete module named 'YARA & Sigma for SOC Analysts' to help you truly master these crucial areas of cyber defense.

Let's now navigate to the bottom of this section and click on "Click here to spawn the target system!". Then, let's SSH into the Target IP using the provided credentials. The vast majority of the actions/commands covered from this point up to end of this section can be replicated inside the target, offering a more comprehensive grasp of the topics presented.

Yara

`YARA (Yet Another Recursive Acronym)`, a widely used open-source pattern matching tool and rule-based malware detection and classification framework let's us create custom rules to spot specific patterns or characteristics in files, processes, or memory. To draft a `YARA` rule for our sample, we'll need to examine the behavior, features, or specific strings/patterns unique to the sample we aim to detect.

Here's a simple example of a `YARA` rule that matches the presence of the string `Sandbox detected` in a process. We remind you that `shell.exe` demonstrated such behavior.

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```
rule Shell_Sandbox_Detection {
    strings:
        $sandbox_string = "Sandbox detected"
    condition:
        $sandbox_string
}
```

Now let's add a lot more strings and patterns into the rule to make it better.

We can utilize the `yarGen` tool, which automates the process of generating `YARA` rules, with the prime objective of crafting the best possible rules for manual post-processing. This, however, necessitates a shrewd automatic preselection and a discerning human analyst to generate a robust rule.

First let's create a new directory called `Test` inside the `/home/htb-student/Samples/MalwareAnalysis` directory of this section's target and then let's copy `shell.exe` (residing in the `/home/htb-student/Samples/MalwareAnalysis` directory) to the newly created `Test` directory as follows.

```
mkdir /home/htb-student/Samples/MalwareAnalysis/Test
```

```
cp /home/htb-student/Samples/MalwareAnalysis/shell.exe /home/htb-student/Samples/MalwareAnalysis/Test/
```

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To automatically create a Yara rule for `shell.exe` we should execute the following (inside the `/home/htb-student/yarGen-0.23.4` directory).

```
sudo python3 yarGen.py -m /home/htb-student/Samples/MalwareAnalysis/Test/
--------------------------------------------------------------------------
                    _____
    __ _____ _____/ ___/__ ___
   / // / _ `/ __/ (_ / -_) _ \
   \_, /\_,_/_/  \___/\__/_//_/
  /___/  Yara Rule Generator
         Florian Roth, July 2020, Version 0.23.3

  Note: Rules have to be post-processed
  See this post for details: https://medium.com/@cyb3rops/121d29322282
--------------------------------------------------------------------------
[+] Using identifier 'Test'
[+] Using reference 'https://github.com/Neo23x0/yarGen'
[+] Using prefix 'Test'
[+] Processing PEStudio strings ...
```

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```
[+] Reading goodware strings from database 'good-strings.db' ...
    (This could take some time and uses several Gigabytes of RAM depending
on your db size)
[+] Loading ./dbs/good-imphashes-part3.db ...
[+] Total: 4029 / Added 4029 entries
[+] Loading ./dbs/good-strings-part9.db ...
[+] Total: 788 / Added 788 entries
[+] Loading ./dbs/good-strings-part8.db ...
[+] Total: 332082 / Added 331294 entries
[+] Loading ./dbs/good-imphashes-part4.db ...
[+] Total: 6426 / Added 2397 entries
[+] Loading ./dbs/good-strings-part2.db ...
[+] Total: 1703601 / Added 1371519 entries
[+] Loading ./dbs/good-exports-part2.db ...
[+] Total: 90960 / Added 90960 entries
[+] Loading ./dbs/good-strings-part4.db ...
[+] Total: 3860655 / Added 2157054 entries
[+] Loading ./dbs/good-exports-part4.db ...
[+] Total: 172718 / Added 81758 entries
[+] Loading ./dbs/good-exports-part7.db ...
[+] Total: 223584 / Added 50866 entries
[+] Loading ./dbs/good-strings-part6.db ...
[+] Total: 4571266 / Added 710611 entries
[+] Loading ./dbs/good-strings-part7.db ...
[+] Total: 5828908 / Added 1257642 entries
[+] Loading ./dbs/good-exports-part1.db ...
[+] Total: 293752 / Added 70168 entries
[+] Loading ./dbs/good-exports-part3.db ...
[+] Total: 326867 / Added 33115 entries
[+] Loading ./dbs/good-imphashes-part9.db ...
[+] Total: 6426 / Added 0 entries
[+] Loading ./dbs/good-exports-part9.db ...
[+] Total: 326867 / Added 0 entries
[+] Loading ./dbs/good-imphashes-part5.db ...
[+] Total: 13764 / Added 7338 entries
[+] Loading ./dbs/good-imphashes-part8.db ...
[+] Total: 13947 / Added 183 entries
[+] Loading ./dbs/good-imphashes-part6.db ...
[+] Total: 13976 / Added 29 entries
[+] Loading ./dbs/good-strings-part1.db ...
[+] Total: 6893854 / Added 1064946 entries
[+] Loading ./dbs/good-imphashes-part7.db ...
[+] Total: 17382 / Added 3406 entries
[+] Loading ./dbs/good-exports-part6.db ...
[+] Total: 328525 / Added 1658 entries
[+] Loading ./dbs/good-imphashes-part2.db ...
[+] Total: 18208 / Added 826 entries
[+] Loading ./dbs/good-exports-part8.db ...
[+] Total: 332359 / Added 3834 entries
[+] Loading ./dbs/good-strings-part3.db ...
```

