CST3510

Memory Analysis

Windows Memory Analysis

Group 10

Contents

1.Introduction

Windows memory analysis is a vital tool in digital forensics, enabling investigators to uncover valuable information hidden within a system's volatile memory (RAM). By examining memory dumps, analysts can gain insight into active processes, network connections, system configurations, and detect traces of malicious activity that may otherwise go unnoticed. This type of analysis is crucial for understanding the exact state of a system at the time of a security incident, allowing investigators to piece together the events leading up to an intrusion and capture evidence that may be admissible in court.[1]

Volatile memory contains transient data that is lost upon system shutdown, including information about running processes, loaded modules, open files, and network connections. [2]. Analysing this data provides a snapshot of the system's operational state, which is essential for incident response and forensic investigations. Memory analysis can reveal advanced threats such as rootkits or fileless malware that reside solely in memory and do not leave traces on the hard drive. This makes memory forensics an indispensable part of a comprehensive cybersecurity strategy.

In this report, we focus on examining an infected Windows memory sample to detect any unauthorized changes and signs of malicious activity. Our analysis centres on identifying hidden processes, potential network-based threats, and artifacts indicating the presence of malware. We utilize the Volatility Framework, a tool designed for memory analysis, to conduct our investigation effectively.

Our methodology begins with the acquisition of two memory dumps: a clean baseline sample and an infected sample. Using the winpmem.exe tool, we captured these memory dumps to enable a comparative analysis. This approach is essential for pinpointing anomalies, deviations, and potential indicators of compromise within the infected sample.

To ensure a systematic and comprehensive examination, the investigation is divided into specific focus areas. Each team member specializes in analysing critical components, such as Analysis of Objects, Pools, and Processes, Analysis of Network and Services, Analysis of Kernel and Registry, Analysis of File System and Timelines, and Intrusion Detection. This targeted approach enables us to thoroughly assess each potential vector of compromise while contributing to an overarching understanding of the infection’s impact on the system. The table below mentions the details of the group members and their roles.

1.2 Group Details

	Student ID	Topic area
Group No. 10	M00857972	Analysis of Objects, Pools, and Processes
	M00874013	Analysis of Network and Services
	M00883220	Analysis of Kernel and Registry
	M00870211	Analysis of File System and Timelines
	M00872751	Intrusion Detection

Table 1: Group Details.

1.3 Tools and Software for memory acquisition

Before initiating the memory analysis of the infected dump, thorough planning and preparation were crucial. This involved setting up appropriate hardware and software tools to ensure the acquisition and analysis processes were conducted effectively and securely.

Hardware

A high-performance host machine was used to carry out the analysis of the infected memory dump. This system provided the computational resources and storage capacity needed for smooth execution of the analysis tools and management of virtual environments. The host machine's specifications are detailed in Table 2 below.

Component	Details
Device Name	Legion Pro i5
Processor	13th Gen Intel(R) Core(TM) i7-13700HX 2.10 GHz
Installed RAM	32 GB
System Type	64-bit Operating System, x64-based CPU
Operating System	Windows 11 Home
OS Version	23H2
OS Build	22631.4460

Table 2 Component Details

Software

A variety of software tools were installed to support memory acquisition and analysis. These tools ensured a secure and efficient workflow. Table 3 outlines the primary software used on the host machine.

Software	Version	Purpose
Oracle VirtualBox	7.0.22	Virtualization platform for creating and managing VMs
winpmem.exe	Latest	Memory acquisition tool for creating memory dumps
Volatility Framework	2.6.1	Memory analysis tool for examining volatile artifacts
Hash Verification Tools	MD5 & SHA-256	Ensuring data integrity during acquisition and transfer

Table 3 Software Details

Virtual machine configuration

Oracle VirtualBox was utilized to create and manage virtual machines, providing an isolated environment for the analysis to prevent any impact on the host system. Within VirtualBox, a virtual machine named *MemoryAnalysis* was set up to provide a secure and controlled environment for conducting memory analysis.

Component	Details
Name	MemoryAnalysis
Operating System	Linux
Version	Debian (64-bit)
Distribution	Kali Linux
Release	2024
Virtual Machine 2 Name	WindowsXP_CleanDump
Operating System	Windows
Version	Windows XP
Purpose	Clean dump environment
Virtualization Tool	Oracle VirtualBox
Purpose in VirtualBox	To create a clean dump in the virtual machine

Table 4 Component details

Kali Linux was used as it comes with a wide range of built-in tools for forensic and security analysis. The operating system supports Volatility and other analysis tools needed for this project, making it a practical choice for memory forensics.

The MemoryAnalysis virtual machine was configured to meet the specific requirements of the project to ensure efficient and secure operation. It was allocated 8 GB of RAM to support smooth performance when running tools like Volatility and handling resource-intensive tasks. Additionally, 6 CPU cores were dedicated to the virtual machine to provide sufficient processing power for memory analysis and related activities. A virtual hard drive was set up to store memory dumps, analysis results, and logs, ensuring ample space for all necessary data.

Profile identification

With the virtual environment fully configured and equipped with the necessary tools and resources, we are now prepared to proceed with profile identification of the infected dump. After logging into the MemoryAnalysis virtual machine, we mounted the shared folder testShare in the home directory, confirming its presence with the ls command. Navigating to the /media/testShare directory, we accessed the infected memory dump file and imported it into the virtual machine for analysis.

It was essential to identify the correct operating system profile of the infected sample to ensure accurate analysis. This ensures that the Volatility Framework interprets the memory structures correctly. We used the imageinfo command provided by Volatility to determine the appropriate profile.

Command: volatility -f cw2_Machine4Infected.dump imageinfo

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump imageinfo
Volatility Foundation Volatility Framework 2.6.1
INFO    : volatility.debug    : Determining profile based on KDBG search...
          Suggested Profile(s) : WinXPSP2x86, WinXPSP3x86 (Instantiated with WinXPSP2x86)
                     AS Layer1 : IA32PagedMemoryPae (Kernel AS)
                     AS Layer2 : FileAddressSpace (/media/testShare/cw2_Machine4Infected.dump)
                      PAE type : PAE
                           DTB : 0x2fe000L
                          KDBG : 0x80545ae0L
          Number of Processors : 1
     Image Type (Service Pack) : 3
                KPCR for CPU 0 : 0xffdff000L
             KUSER_SHARED_DATA : 0xffdf0000L
           Image date and time : 2012-07-22 02:45:08 UTC+0000
     Image local date and time : 2012-07-21 22:45:08 -0400
```

Figure 1 volatility command for infected dump

The output provided by the imageinfo plugin included several key details about the memory dump:

- Suggested Profiles: WinXPSP2x86, WinXPSP3x86
- PAE Type: PAE (Physical Address Extension)

- Image Type (Service Pack): 3
- Image Type (Service Pack): 2
- Number of Processors: 1
- Image Date and Time: 2012-07-22 02:45:08 UTC+0000

Based on the output, the suggested profiles are WinXPSP2x86 and WinXPSP3x86. Among these, WinXPSP3x86 was selected as the appropriate profile because the Image Type specifically indicates Service Pack 3. This information is critical because using an incorrect profile would lead to inaccurate plugin results or failure to parse the memory artifacts.

After successfully identifying and verifying the correct profile as **WinXPSP3x86** for the infected memory dump, we will now proceed with the memory acquisition of the clean dump. This step is essential to establish a baseline for comparison against the infected dump. By acquiring a clean memory sample from a system with the same configuration and operating system, we can identify any anomalies or deviations present in the infected dump during the subsequent analysis.

2. Memory Acquisition

Memory acquisition is the process of capturing the contents of a computer's volatile memory (RAM) for analysis in digital forensics. This practice is crucial because RAM contains transient data that is lost upon shutdown, including running processes, active network connections, open files, encryption keys, and traces of malicious activity that may not be present on the hard drive [3]. By acquiring and analysing this data, forensic investigators can gain valuable insights into the state of a system at a specific point in time, which is essential for incident response, malware analysis, and understanding the actions of potential attackers.[4]

Importance of Memory Acquisition

Memory acquisition plays a pivotal role in Preservation of Volatile Data: RAM holds data that is not permanently written to disk. Acquiring memory ensures that this ephemeral information is preserved before it is lost upon system shutdown or restart, providing a more complete picture of system activity. [5]

Methodology for Memory Acquisition

To conduct the memory acquisition, we used a Windows XP virtual environment configured in Oracle VirtualBox. A virtual machine provides a controlled and isolated environment, reducing the risk of affecting the host system during the acquisition process. We configured a shared folder named test share to facilitate data transfer between the host machine and the virtual machine. This setup allowed us to transfer tools and the acquired memory dump securely and efficiently.

Memory acquisition of clean dump

Once logged into the Administrator account, open "My Network Places" from the Windows Explorer. Here, navigate through the "Entire Network" to locate "VirtualBox Shared Folders" and then select the configured shared folder (`test share`). The shared file is visible and accessible within this folder.

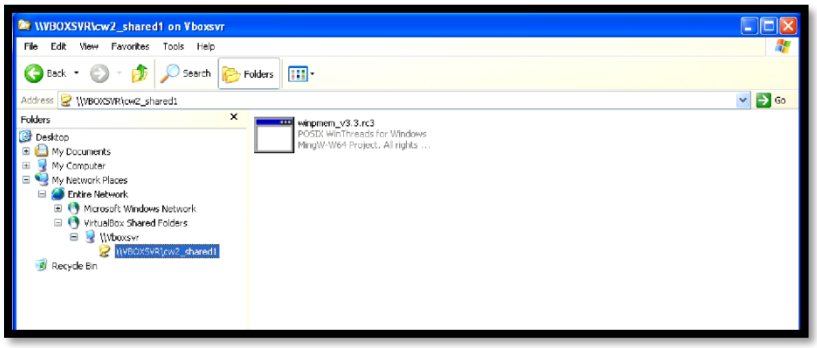


Figure 2: Memory acquisition shared folder.

Executing the Memory Acquisition:

Using the Command Prompt, we ran winpmem_v3.3.rc3.exe, which captured the system's memory state to a raw file named windowCW2s.raw saved on the local C: drive. This file serves as a complete memory snapshot of the current state of the virtual machine. The following command was executed:

winpmem_v3.3.rc3.exe -dd -o windowCW2s.raw --format raw --volume_format raw

The -dd option instructs the tool to acquire the physical memory of the system, capturing the entire contents of the RAM. The -o windowCW2s.raw option specifies the output file name, ensuring that the memory dump is saved as windowCW2s.raw for easy identification and further analysis. The --format raw flag ensures that the output is saved in a raw format, which is compatible with most forensic tools, including the Volatility Framework. Additionally, the --volume_format raw parameter specifies the format of the volume, maintaining consistency with the raw output and ensuring the integrity and compatibility of the memory dump across forensic platforms.

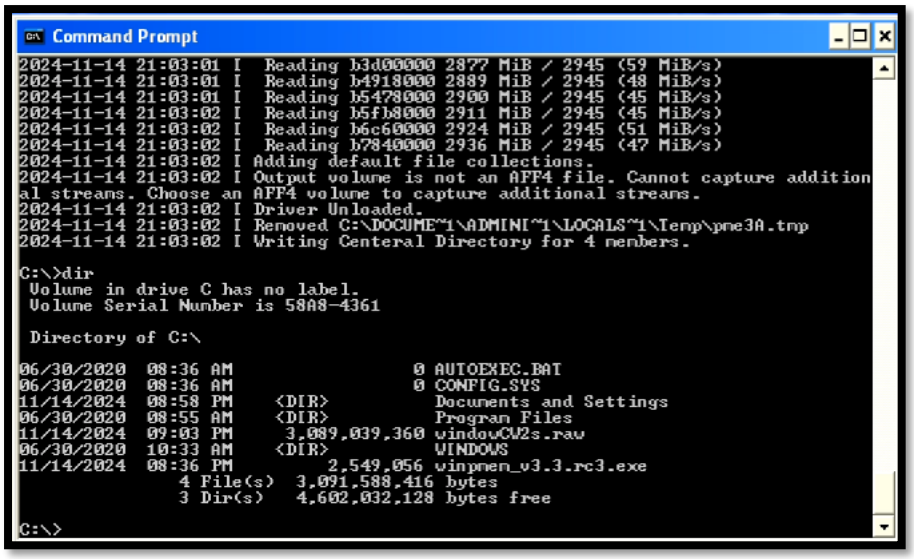


Figure 3:The output of the Memory acquisition Executing.

Verifying dump creation

After running the memory acquisition tool winpmem, the memory dump was successfully created and saved to the local **C:** drive of the Windows XP virtual machine. The dump file, named windowCW2s.raw, contains a complete snapshot of the system's RAM at the time of acquisition. Storing the dump on the C: drive ensures that the data remains within the controlled environment of the virtual machine, preserving the integrity and confidentiality of the forensic evidence.

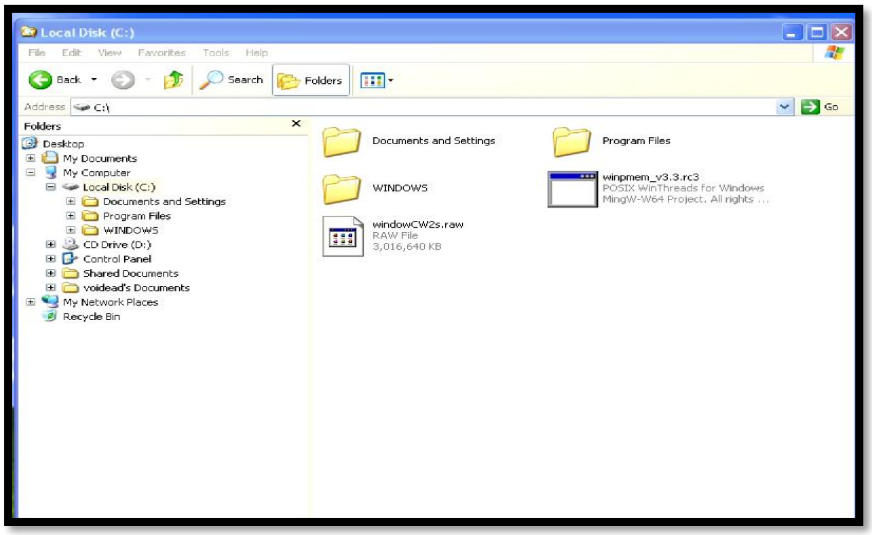


Figure 4: verification that the clean dump been created.

Transferring the Memory Dump to the Shared Folder

After verification, windowCW2s.raw was copied to the shared folder \\VBOXSVR\cw2_shared1. This setup allowed the dump to be accessed from the host system, specifically Kali Linux, for further forensic analysis.

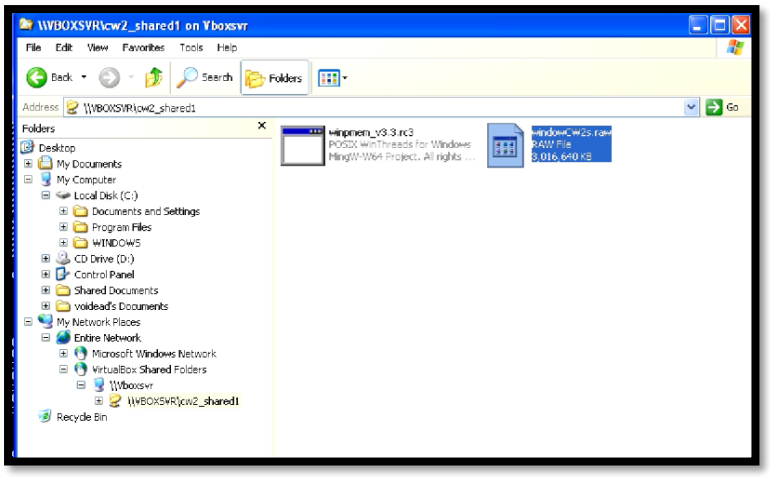


Figure 5: Confirming that the clean dump is transferred to the shared folder.

Verifying the Clean Dump in Kali Linux

After successfully creating the clean memory dump in the Windows XP environment, we transitioned to Kali Linux to verify the integrity of the dump and ensure it was created without errors. We navigated to the directory /media/testShare, which is the mount point for the shared folder where the clean dump was stored. Executing the ls command displayed the files within this folder, including the clean dump named windowCW2s.raw, confirming its presence. This verification step is crucial to ensure that the memory dump is available for analysis in our forensic environment.

Figure 6: ls command under the shared folder in kali.

Profile Identification of clean dump

To analyse the clean dump accurately, it was necessary to identify its operating system profile. This step ensures that the correct plugins and settings are used during analysis with the Volatility Framework. We utilized the imageinfo plugin to determine the profile associated with the clean dump.

Command Executed:

volatility -f windowCW2s.raw imageinfo

Explanation of the Command:

- **volatility**: Invokes the Volatility Framework for memory analysis.
- **-f windowCW2s.raw**: Specifies the memory dump file to analyse.
- **imageinfo**: A plugin that analyses the memory image to suggest the most appropriate operating system profiles.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw imageinfo
Volatility Foundation Volatility Framework 2.6.1
INFO    : volatility.debug    : Determining profile based on KDBG search...
          Suggested Profile(s) : WinXPSP2x86, WinXPSP3x86 (Instantiated with WinXPSP2x86)
                     AS Layer1 : IA32PagedMemoryPae (Kernel AS)
                     AS Layer2 : FileAddressSpace (/media/testShare/windowCW2s.raw)
                      PAE type : PAE
                           DTB : 0x34c000L
                          KDBG : 0x8054d2e0L
          Number of Processors : 4
     Image Type (Service Pack) : 3
                KPCR for CPU 0 : 0xffdff000L
                KPCR for CPU 1 : 0xbab50000L
                KPCR for CPU 2 : 0xbab58000L
                KPCR for CPU 3 : 0xbab60000L
             KUSER_SHARED_DATA : 0xffdf0000L
           Image date and time : 2024-11-14 15:32:06 UTC+0000
     Image local date and time : 2024-11-14 21:02:06 +0530
```

Figure 7: Imageinfo command to view the Profiles of the clean dump.

Based on the output, the suggested profiles are WinXPSP2x86 and WinXPSP3x86. Among these, WinXPSP3x86 was selected as the appropriate profile because the Image Type explicitly indicates Service Pack 3. Additionally, the correct interpretation of the KDBG address (0x8054d2e0) and the PAE type further confirms the accuracy of the profile.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 pslist
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  Name                    PID   PPID   Thds     Hnds   Sess  Wow64 Start                          Exit
---------- -------------------- ------ ------ ------ -------- ------ ------ ------------------------------ ------------------------------
0x8a25c830 System                    4      0     66      266 ------      0
0x8a012c08 smss.exe                560      4      3       19 ------      0 2024-11-14 09:36:51 UTC+0000
0x8a0c1020 csrss.exe               616    560     12      368      0      0 2024-11-14 09:36:52 UTC+0000
0x89fe47e8 winlogon.exe            640    560     20      560      0      0 2024-11-14 09:36:52 UTC+0000
0x89ff5c08 services.exe            684    640     17      305      0      0 2024-11-14 09:36:52 UTC+0000
0x8a021da0 lsass.exe               696    640     22      367      0      0 2024-11-14 09:36:52 UTC+0000
0x89cb6518 VBoxService.exe         868    684      9      130      0      0 2024-11-14 09:36:52 UTC+0000
0x89ffe8e0 svchost.exe             920    684     22      237      0      0 2024-11-14 15:06:54 UTC+0000
0x8a004450 svchost.exe            1000    684     10      266      0      0 2024-11-14 15:06:54 UTC+0000
0x8a0121c0 svchost.exe            1096    684     59     1161      0      0 2024-11-14 15:06:54 UTC+0000
0x89c177a8 svchost.exe            1244    684      5       83      0      0 2024-11-14 15:06:54 UTC+0000
0x8a016538 svchost.exe            1348    684     11      185      0      0 2024-11-14 15:06:54 UTC+0000
0x89bebd00 spoolsv.exe            1568    684     12      129      0      0 2024-11-14 15:06:56 UTC+0000
0x8a0a3500 svchost.exe            1684    684      4      111      0      0 2024-11-14 15:07:03 UTC+0000
0x8a037a78 IPROSetMonitor.        1744    684      2       44      0      0 2024-11-14 15:07:03 UTC+0000
0x8a06b5a8 alg.exe                 404    684      6      111      0      0 2024-11-14 15:07:07 UTC+0000
```

Figure 8: showing the clean dump was created successfully.

To validate the correct functioning of the selected profile and identify active processes in the clean memory dump, the pslist plugin was executed using the Volatility Framework. The pslist command traverses the EPROCESS linked list maintained by the Windows kernel to enumerate processes running at the time the memory image was captured.[6] This step confirms that the WinXPSP3x86 profile accurately interprets the memory structures within the clean dump. The output lists standard system processes, including System, smss.exe, csrss.exe, winlogon.exe, services.exe, and multiple instances of svchost.exe, which are critical to the normal operation of a Windows XP system. Additionally, user-specific processes such as VBoxService.exe and alg.exe were identified, indicating that the clean system was functioning as expected without anomalies. The successful execution of pslist reinforces that the profile selection is

correct and serves as a reliable baseline for comparison against the infected memory dump.

Validating the Integrity of the Infected Dump

Finally, we verified the integrity of the infected memory dump by comparing its hash value against the reference sample provided by our lab instructor. Utilizing the `md5sum` command, we computed the hash for the infected dump, as illustrated in Image 12a. The generated hash matched the reference value, confirming that the correct sample was utilized, and its integrity remained uncompromised.