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```
[+] Total: 9152616 / Added 2258762 entries
[+] Loading ./dbs/good-strings-part5.db ...
[+] Total: 12284943 / Added 3132327 entries
[+] Loading ./dbs/good-imphashes-part1.db ...
[+] Total: 19764 / Added 1556 entries
[+] Loading ./dbs/good-exports-part5.db ...
[+] Total: 404321 / Added 71962 entries
[+] Processing malware files ...
[+] Processing /home/htb-student/Samples/MalwareAnalysis/Test/shell.exe
...
[+] Generating statistical data ...
[+] Generating Super Rules ... (a lot of magic)
[+] Generating Simple Rules ...
[-] Applying intelligent filters to string findings ...
[-] Filtering string set for /home/htb-
student/Samples/MalwareAnalysis/Test/shell.exe ...
[=] Generated 1 SIMPLE rules.
[=] All rules written to yargen_rules.yar
[+] yarGen run finished
```

We will notice that a file named `yargen_rule.yar` is generated by `yarGen` that incorporates unique strings, which are automatically extracted and inserted into the rule.

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```
cat yargen_rules.yar
/*
   YARA Rule Set
   Author: yarGen Rule Generator
   Date: 2023-08-02
   Identifier: Test
   Reference: https://github.com/Neo23x0/yarGen
*/

/* Rule Set ----------------------------------------------------------
--- */

rule _home_htb_student_Samples_MalwareAnalysis_Test_shell {
   meta:
      description = "Test - file shell.exe"
      author = "yarGen Rule Generator"
      reference = "https://github.com/Neo23x0/yarGen"
      date = "2023-08-02"
      hash1 =
"bd841e796feed0088ae670284ab991f212cf709f2391310a85443b2ed1312bda"
   strings:
      $x1 = "C:\\Windows\\System32\\cmd.exe" fullword ascii
      $s2 = "http://ms-windows-update.com/svchost.exe" fullword ascii
      $s3 = "C:\\Windows\\System32\\notepad.exe" fullword ascii
      $s4 = "/k ping 127.0.0.1 -n 5" fullword ascii
```

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```
        $s5 = "iuqerfsodp9ifjaposdfjhgosurijfaewrwergwea.com" fullword ascii
        $s6 = "  VirtualQuery failed for %d bytes at address %p" fullword
ascii
        $s7 = "[-] Error code is : %lu" fullword ascii
        $s8 = "C:\\Program Files\\VMware\\VMware Tools\\" fullword ascii
        $s9 = "Failed to open the registry key." fullword ascii
        $s10 = "  VirtualProtect failed with code 0x%x" fullword ascii
        $s11 = "Connection sent to C2" fullword ascii
        $s12 = "VPAPAPAPI" fullword ascii
        $s13 = "AWAVAUATVSH" fullword ascii
        $s14 = "45.33.32.156" fullword ascii
        $s15 = "  Unknown pseudo relocation protocol version %d." fullword
ascii
        $s16 = "AQAPRQVH1" fullword ascii
        $s17 = "connect" fullword ascii /* Goodware String - occured 429
times */
        $s18 = "socket" fullword ascii /* Goodware String - occured 452
times */
        $s19 = "tSIcK<L" fullword ascii
        $s20 = "Windows-Update/7.6.7600.256 %s" fullword ascii
    condition:
        uint16(0) == 0x5a4d and filesize < 60KB and
        1 of ($x*) and 4 of them
}
```

We can review the rule and modify it as necessary, adding more strings and conditions to enhance its reliability and effectiveness.

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Detecting Malware Using Yara Rules

We can then use this rule to scan a directory as follows.