```
kali@kali:/media/testShare$ md5sum cw2_Machine4Infected.dump
7494f3b77db1525c1974f5380744ae46  cw2_Machine4Infected.dump
kali@kali:/media/testShare$
```

Figure 9: the hashes of the infected dump using md5sum

The figure below shows the MD5sum of the infected dump provided by our lab tutor.

Infected Sample 4 (md5: 7494f3b77db1525c1974f5380744ae46)
https://drive.google.com/file/d/1B43QQs6-0ZYO4rN155NFDo6JFJI-MHGb/view?usp=share_link

Figure 10: the hashes of the sample which were given

3.Pre–analysis

To effectively analyse the memory dumps and identify potential signs of malicious activity, we conducted a comparative analysis of the process lists from both the clean and infected memory dumps. This approach allows us to establish a baseline of normal system activity and detect anomalies that may indicate a compromise. Commands used for pre analysis.

Command Component	Explanation
volatility	Invokes the Volatility Framework for memory analysis.
-f <memory_dump>	Specifies the memory dump file to analyze. For example: windowCW2s.raw (clean dump) or cw2_Machine4Infected.dump (infected dump).
--profile=<profile>	Specifies the appropriate operating system profile for the memory dump, such as WinXPSP3x86.
imageinfo	Analyzes the memory image to suggest the most appropriate operating system profiles.
pslist	Lists all active processes, including their PIDs, PPIDs, thread count, handle count, and start times.
pstree	Displays a hierarchical view of processes, showing parent-child relationships.

--output=dot	An additional option for the pstree plugin that formats the process tree output into DOT format for graphical visualization.
--output-file=<filename>	Specifies the name of the DOT file to save the output (e.g., clean_dump_dot.dot or infected_dump_dot.dot).
psscan	Scans for both visible and hidden processes in the memory dump, including terminated ones.
psxview	Verifies process visibility across multiple views to detect hidden processes or inconsistencies.
privs	Displays the privileges assigned to each process, highlighting elevated or unusual privileges.

Table 5: Volatility Command Components and Their Explanations

Gathering Process Lists

We began by extracting the process lists from the clean and infected memory dumps using the pslist plugin of the Volatility Framework. The pslist command enumerates active processes by walking the EPROCESS linked list maintained by the Windows kernel.[7] It provides a snapshot of all active processes, including their Process IDs (PID), Parent Process IDs (PPID), thread counts, handle counts, and other relevant information.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 pslist
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  Name                    PID   PPID   Thds     Hnds   Sess  Wow64 Start                          Exit
---------- -------------------- ------ ------ ------ -------- ------ ------ ------------------------------ ------------------------------
0x8a25c830 System                    4      0     66      266 ------      0
0x8a012c08 smss.exe                560      4      3       19 ------      0 2024-11-14 09:36:51 UTC+0000
0x8a0c1020 csrss.exe               616    560     12      368      0      0 2024-11-14 09:36:52 UTC+0000
0x89fe47e8 winlogon.exe            640    560     20      560      0      0 2024-11-14 09:36:52 UTC+0000
0x89ff5c08 services.exe            684    640     17      305      0      0 2024-11-14 09:36:52 UTC+0000
0x8a021da0 lsass.exe               696    640     22      367      0      0 2024-11-14 09:36:52 UTC+0000
0x89cb6518 VBoxService.exe         868    684      9      130      0      0 2024-11-14 09:36:52 UTC+0000
0x89ffe8e0 svchost.exe             920    684     22      237      0      0 2024-11-14 15:06:54 UTC+0000
0x8a004450 svchost.exe            1000    684     10      266      0      0 2024-11-14 15:06:54 UTC+0000
0x8a0121c0 svchost.exe            1096    684     59     1161      0      0 2024-11-14 15:06:54 UTC+0000
0x89c177a8 svchost.exe            1244    684      5       83      0      0 2024-11-14 15:06:54 UTC+0000
0x8a016538 svchost.exe            1348    684     11      185      0      0 2024-11-14 15:06:54 UTC+0000
0x89bebd00 spoolsv.exe            1568    684     12      129      0      0 2024-11-14 15:06:56 UTC+0000
0x8a0a3500 svchost.exe            1684    684      4      111      0      0 2024-11-14 15:07:03 UTC+0000
0x8a037a78 IPROSetMonitor.        1744    684      2       44      0      0 2024-11-14 15:07:03 UTC+0000
0x8a06b5a8 alg.exe                 404    684      6      111      0      0 2024-11-14 15:07:07 UTC+0000
0x89b02ae8 wscntfy.exe            1256   1096      1       31      0      0 2024-11-14 15:15:40 UTC+0000
0x89c948c8 explorer.exe            436    416     14      502      0      0 2024-11-14 15:15:40 UTC+0000
0x89b4da28 VBoxTray.exe            252    436     13      126      0      0 2024-11-14 15:15:41 UTC+0000
0x89baada0 wuauclt.exe             176   1096      3      112      0      0 2024-11-14 15:15:42 UTC+0000
0x89d08020 cmd.exe                 180   1096      1       33      0      0 2024-11-14 15:28:44 UTC+0000
0x89b7dda0 winpmem_v3.3.rc         860    180      3       36      0      0 2024-11-14 15:32:06 UTC+0000
kali@kali:/media/testShare$
```

Figure 11: The output of pslist of the clean dump.

In the output, it shows the clean dump contains expected system processes, such as System, smss.exe, csrss.exe, winlogon.exe, services.exe, and multiple instances of **svchost.exe**, along with user processes like **cmd.exe, explorer.exe**, and **winpmem_v3.3.rc.** The process starts times follow a logical sequence, with the System process (PID: 4) starting first at **09:36:51 UTC**, followed closely by critical processes like smss.exe and csrss.exe. User processes such as cmd.exe and winpmem_v3.3.rc start later, around **15:32:06 UTC**, coinciding with the memory acquisition. The orderly start times indicate a stable and expected system state. Same command was used for infected dump as shown in the screenshot below.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 pslist
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  Name                    PID   PPID   Thds     Hnds   Sess  Wow64 Start                          Exit
---------- -------------------- ------ ------ ------ -------- ------ ------ ------------------------------ ------------------------------
0x823c89c8 System                    4      0     53      240 ------      0
0x822f1020 smss.exe                368      4      3       19 ------      0 2012-07-22 02:42:31 UTC+0000
0x822a0598 csrss.exe               584    368      9      326      0      0 2012-07-22 02:42:32 UTC+0000
0x82298700 winlogon.exe            608    368     23      519      0      0 2012-07-22 02:42:32 UTC+0000
0x81e2ab28 services.exe            652    608     16      243      0      0 2012-07-22 02:42:32 UTC+0000
0x81e2a3b8 lsass.exe               664    608     24      330      0      0 2012-07-22 02:42:32 UTC+0000
0x82311360 svchost.exe             824    652     20      194      0      0 2012-07-22 02:42:33 UTC+0000
0x81e29ab8 svchost.exe             908    652      9      226      0      0 2012-07-22 02:42:33 UTC+0000
0x823001d0 svchost.exe            1004    652     64     1118      0      0 2012-07-22 02:42:33 UTC+0000
0x821dfda0 svchost.exe            1056    652      5       60      0      0 2012-07-22 02:42:33 UTC+0000
0x82295650 svchost.exe            1220    652     15      197      0      0 2012-07-22 02:42:35 UTC+0000
0x821dea70 explorer.exe           1484   1464     17      415      0      0 2012-07-22 02:42:36 UTC+0000
0x81eb17b8 spoolsv.exe            1512    652     14      113      0      0 2012-07-22 02:42:36 UTC+0000
0x81e7bda0 reader_sl.exe          1640   1484      5       39      0      0 2012-07-22 02:42:36 UTC+0000
0x820e8da0 alg.exe                 788    652      7      104      0      0 2012-07-22 02:43:01 UTC+0000
0x821fcda0 wuauclt.exe            1136   1004      8      173      0      0 2012-07-22 02:43:46 UTC+0000
0x8205bda0 wuauclt.exe            1588   1004      5      132      0      0 2012-07-22 02:44:01 UTC+0000
kali@kali:/media/testShare$
```

Figure 12: The output of pslist of the infected dump.

The output from infected dump shows the infected dump contains expected system processes such as System, smss.exe, csrss.exe, winlogon.exe, services.exe, and multiple instances of svchost.exe, along with additional processes like reader_sl.exe and multiple wuauclt.exe instances. The process starts times begin with the System process (PID: 4) at **02:42:31 UTC**, followed immediately by critical processes like smss.exe, csrss.exe, and winlogon.exe within the next few seconds. User processes, such as **explorer.exe**, **wuauclt.exe, and reader_sl.exe,** start slightly later but remain within a close time frame, indicating no significant delays. Overall, the process starts times in the infected dump appear sequential and consistent with typical system behaviour.

Next, we will examine the process tree using the pstree plugin. The pstree output provides a hierarchical view of processes, showing the parent-child relationships between them.[8] This analysis will help us identify which processes were launched by others, providing a clearer understanding of the process flow and system activity.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 pstree
Volatility Foundation Volatility Framework 2.6.1
Name                                                  Pid   PPid   Thds   Hnds Time
-------------------------------------------------- ------ ------ ------ ------ ----
 0x8a25c830:System                                      4      0     66    266 1970-01-01 00:00:00 UTC+0000
. 0x8a012c08:smss.exe                                 560      4      3     19 2024-11-14 09:36:51 UTC+0000
.. 0x89fe47e8:winlogon.exe                            640    560     20    560 2024-11-14 09:36:52 UTC+0000
... 0x89ff5c08:services.exe                           684    640     17    305 2024-11-14 09:36:52 UTC+0000
.... 0x8a06b5a8:alg.exe                               404    684      6    111 2024-11-14 15:07:07 UTC+0000
.... 0x89ffe8e0:svchost.exe                           920    684     22    237 2024-11-14 15:06:54 UTC+0000
.... 0x89bebd00:spoolsv.exe                          1568    684     12    129 2024-11-14 15:06:56 UTC+0000
.... 0x89c177a8:svchost.exe                          1244    684      5     83 2024-11-14 15:06:54 UTC+0000
.... 0x8a016538:svchost.exe                          1348    684     11    185 2024-11-14 15:06:54 UTC+0000
.... 0x8a0121c0:svchost.exe                          1096    684     59   1161 2024-11-14 15:06:54 UTC+0000
..... 0x89baada0:wuauclt.exe                          176   1096      3    112 2024-11-14 15:15:42 UTC+0000
..... 0x89d08020:cmd.exe                              180   1096      1     33 2024-11-14 15:28:44 UTC+0000
...... 0x89b7dda0:winpmem_v3.3.rc                     860    180      3     36 2024-11-14 15:32:06 UTC+0000
..... 0x89b02ae8:wscntfy.exe                         1256   1096      1     31 2024-11-14 15:15:40 UTC+0000
.... 0x8a037a78:IPROSetMonitor.                      1744    684      2     44 2024-11-14 15:07:03 UTC+0000
.... 0x89cb6518:VBoxService.exe                       868    684      9    130 2024-11-14 09:36:52 UTC+0000
.... 0x8a004450:svchost.exe                          1000    684     10    266 2024-11-14 15:06:54 UTC+0000
.... 0x8a0a3500:svchost.exe                          1684    684      4    111 2024-11-14 15:07:03 UTC+0000
... 0x8a021da0:lsass.exe                              696    640     22    367 2024-11-14 09:36:52 UTC+0000
.. 0x8a0c1020:csrss.exe                               616    560     12    368 2024-11-14 09:36:52 UTC+0000
 0x89c948c8:explorer.exe                              436    416     14    502 2024-11-14 15:15:40 UTC+0000
. 0x89b4da28:VBoxTray.exe                             252    436     13    126 2024-11-14 15:15:41 UTC+0000
```

Figure 13 The output of pstree of the clean dump.

The output of the pstree plugin for the clean dump provides a hierarchical view of processes running on the system at the time of acquisition. The root process is **System (PID: 4)**, which is responsible for initiating all other processes. Key system processes such as smss.exe, winlogon.exe, services.exe, and multiple instances of svchost.exe are visible, with **services.exe (PID: 684)** acting as the parent for many critical processes like **alg.exe, spoolsv.exe, VBoxService.exe**, and additional **svchost.exe** instances.

User processes like **cmd.exe, explorer.exe, and winpmem_v3.3.rc** are also present, showing normal user activity, particularly during memory acquisition. Processes like **VBoxTray.exe** and **VBoxService.exe** reflect the virtual machine environment, which is expected. Overall, the hierarchy appears structured and typical for a clean Windows XP system, with no immediate signs of unusual or unexpected parent-child relationships. Next, we will use the same command for the infected dump as shown in the screenshot below.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 pstree
Volatility Foundation Volatility Framework 2.6.1
Name                                                  Pid   PPid   Thds   Hnds Time
-------------------------------------------------- ------ ------ ------ ------ ----
 0x823c89c8:System                                      4      0     53    240 1970-01-01 00:00:00 UTC+0000
. 0x822f1020:smss.exe                                 368      4      3     19 2012-07-22 02:42:31 UTC+0000
.. 0x82298700:winlogon.exe                            608    368     23    519 2012-07-22 02:42:32 UTC+0000
... 0x81e2ab28:services.exe                           652    608     16    243 2012-07-22 02:42:32 UTC+0000
.... 0x821dfda0:svchost.exe                          1056    652      5     60 2012-07-22 02:42:33 UTC+0000
.... 0x81eb17b8:spoolsv.exe                          1512    652     14    113 2012-07-22 02:42:36 UTC+0000
.... 0x81e29ab8:svchost.exe                           908    652      9    226 2012-07-22 02:42:33 UTC+0000
.... 0x823001d0:svchost.exe                          1004    652     64   1118 2012-07-22 02:42:33 UTC+0000
..... 0x8205bda0:wuauclt.exe                         1588   1004      5    132 2012-07-22 02:44:01 UTC+0000
..... 0x821fcda0:wuauclt.exe                         1136   1004      8    173 2012-07-22 02:43:46 UTC+0000
.... 0x82311360:svchost.exe                           824    652     20    194 2012-07-22 02:42:33 UTC+0000
.... 0x820e8da0:alg.exe                               788    652      7    104 2012-07-22 02:43:01 UTC+0000
.... 0x82295650:svchost.exe                          1220    652     15    197 2012-07-22 02:42:35 UTC+0000
... 0x81e2a3b8:lsass.exe                              664    608     24    330 2012-07-22 02:42:32 UTC+0000
.. 0x822a0598:csrss.exe                               584    368      9    326 2012-07-22 02:42:32 UTC+0000
 0x821dea70:explorer.exe                             1484   1464     17    415 2012-07-22 02:42:36 UTC+0000
. 0x81e7bda0:reader_sl.exe                           1640   1484      5     39 2012-07-22 02:42:36 UTC+0000
kali@kali:/media/testShare$
```

Figure 14 The output of pstree of the infected dump.

In the output of the pstree plugin for the infected dump, several differences can be observed when compared to the clean dump. The root process, System (PID: 4), and core processes like **smss.exe, winlogon.exe,** and **services.exe** are present as expected. However, notable deviations appear in the process hierarchy:

1. Presence of **reader_sl.exe (PID: 1640):** This process does not exist in the clean dump and is spawned under **explorer.exe (PID: 1484).**
2. Additional Instances of **wuauclt.exe**: There are two instances of **wuauclt.exe (PIDs: 1136 and 1588)** in the infected dump, whereas only one instance appears in the clean dump. One instance **(PID: 1588)** has a parent process of **services.exe (PID: 652),** which may indicate unexpected behaviour.

Overall, the infected dump has more processes and slight deviations in the parent-child relationships, with processes like reader_sl.exe and the additional **wuauclt.exe** instances being the most notable differences.

Next, we will use the psscan plugin to analyse the clean memory dump. The psscan plugin identifies processes by scanning for EPROCESS structures in memory, including those that may not appear in the standard process list (pslist) due to termination or hiding by malware.[9] This allows us to detect any hidden or previously terminated processes.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 psscan
Volatility Foundation Volatility Framework 2.6.1
Offset(P)          Name                PID   PPID PDB        Time created                   Time exited
------------------ ---------------- ------ ------ ---------- ------------------------------ ------------------------------
0x0000000009d02ae8 wscntfy.exe        1256   1096 0x0aac0280 2024-11-14 15:15:40 UTC+0000
0x0000000009d4da28 VBoxTray.exe        252    436 0x0aac0220 2024-11-14 15:15:41 UTC+0000
0x0000000009d7dda0 winpmem_v3.3.rc     860    180 0x0aac01a0 2024-11-14 15:32:06 UTC+0000
0x0000000009daada0 wuauclt.exe         176   1096 0x0aac02c0 2024-11-14 15:15:42 UTC+0000
0x0000000009debd00 spoolsv.exe        1568    684 0x0aac01c0 2024-11-14 15:06:56 UTC+0000
0x0000000009e177a8 svchost.exe        1244    684 0x0aac0160 2024-11-14 15:06:54 UTC+0000
0x0000000009e948c8 explorer.exe        436    416 0x0aac0260 2024-11-14 15:15:40 UTC+0000
0x0000000009eb6518 VBoxService.exe     868    684 0x0aac00e0 2024-11-14 09:36:52 UTC+0000
0x0000000009f08020 cmd.exe             180   1096 0x0aac0300 2024-11-14 15:28:44 UTC+0000
0x000000000a1e47e8 winlogon.exe        640    560 0x0aac0080 2024-11-14 09:36:52 UTC+0000
0x000000000a1f5c08 services.exe        684    640 0x0aac00a0 2024-11-14 09:36:52 UTC+0000
0x000000000a1fe8e0 svchost.exe         920    684 0x0aac0100 2024-11-14 15:06:54 UTC+0000
0x000000000a204450 svchost.exe        1000    684 0x0aac0120 2024-11-14 15:06:54 UTC+0000
0x000000000a2121c0 svchost.exe        1096    684 0x0aac0140 2024-11-14 15:06:54 UTC+0000
0x000000000a212c08 smss.exe            560      4 0x0aac0040 2024-11-14 09:36:51 UTC+0000
0x000000000a216538 svchost.exe        1348    684 0x0aac0180 2024-11-14 15:06:54 UTC+0000
0x000000000a221da0 lsass.exe           696    640 0x0aac00c0 2024-11-14 09:36:52 UTC+0000
0x000000000a237a78 IPROSetMonitor.    1744    684 0x0aac0200 2024-11-14 15:07:03 UTC+0000
0x000000000a26b5a8 alg.exe             404    684 0x0aac0240 2024-11-14 15:07:07 UTC+0000
0x000000000a2a3500 svchost.exe        1684    684 0x0aac01e0 2024-11-14 15:07:03 UTC+0000
0x000000000a2c1020 csrss.exe           616    560 0x0aac0060 2024-11-14 09:36:52 UTC+0000
0x000000000a45c830 System                4      0 0x0aac0020
0x000000000045af6ae8 wscntfy.exe      1256   1096 0x0aac0280 2024-11-14 15:15:40 UTC+0000
0x000000000045e31da0 winpmem_v3.3.rc   860    180 0x0aac01a0 2024-11-14 15:32:06 UTC+0000
0x000000000045eea518 VBoxService.exe   868    684 0x0aac00e0 2024-11-14 09:36:52 UTC+0000
0x000000004619eda0 wuauclt.exe         176   1096 0x0aac02c0 2024-11-14 15:15:42 UTC+0000
0x000000000461dfd00 spoolsv.exe       1568    684 0x0aac01c0 2024-11-14 15:06:56 UTC+0000
0x000000000461ecc08 services.exe       684    640 0x0aac00a0 2024-11-14 09:36:52 UTC+0000
0x000000004627d020 cmd.exe             180   1096 0x0aac0300 2024-11-14 15:28:44 UTC+0000
0x000000000462eea78 IPROSetMonitor.   1744    684 0x0aac0200 2024-11-14 15:07:03 UTC+0000
0x000000004630b7a8 svchost.exe        1244    684 0x0aac0160 2024-11-14 15:06:54 UTC+0000
```

Figure 15 The output of psscan of the clean dump.