```
yara /home/htb-student/yarGen-0.23.4/yargen_rules.yar /home/htb-
student/Samples/MalwareAnalysis/
home_htb_student_Samples_MalwareAnalysis_Test_shell /home/htb-
student/Samples/MalwareAnalysis//shell.exe
```

We will notice that `shell.exe` is returned!

Below are some references for YARA rules:

- Yara documentation : https://yara.readthedocs.io/en/stable/writingrules.html
- Yara resources - https://github.com/InQuest/awesome-yara

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- The DFIR Report - https://github.com/The-DFIR-Report/Yara-Rules

Sigma

`Sigma` is a comprehensive and standardized rule format extensively used by security analysts and `Security Information and Event Management (SIEM)` systems. The objective is to detect and identify specific patterns or behaviors that could potentially signify security threats or events. The standardized format of `Sigma` rules enables security teams to define and disseminate detection logic across diverse security platforms.

To construct a `Sigma` rule based on certain actions - for instance, dropping a file in a temporary location - we can devise a sample rule along these lines.

```
title: Suspicious File Drop in Users Temp Location
status: experimental
description: Detects suspicious activity where a file is dropped in the
temp location

logsource:
    category: process_creation
detection:
    selection:
        TargetFilename:
            - '*\\AppData\\Local\\Temp\\svchost.exe'
    condition: selection
    level: high