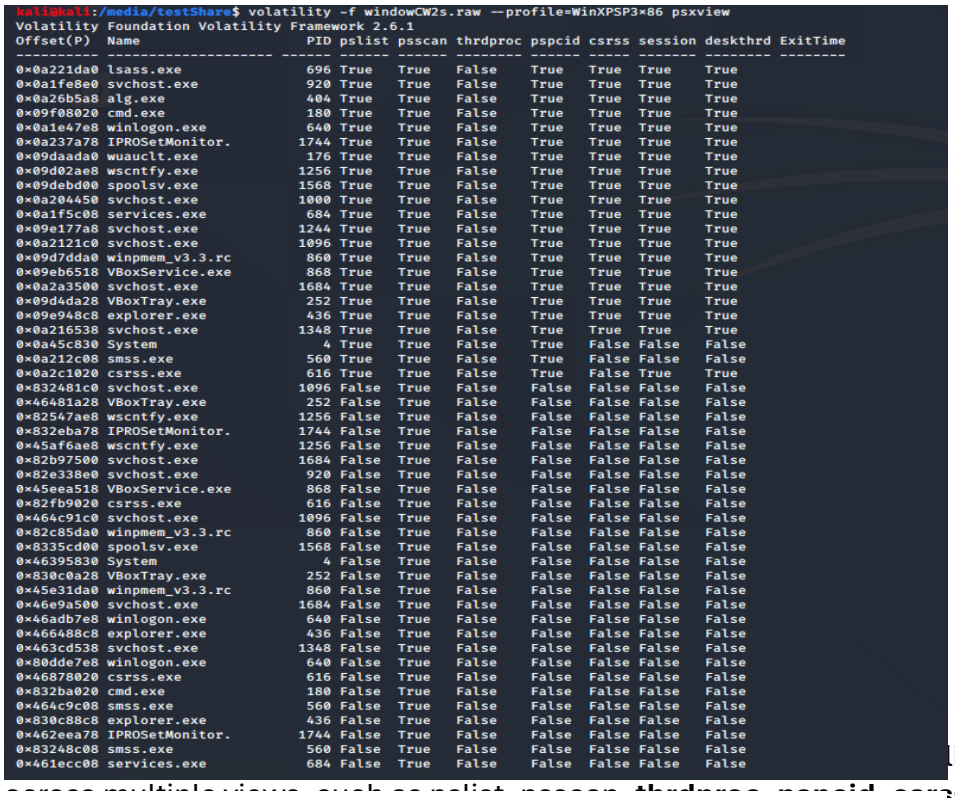
The psscan output for the clean dump shows a list of processes, including system processes like System, **smss.exe, csrss.exe, winlogon.exe,** and **services.exe**, as well as user processes such as **VBoxTray.exe, cmd.exe,** and **winpmem_v3.3.rc. The table** includes details such as the PID (Process ID), PPID (Parent Process ID), and the creation times of the processes. All processes appear consistent with what was previously observed in the pslist output, and no unexpected or hidden processes are visible. This reinforces that the clean dump reflects a stable and unaltered system state. Next, we will run the same command on the infected dump.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 psscan
Volatility Foundation Volatility Framework 2.6.1
Offset(P)          Name                PID   PPID PDB        Time created                   Time exited
------------------ ---------------- ------ ------ ---------- ------------------------------ ------------------------------
0x0000000002029ab8 svchost.exe         908    652 0x079400e0 2012-07-22 02:42:33 UTC+0000
0x000000000202a3b8 lsass.exe           664    608 0x079400a0 2012-07-22 02:42:32 UTC+0000
0x000000000202ab28 services.exe        652    608 0x07940080 2012-07-22 02:42:32 UTC+0000
0x000000000207bda0 reader_sl.exe      1640   1484 0x079401e0 2012-07-22 02:42:36 UTC+0000
0x00000000020b17b8 spoolsv.exe        1512    652 0x079401c0 2012-07-22 02:42:36 UTC+0000
0x000000000225bda0 wuauclt.exe        1588   1004 0x07940200 2012-07-22 02:44:01 UTC+0000
0x00000000022e8da0 alg.exe             788    652 0x07940140 2012-07-22 02:43:01 UTC+0000
0x00000000023dea70 explorer.exe       1484   1464 0x079401a0 2012-07-22 02:42:36 UTC+0000
0x00000000023dfda0 svchost.exe        1056    652 0x07940120 2012-07-22 02:42:33 UTC+0000
0x00000000023fcda0 wuauclt.exe        1136   1004 0x07940180 2012-07-22 02:43:46 UTC+0000
0x0000000002495650 svchost.exe        1220    652 0x07940160 2012-07-22 02:42:35 UTC+0000
0x0000000002498700 winlogon.exe        608    368 0x07940060 2012-07-22 02:42:32 UTC+0000
0x00000000024a0598 csrss.exe           584    368 0x07940040 2012-07-22 02:42:32 UTC+0000
0x00000000024f1020 smss.exe            368      4 0x07940020 2012-07-22 02:42:31 UTC+0000
0x00000000025001d0 svchost.exe        1004    652 0x07940100 2012-07-22 02:42:33 UTC+0000
0x0000000002511360 svchost.exe         824    652 0x079400c0 2012-07-22 02:42:33 UTC+0000
0x00000000025c89c8 System                4      0 0x002fe000
```

Figure 16: The output of psscan of the infected dump.

The psscan output for the infected dump shows a list of processes, including both system and user processes, such as System, **smss.exe, csrss.exe, services.exe,** and **explorer.exe.** Compared to the clean dump, no hidden or terminated processes appear to have been recovered, as all the processes listed here were also visible in the previous pslist output. This suggests that no processes were explicitly hidden or terminated in the infected dump. However, processes like **reader_sl.exe** and multiple instances of **wuauclt.exe**, which are already flagged as additional in the infected dump, appear again here. This output confirms that all currently active processes were accounted for earlier, and psscan did not reveal any further hidden artifacts.

Further, we will use the **psxview** plugin to analyse the visibility of processes across multiple memory structures. Unlike pslist or psscan, which rely on specific enumeration methods, psxview cross-references processes through various views, such as pslist, psscan, csrss, and session. This allows us to identify any processes that may be hidden or not fully visible in standard outputs, a common technique used by malware to evade detection. By running psxview on both the clean and infected memory dumps, we aim to verify the consistency of process visibility and identify any anomalies or hidden processes that may not have appeared earlier.



```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 psxview
Volatility Foundation Volatility Framework 2.6.1
Offset(P)  Name                    PID pslist psscan thrdproc pspcid csrss session deskthrd ExitTime
---------- -------------------- ------ ------ ------ -------- ------ ----- ------- -------- --------
0x0a221da0 lsass.exe               696 True   True   False    True   True  True    True
0x0a1fe8e0 svchost.exe             920 True   True   False    True   True  True    True
0x0a26b5a8 alg.exe                 404 True   True   False    True   True  True    True
0x09f08020 cmd.exe                 180 True   True   False    True   True  True    True
0x0a1e47e8 winlogon.exe            640 True   True   False    True   True  True    True
0x0a237a78 IPROSetMonitor.        1744 True   True   False    True   True  True    True
0x09daada0 wuauclt.exe             176 True   True   False    True   True  True    True
0x09d02ae8 wscntfy.exe            1256 True   True   False    True   True  True    True
0x09debd00 spoolsv.exe            1568 True   True   False    True   True  True    True
0x0a204450 svchost.exe            1000 True   True   False    True   True  True    True
0x0a1f5c08 services.exe            684 True   True   False    True   True  True    True
0x09e177a8 svchost.exe            1244 True   True   False    True   True  True    True
0x0a2121c0 svchost.exe            1096 True   True   False    True   True  True    True
0x09d7dda0 winpmem_v3.3.rc         860 True   True   False    True   True  True    True
0x09eb6518 VBoxService.exe         868 True   True   False    True   True  True    True
0x0a2a3500 svchost.exe            1684 True   True   False    True   True  True    True
0x09d4da28 VBoxTray.exe            252 True   True   False    True   True  True    True
0x09e948c8 explorer.exe            436 True   True   False    True   True  True    True
0x0a216538 svchost.exe            1348 True   True   False    True   True  True    True
0x0a45c830 System                    4 True   True   False    True   False False   False
0x0a212c08 smss.exe                560 True   True   False    True   False False   False
0x0a2c1020 csrss.exe               616 True   True   False    True   False True    True
0x832481c0 svchost.exe            1096 False  True   False    False  False False   False
0x46481a28 VBoxTray.exe            252 False  True   False    False  False False   False
0x82547ae8 wscntfy.exe            1256 False  True   False    False  False False   False
0x832eba78 IPROSetMonitor.        1744 False  True   False    False  False False   False
0x45af6ae8 wscntfy.exe            1256 False  True   False    False  False False   False
0x82b97500 svchost.exe            1684 False  True   False    False  False False   False
0x82e338e0 svchost.exe             920 False  True   False    False  False False   False
0x45eea518 VBoxService.exe         868 False  True   False    False  False False   False
0x82fb9020 csrss.exe               616 False  True   False    False  False False   False
0x464c91c0 svchost.exe            1096 False  True   False    False  False False   False
0x82c85da0 winpmem_v3.3.rc         860 False  True   False    False  False False   False
0x8335cd00 spoolsv.exe            1568 False  True   False    False  False False   False
0x46395830 System                    4 False  True   False    False  False False   False
0x830c0a28 VBoxTray.exe            252 False  True   False    False  False False   False
0x45e31da0 winpmem_v3.3.rc         860 False  True   False    False  False False   False
0x46e9a500 svchost.exe            1684 False  True   False    False  False False   False
0x46adb7e8 winlogon.exe            640 False  True   False    False  False False   False
0x466488c8 explorer.exe            436 False  True   False    False  False False   False
0x463cd538 svchost.exe            1348 False  True   False    False  False False   False
0x80dde7e8 winlogon.exe            640 False  True   False    False  False False   False
0x46878020 csrss.exe               616 False  True   False    False  False False   False
0x832ba020 cmd.exe                 180 False  True   False    False  False False   False
0x464c9c08 smss.exe                560 False  True   False    False  False False   False
0x830c88c8 explorer.exe            436 False  True   False    False  False False   False
0x462eea78 IPROSetMonitor.        1744 False  True   False    False  False False   False
0x83248c08 smss.exe                560 False  True   False    False  False False   False
0x461ecc08 services.exe            684 False  True   False    False  False False   False
```

Figure 17 The output of psxview of the clean dump.

lity of processes

ss, session, and

d multiple instances of svchost.exe generally appear as True across most views, indicating that they are consistently visible and functioning as expected. However, some processes show False in certain views, such as csrss and session, while remaining True in others. This behaviour is common in clean systems, where certain processes may not register in every structure due to normal system operations. Overall, the output confirms that the processes in the clean dump are visible and accounted for, with no hidden processes detected. Next, the same command was executed for infected dump.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 psxview
Volatility Foundation Volatility Framework 2.6.1
Offset(P)  Name                    PID pslist psscan thrdproc pspcid csrss session deskthrd ExitTime
---------- -------------------- ------ ------ ------ -------- ------ ----- ------- -------- --------
0x02498700 winlogon.exe            608 True   True   True     True   True  True    True
0x02511360 svchost.exe             824 True   True   True     True   True  True    True
0x022e8da0 alg.exe                 788 True   True   True     True   True  True    True
0x020b17b8 spoolsv.exe            1512 True   True   True     True   True  True    True
0x0202ab28 services.exe            652 True   True   True     True   True  True    True
0x02495650 svchost.exe            1220 True   True   True     True   True  True    True
0x0207bda0 reader_sl.exe          1640 True   True   True     True   True  True    True
0x025001d0 svchost.exe            1004 True   True   True     True   True  True    True
0x02029ab8 svchost.exe             908 True   True   True     True   True  True    True
0x023fcda0 wuauclt.exe            1136 True   True   True     True   True  True    True
0x0225bda0 wuauclt.exe            1588 True   True   True     True   True  True    True
0x0202a3b8 lsass.exe               664 True   True   True     True   True  True    True
0x023dea70 explorer.exe           1484 True   True   True     True   True  True    True
0x023dfda0 svchost.exe            1056 True   True   True     True   True  True    True
0x024f1020 smss.exe                368 True   True   True     True   False False   False
0x025c89c8 System                    4 True   True   True     True   False False   False
0x024a0598 csrss.exe               584 True   True   True     True   False True    True
```

Figure 18 The output of psxview of the infected dump.