falsepositives:
    - Legitimate exe file drops in temp location
```

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In this instance, the rule is designed to identify when the file `svchost.exe` is dropped in the `Temp` directory.

During analysis, it's advantageous to have a system monitoring agent operating continuously. In this context, we've chosen `Sysmon` to gather the logs. `Sysmon` is a powerful tool that captures detailed event data and aids in the creation of `Sigma` rules. Its log categories encompass process creation (`EventID 1`), network connection (`EventID 3`), file creation (`EventID 11`), registry modification (`EventID 13`), among others. The scrutiny of these events assists in pinpointing indicators of compromise (`IOC` s) and understanding behavior patterns, thus facilitating the crafting of effective detection rules.

For instance, `Sysmon` has collected logs such as `process creation` , `process access` , `file creation` , and `network connection` , among others, in response to the activities conducted by `shell.exe` . This compiled information proves instrumental in enhancing our

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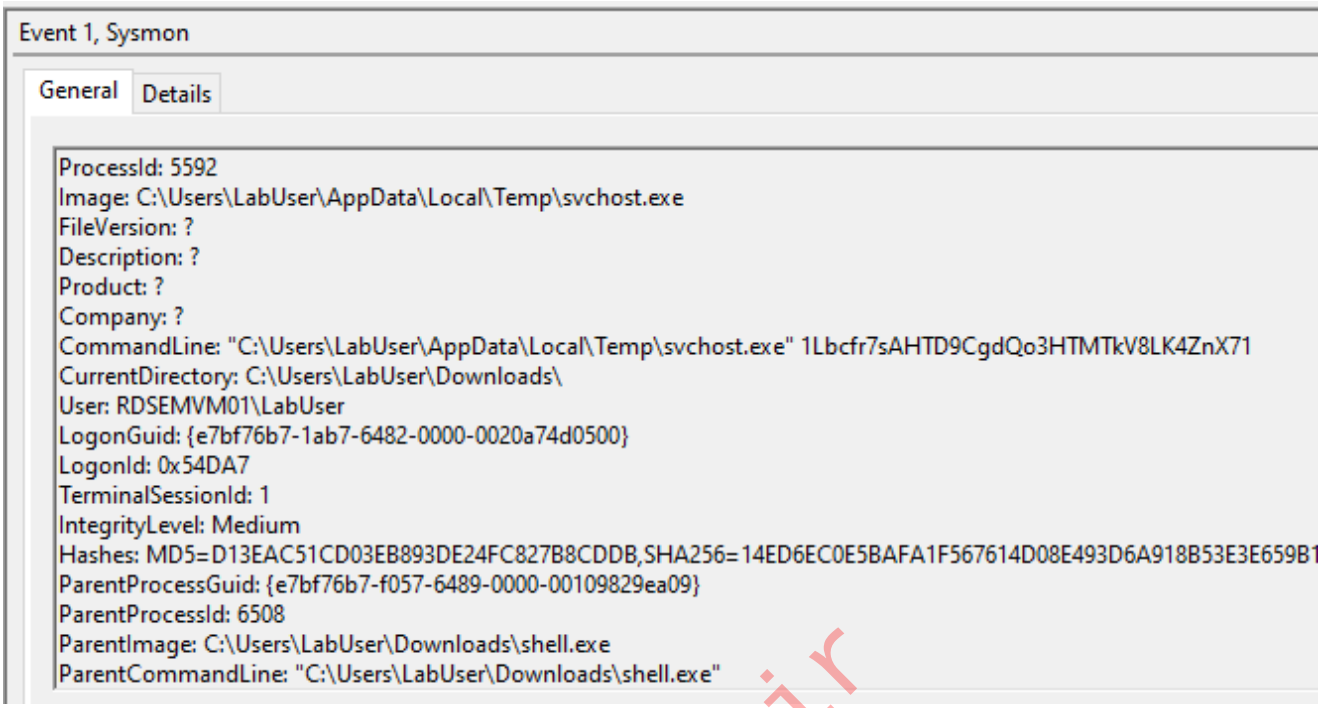
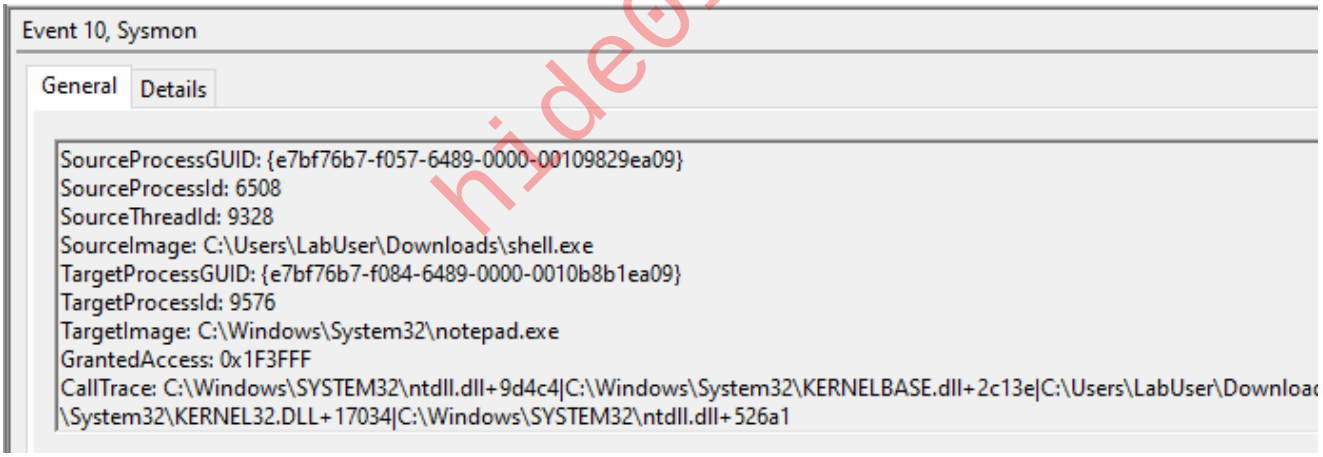
understanding of the sample's behavior and developing more precise and effective detection rules.

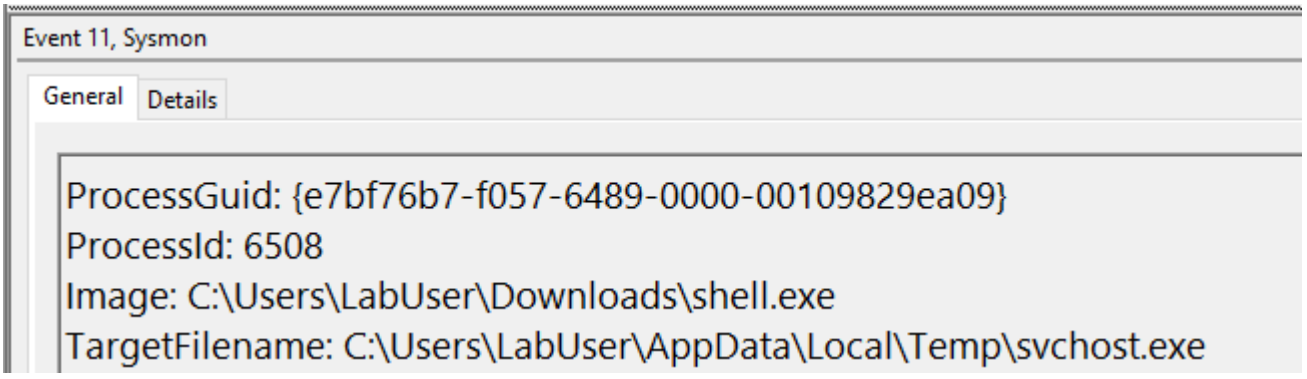
Process Create Logs:



Process Access Logs (not configured in the Windows targets of this module):



File Creation Logs:



Network Connection Logs:

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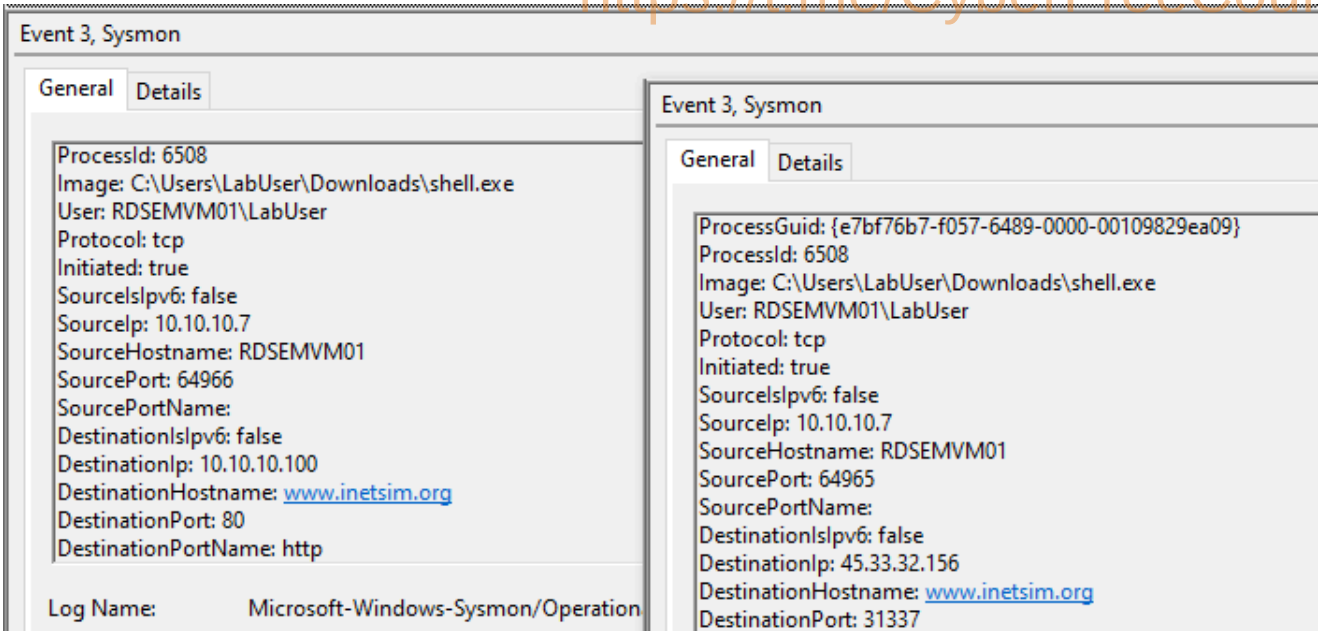

Below are some references for Sigma rules:

- Sigma documentation : https://github.com/SigmaHQ/sigma/wiki/Specification
- Sigma resources - https://github.com/SigmaHQ/sigma/tree/master/rules
- The DFIR Report - https://github.com/The-DFIR-Report/Sigma-Rules/tree/main/rules

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Skills Assessment

A cybersecurity incident has been announced. Incident Responders have swiftly collected a malware sample (`apple.exe`) from the implicated machine. Your responsibility now is to perform comprehensive analysis of this sample, conducting static, dynamic, and code analysis, in an effort to unravel as much as possible about the malware's functioning and modus operandi.

Download `additional_samples.zip` from this module's resources (available at the upper right corner) and transfer the .zip file to this section's target. Unzip `additional_samples.zip` (password: `infected`) and start analyzing `apple.exe` . Then, answer the questions below.