The output of the psxview plugin for the infected dump reveals the visibility of processes across multiple memory views, such as pslist, psscan, thrdproc, pspcid, csrss, session, and deskthrd. Most processes, including winlogon.exe, svchost.exe, services.exe, and **wuauclt.exe**, show True across all views, indicating consistent visibility. However, the **System process (PID: 4)** shows False under the csrss and session views, which can sometimes be expected for certain system-level processes.

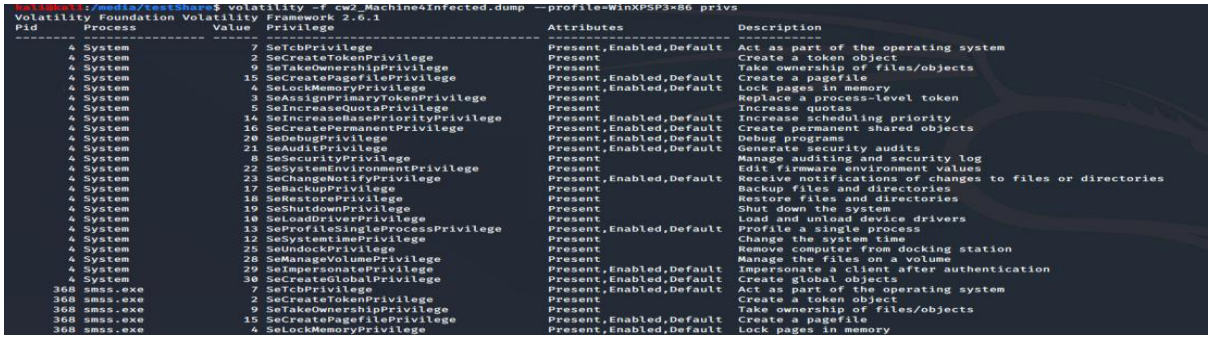
Additionally, **reader_sl.exe (PID: 1640),** a process does not present in the clean dump, shows True across all views, confirming its presence and visibility in multiple structures. This suggests it is active and not hidden.

Next, we will use the privs plugin to analyse the privileges associated with processes in the memory dump. The privs plugin displays the privileges granted to each process, such as SeDebugPrivilege or SeShutdownPrivilege, which can help identify processes with escalated or unusual privileges.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 privs
Volatility Foundation Volatility Framework 2.6.1
Pid      Process          Value  Privilege                       Attributes                Description
-------- --------------- ------ ------------------------------- ------------------------- -----------
       4 System               7 SeTcbPrivilege                  Present,Enabled,Default   Act as part of the operating system
       4 System               2 SeCreateTokenPrivilege          Present                   Create a token object
       4 System               9 SeTakeOwnershipPrivilege        Present                   Take ownership of files/objects
       4 System              15 SeCreatePagefilePrivilege       Present,Enabled,Default   Create a pagefile
       4 System               4 SeLockMemoryPrivilege           Present,Enabled,Default   Lock pages in memory
       4 System               3 SeAssignPrimaryTokenPrivilege   Present                   Replace a process-level token
       4 System               5 SeIncreaseQuotaPrivilege        Present                   Increase quotas
       4 System              14 SeIncreaseBasePriorityPrivilege Present,Enabled,Default   Increase scheduling priority
       4 System              16 SeCreatePermanentPrivilege      Present,Enabled,Default   Create permanent shared objects
       4 System              20 SeDebugPrivilege                Present,Enabled,Default   Debug programs
       4 System              21 SeAuditPrivilege                Present,Enabled,Default   Generate security audits
       4 System               8 SeSecurityPrivilege             Present                   Manage auditing and security log
       4 System              22 SeSystemEnvironmentPrivilege    Present                   Edit firmware environment values
       4 System              23 SeChangeNotifyPrivilege         Present,Enabled,Default   Receive notifications of changes to files or directories
       4 System              17 SeBackupPrivilege               Present                   Backup files and directories
       4 System              18 SeRestorePrivilege              Present                   Restore files and directories
       4 System              19 SeShutdownPrivilege             Present                   Shut down the system
       4 System              10 SeLoadDriverPrivilege           Present                   Load and unload device drivers
       4 System              13 SeProfileSingleProcessPrivilege Present,Enabled,Default   Profile a single process
       4 System              12 SeSystemtimePrivilege           Present                   Change the system time
       4 System              25 SeUndockPrivilege               Present                   Remove computer from docking station
       4 System              28 SeManageVolumePrivilege         Present                   Manage the files on a volume
       4 System              29 SeImpersonatePrivilege          Present,Enabled,Default   Impersonate a client after authentication
       4 System              30 SeCreateGlobalPrivilege         Present,Enabled,Default   Create global objects
     560 smss.exe             7 SeTcbPrivilege                  Present,Enabled,Default   Act as part of the operating system
     560 smss.exe             2 SeCreateTokenPrivilege          Present                   Create a token object
     560 smss.exe             9 SeTakeOwnershipPrivilege        Present                   Take ownership of files/objects
     560 smss.exe            15 SeCreatePagefilePrivilege       Present,Enabled,Default   Create a pagefile
     560 smss.exe             4 SeLockMemoryPrivilege           Present,Enabled,Default   Lock pages in memory
     560 smss.exe             3 SeAssignPrimaryTokenPrivilege   Present                   Replace a process-level token
```

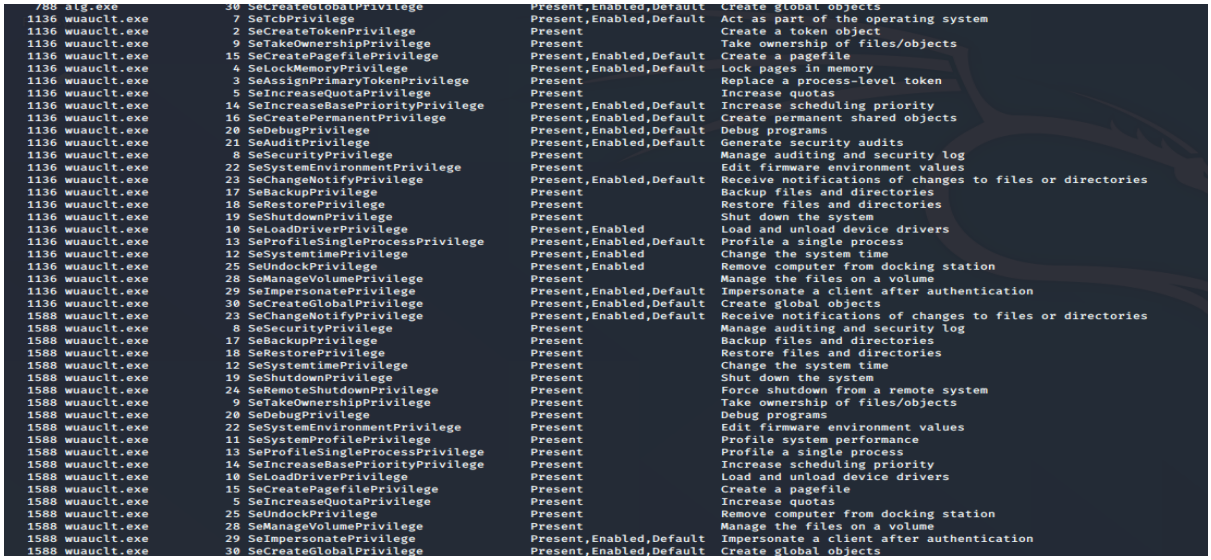
Figure 19 The output of prive of the clean dump.

The output of the privs plugin for the clean dump shows a list of processes and their associated privileges, including the System process and smss.exe. Privileges such as SeDebugPrivilege (debugging programs), SeShutdownPrivilege (shutting down the system), and SeTakeOwnershipPrivilege (taking ownership of files or objects) are present, enabled, and set as default for several system-critical processes. These privileges are typical for processes like System and smss.exe in a clean system environment, as they perform essential operating system functions. Additionally, privileges such as SeCreatePagefilePrivilege and SeIncreaseQuotaPrivilege reflect the ability to manage memory and system resources.



```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 privs
Volatility Foundation Volatility Framework 2.6.1
Pid      Process            Value  Privilege                       Attributes                Description
-------- ---------------- ------ ------------------------------- ------------------------- -----------
       4 System                  7 SeTcbPrivilege                  Present,Enabled,Default   Act as part of the operating system
       4 System                  2 SeCreateTokenPrivilege          Present                   Create a token object
       4 System                  9 SeTakeOwnershipPrivilege        Present                   Take ownership of files/objects
       4 System                 15 SeCreatePagefilePrivilege       Present,Enabled,Default   Create a pagefile
       4 System                  4 SeLockMemoryPrivilege           Present,Enabled,Default   Lock pages in memory
       4 System                  3 SeAssignPrimaryTokenPrivilege   Present                   Replace a process-level token
       4 System                  5 SeIncreaseQuotaPrivilege        Present                   Increase quotas
       4 System                 14 SeIncreaseBasePriorityPrivilege Present,Enabled,Default   Increase scheduling priority
       4 System                 16 SeCreatePermanentPrivilege      Present,Enabled,Default   Create permanent shared objects
       4 System                 20 SeDebugPrivilege                Present,Enabled,Default   Debug programs
       4 System                 21 SeAuditPrivilege                Present,Enabled,Default   Generate security audits
       4 System                  8 SeSecurityPrivilege             Present                   Manage auditing and security log
       4 System                 22 SeSystemEnvironmentPrivilege    Present                   Edit firmware environment values
       4 System                 23 SeChangeNotifyPrivilege         Present,Enabled,Default   Receive notifications of changes to files or directories
       4 System                 17 SeBackupPrivilege               Present                   Backup files and directories
       4 System                 18 SeRestorePrivilege              Present                   Restore files and directories
       4 System                 19 SeShutdownPrivilege             Present                   Shut down the system
       4 System                 10 SeLoadDriverPrivilege           Present                   Load and unload device drivers
       4 System                 13 SeProfileSingleProcessPrivilege Present,Enabled,Default   Profile a single process
       4 System                 12 SeSystemtimePrivilege           Present                   Change the system time
       4 System                 25 SeUndockPrivilege               Present                   Remove computer from docking station
       4 System                 28 SeManageVolumePrivilege         Present                   Manage the files on a volume
       4 System                 29 SeImpersonatePrivilege          Present,Enabled,Default   Impersonate a client after authentication
       4 System                 30 SeCreateGlobalPrivilege         Present,Enabled,Default   Create global objects
     368 smss.exe                7 SeTcbPrivilege                  Present,Enabled,Default   Act as part of the operating system
     368 smss.exe                2 SeCreateTokenPrivilege          Present                   Create a token object
     368 smss.exe                9 SeTakeOwnershipPrivilege        Present                   Take ownership of files/objects
     368 smss.exe               15 SeCreatePagefilePrivilege       Present,Enabled,Default   Create a pagefile
     368 smss.exe                4 SeLockMemoryPrivilege           Present,Enabled,Default   Lock pages in memory
```

Figure 20 The output of prive of the infected dump 1/2.



```
 788 alg.exe              30 SeCreateGlobalPrivilege         Present,Enabled,Default   Create global objects
1136 wuauclt.exe           7 SeTcbPrivilege                  Present,Enabled,Default   Act as part of the operating system
1136 wuauclt.exe           2 SeCreateTokenPrivilege          Present                   Create a token object
1136 wuauclt.exe           9 SeTakeOwnershipPrivilege        Present                   Take ownership of files/objects
1136 wuauclt.exe          15 SeCreatePagefilePrivilege       Present,Enabled,Default   Create a pagefile
1136 wuauclt.exe           4 SeLockMemoryPrivilege           Present,Enabled,Default   Lock pages in memory
1136 wuauclt.exe           3 SeAssignPrimaryTokenPrivilege   Present                   Replace a process-level token
1136 wuauclt.exe           5 SeIncreaseQuotaPrivilege        Present                   Increase quotas
1136 wuauclt.exe          14 SeIncreaseBasePriorityPrivilege Present,Enabled,Default   Increase scheduling priority
1136 wuauclt.exe          16 SeCreatePermanentPrivilege      Present,Enabled,Default   Create permanent shared objects
1136 wuauclt.exe          20 SeDebugPrivilege                Present,Enabled,Default   Debug programs
1136 wuauclt.exe          21 SeAuditPrivilege                Present,Enabled,Default   Generate security audits
1136 wuauclt.exe           8 SeSecurityPrivilege             Present                   Manage auditing and security log
1136 wuauclt.exe          22 SeSystemEnvironmentPrivilege    Present                   Edit firmware environment values
1136 wuauclt.exe          23 SeChangeNotifyPrivilege         Present,Enabled,Default   Receive notifications of changes to files or directories
1136 wuauclt.exe          17 SeBackupPrivilege               Present                   Backup files and directories
1136 wuauclt.exe          18 SeRestorePrivilege              Present                   Restore files and directories
1136 wuauclt.exe          19 SeShutdownPrivilege             Present                   Shut down the system
1136 wuauclt.exe          10 SeLoadDriverPrivilege           Present,Enabled           Load and unload device drivers
1136 wuauclt.exe          13 SeProfileSingleProcessPrivilege Present,Enabled,Default   Profile a single process
1136 wuauclt.exe          12 SeSystemtimePrivilege           Present,Enabled           Change the system time
1136 wuauclt.exe          25 SeUndockPrivilege               Present,Enabled           Remove computer from docking station
1136 wuauclt.exe          28 SeManageVolumePrivilege         Present                   Manage the files on a volume
1136 wuauclt.exe          29 SeImpersonatePrivilege          Present,Enabled,Default   Impersonate a client after authentication
1136 wuauclt.exe          30 SeCreateGlobalPrivilege         Present,Enabled,Default   Create global objects
1588 wuauclt.exe          23 SeChangeNotifyPrivilege         Present,Enabled,Default   Receive notifications of changes to files or directories
1588 wuauclt.exe           8 SeSecurityPrivilege             Present                   Manage auditing and security log
1588 wuauclt.exe          17 SeBackupPrivilege               Present                   Backup files and directories
1588 wuauclt.exe          18 SeRestorePrivilege              Present                   Restore files and directories
1588 wuauclt.exe          12 SeSystemtimePrivilege           Present                   Change the system time
1588 wuauclt.exe          19 SeShutdownPrivilege             Present                   Shut down the system
1588 wuauclt.exe          24 SeRemoteShutdownPrivilege       Present                   Force shutdown from a remote system
1588 wuauclt.exe           9 SeTakeOwnershipPrivilege        Present                   Take ownership of files/objects
1588 wuauclt.exe          20 SeDebugPrivilege                Present                   Debug programs
1588 wuauclt.exe          22 SeSystemEnvironmentPrivilege    Present                   Edit firmware environment values
1588 wuauclt.exe          11 SeSystemProfilePrivilege        Present                   Profile system performance
1588 wuauclt.exe          13 SeProfileSingleProcessPrivilege Present                   Profile a single process
1588 wuauclt.exe          14 SeIncreaseBasePriorityPrivilege Present                   Increase scheduling priority
1588 wuauclt.exe          10 SeLoadDriverPrivilege           Present                   Load and unload device drivers
1588 wuauclt.exe          15 SeCreatePagefilePrivilege       Present                   Create a pagefile
1588 wuauclt.exe           5 SeIncreaseQuotaPrivilege        Present                   Increase quotas
1588 wuauclt.exe          25 SeUndockPrivilege               Present                   Remove computer from docking station
1588 wuauclt.exe          28 SeManageVolumePrivilege         Present                   Manage the files on a volume
1588 wuauclt.exe          29 SeImpersonatePrivilege          Present,Enabled,Default   Impersonate a client after authentication
1588 wuauclt.exe          30 SeCreateGlobalPrivilege         Present,Enabled,Default   Create global objects
```

Figure 21 The output of prive of the infected dump 2/2.

instances of wuauclt.exe (PIDs: 1136 and 1588) stand out. Both processes are legitimate under normal circumstances. wuauclt.exe is a legitimate Windows process responsible for managing automatic updates, while reader_sl.exe is associated with Adobe Reader and is typically used to speed up the launch of Adobe PDF files. These processes possess significant privileges, such as SeDebugPrivilege, which allows debugging of programs, and SeLoadDriverPrivilege, which enables the loading of device drivers.

Analysis of the Clean Memory Dump using dot graph

To better understand and analyse the process trees generated from the clean and infected memory dumps, we will use **DOT diagrams**. A **DOT diagram** is a graphical representation created using the Graphviz tool, which helps visualize relationships and hierarchies in a structured format. By converting the process trees into a DOT format and rendering them as PNG images, we can easily identify parent-child relationships between processes and highlight any anomalies.

The process tree is extracted using Volatility's **pstree** plugin with additional arguments to output the results in the DOT format. Explanation of the command:

- **-f windowCW2s.raw**: Specifies the clean memory dump file.
- **--profile=WinXPSP3x86**: Indicates the memory profile, matching the operating system in the clean dump.
- **pstree**: The plugin used to extract the process tree.
- **--output=dot**: Outputs the tree in DOT format, suitable for further visualization.
- **--output-file=clean_dump_dot.dot**: Saves the DOT file with the name clean_dump_dot.dot.

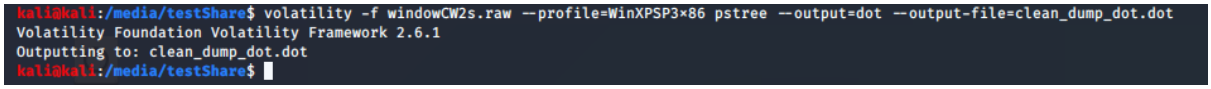


Figure 22: The output of pstree dot of the clean dump.

The next command processes the DOT file and outputs a PNG image of the process tree, which provides an easy-to-understand graphical representation of the processes and their relationships. Explanation of the command:

- **dot**: This is a Graphviz tool used to process and render DOT files.
- **-Tpng**: Specifies the desired output format, which is PNG in this case.
- **<output_file>.dot**: The input file created earlier using Volatility's pstree plugin in DOT format.
- **-o <output_file>.png**: Specifies the output file name and format, creating a PNG file.

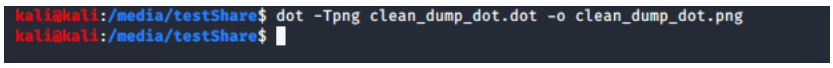


Figure 23: creating png of the dot

The screenshot below displays the **process tree graph** generated from the **clean memory dump**. This graph represents the relationships and hierarchy between processes in the clean system. Each node in the graph corresponds to a process, providing detailed information such as the process name, Process ID (PID), Parent Process ID (PPID), thread count, handle count, and the time the process was started. The arrows between nodes indicate the parent-child relationships, showing how processes were spawned.

In this clean graph, we observe a structured and expected hierarchy:

- The root process, **System (PID: 4)**, spawns critical system processes such as **smss.exe**, which then initiates **csrss.exe** and **winlogon.exe**.
- **services.exe**, launched by **winlogon.exe**, spawns multiple instances of **svchost.exe**, which are responsible for managing various Windows services.
- User-level processes, such as **explorer.exe**, represent the Windows interface, while **cmd.exe** and VirtualBox-related processes (**VBoxTray.exe** and **VBoxService.exe**) reflect activities related to the virtual environment.

The graph demonstrates a stable and organised system state, with no unexpected processes or anomalies. Each process has logical parent-child relationships, and the thread and handle counts are within normal ranges.

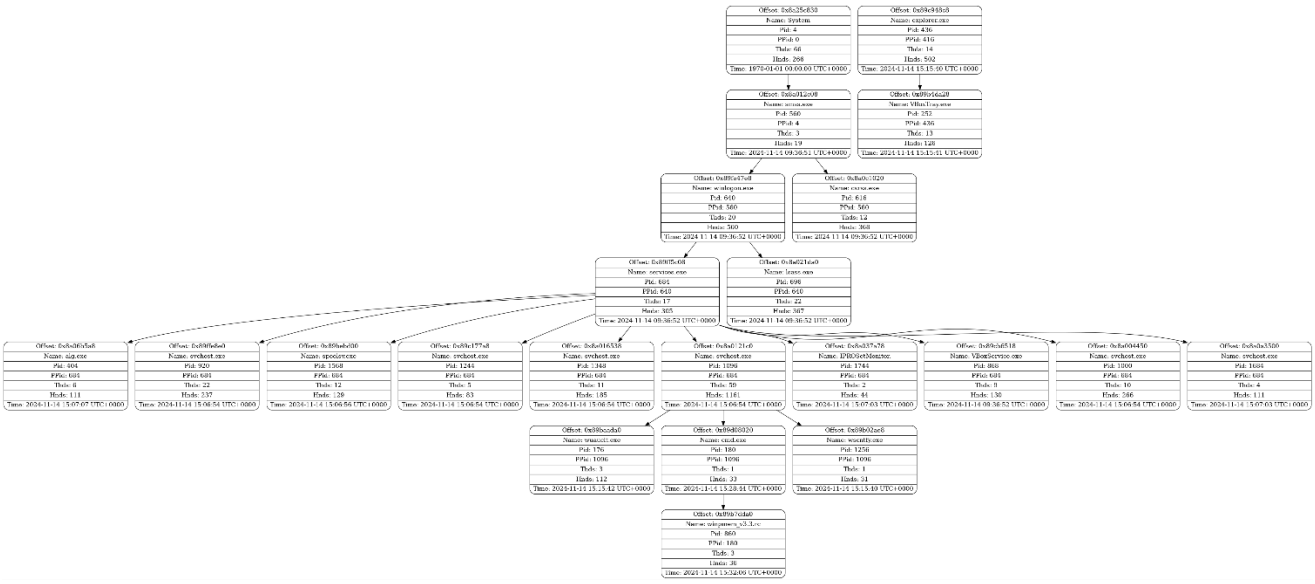


Figure 24 : The clean dump dot graph.

Analysis of the infected dump using dot graph

The same commands used to create the process tree graph for the clean dump were executed for the infected dump; however, the filenames were adjusted to reflect the infected dump. The DOT file for the infected dump process tree was generated using the pstree plugin in Volatility, and the name was set to **infected_dump_dot.dot** to distinguish it. Similarly, the generated DOT file was converted to a PNG image using the dot tool, with the output named **infected_dump_dot.png**.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 pstree --output=dot --output-file=infected_dump_dot.dot
Volatility Foundation Volatility Framework 2.6.1
Outputting to: infected_dump_dot.dot
kali@kali:/media/testShare$ dot -Tpng infected_dump_dot.dot -o infected_dump_dot.png
kali@kali:/media/testShare$
```

Figure 25 The output of pstree dot of the infected dump & creating png of the dot.

The screenshot below displays the **process tree graph generated from the infected memory dump**.

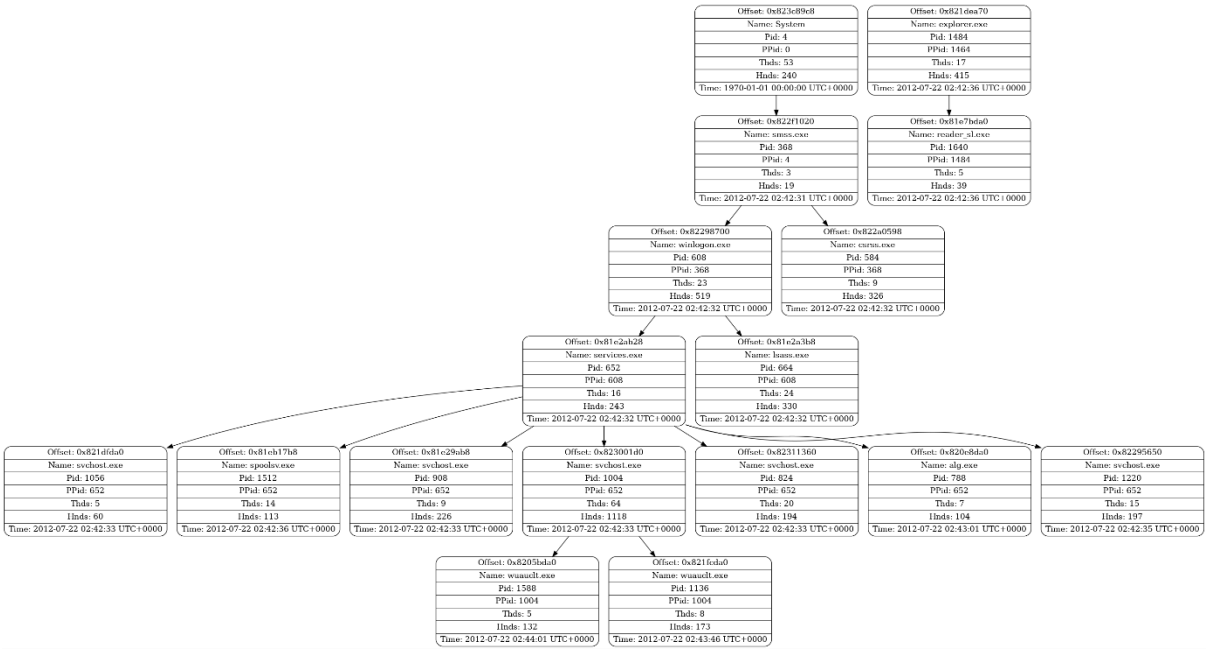


Figure 26 The infected dump dot graph.

Observations in the Infected Graph

The **System** (PID: 4) process acts as the root of the hierarchy, serving as the parent for all initial critical processes such as smss.exe. It maintains **53 threads** and **240 handles**, which is consistent with its role as the root process, providing stability for the entire system.

Among the critical system processes, smss.exe (PID: 368) is directly spawned by the System process. It has **3 threads** and **19 handles** and initializes the Windows environment by launching other essential processes. csrss.exe (PID: 584), spawned by smss.exe, manages graphical and console operations for the operating system. With **9 threads** and **326 handles**, it plays a vital role in maintaining system functionality.

Similarly, winlogon.exe (PID: 608), another child of smss.exe, is responsible for starting user logon sessions. It handles **23 threads** and **519 handles**, reflecting its resource-intensive role.

The **Service Manager**, represented by services.exe (PID: 652), is spawned by winlogon.exe. It is responsible for managing Windows services, operating with **16 threads** and **243 handles**, which aligns with its expected behaviour. From services.exe, multiple instances of svchost.exe are spawned to manage various system services. For instance, svchost.exe (PID: 1056) operates with **5 threads** and **60 handles**, indicating standard service management. However, svchost.exe (PID: 908) shows elevated activity with **6 threads** and **226 handles**, suggesting it may be handling more complex or numerous tasks. This discrepancy in handle counts warrants further inspection.

Suspicious processes stand out in the infected graph. One such process is reader_sl.exe (PID: 1640), which is spawned by explorer.exe (PID: 1484). While typically associated with Adobe Reader, its presence in the infected dump raises concerns. It runs with **5 threads** and **39 handles**, and its elevated privileges make it a potential target for misuse by malicious actors. Similarly, wuauclt.exe, which is responsible for Windows Updates, appears multiple times in the infected dump (PIDs: 1136 and 1588). These instances show handle counts of **173** and **132**, respectively, higher than expected, suggesting abnormal activity or potential exploitation.

User-level processes, such as explorer.exe (PID: 1484), operate as expected, with **17 threads** and **415 handles**, representing the graphical user interface. However, it spawns both reader_sl.exe and the suspicious instances of wuauclt.exe, indicating that the infected environment may compromise processes at the user level.

The timing and sequence of process starts in the infected graph follow a logical pattern, with system-level processes such as smss.exe (02:42:31 UTC) starting first, followed by service and user-level processes. However, the later appearance of suspicious processes like reader_sl.exe and multiple wuauclt.exe instances deviates from the clean dump's baseline. These anomalies, coupled with elevated privileges and handle counts, highlight potential malicious activity requiring further investigation.

4. Examination

4.1 Analysis of Objects, Pools & Processes

M00857972

1. List the different types of Windows objects that you can find in both memory dumps and explain them. Also, count the number of instantiations (or repetitions) for every object. (10%)

The operating system kernel in Windows uses objects, which are fundamental abstractions, to represent system resources like files, devices, threads, processes, and synchronization mechanisms. These items give the operating system a centralized method of managing and gaining access to resources, guaranteeing security and stability. A key component of the Windows kernel design, the Executive layer oversees managing objects and overseeing Windows Executive Memory. (Anon 2018). To analyse to see which types of window objects is in both dumps I am going to run the plugin objtypescan which provides all the list of the object types in the memory and by running this plugin you will be able to see the offset, number of objects, number of handles, key, name and the pool type (Batur 2023)

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump  --profile=WinXPSP3x86 objtypescan
Volatility Foundation Volatility Framework 2.6.1
Offset       nObjects   nHandles Key      Name                           PoolType
---------- ---------- ---------- -------- ------------------------------ --------------------
0x02418bf8        0x0        0x0 Filt     FilterCommunicationPort        NonPagedPool
0x024c0a40        0x0        0x0 Filt     FilterConnectionPort           NonPagedPool
0x025b43e8       0x26       0x33 IoCo     IoCompletion                   NonPagedPool
0x025b45b8       0x59        0x0 Driv     Driver                         NonPagedPool
0x025b4788      0x158        0x0 Devi     Device                         NonPagedPool
0x025b4958        0x2        0x0 Cont     Controller                     NonPagedPool
0x025b4b28        0xa        0x0 Adap     Adapter                        NonPagedPool
0x025c1980      0x22d      0x22b Key      Key                            PagedPool
0x025c4040        0x0        0x0 Prof     Profile                        NonPagedPool
0x025c4690       0xe5       0x35 Sect     Section                        PagedPool
0x025c4ad0        0x7       0x13 Desk     Desktop                        NonPagedPool
0x025c4ca0        0x5       0x1e Wind     WindowStation                  NonPagedPool
0x025c4e70        0x1       0x10 Keye     KeyedEvent                     PagedPool
0x025c52e8       0x1f       0x1f Time     Timer                          NonPagedPool
0x025c54b8      0x117      0x12b Sema     Semaphore                      NonPagedPool
0x025c5688        0x5        0x0 Call     Callback                       NonPagedPool
0x025c5858       0x93       0xad Muta     Mutant                         NonPagedPool
0x025c5a28        0x0        0x0 Even     EventPair                      NonPagedPool
0x025c5bf8       0x5d8      0x614 Even     Event                          NonPagedPool
0x025c8040       0x11       0x48 Proc     Process                        NonPagedPool
0x025c85a0        0x0        0x0 Debu     DebugObject                    NonPagedPool
0x025c8ca0        0x1        0x1 Job      Job                            NonPagedPool
0x025c8e70      0x135      0x200 Thre     Thread                         NonPagedPool
0x025e75b0       0x1e       0x1b WmiG     WmiGuid                        NonPagedPool
0x025eb040       0x5ba      0x2c2 File     File                           NonPagedPool
0x025ec588        0x3        0x3 Wait     WaitablePort                   NonPagedPool
0x025ec758       0xee       0xec Port     Port                           PagedPool
0x025ed158       0x3e       0x31 Toke     Token                          PagedPool
0x025ed328       0x8f        0x2 Symb     SymbolicLink                   PagedPool
0x025ed4f8       0x21       0x39 Dire     Directory                      PagedPool
0x025ed6c8       0x1f        0x0 ObjT     Type                           NonPagedPool
```

Figure 1: image of the different types of window objects in infected dump using plugin objtypescan

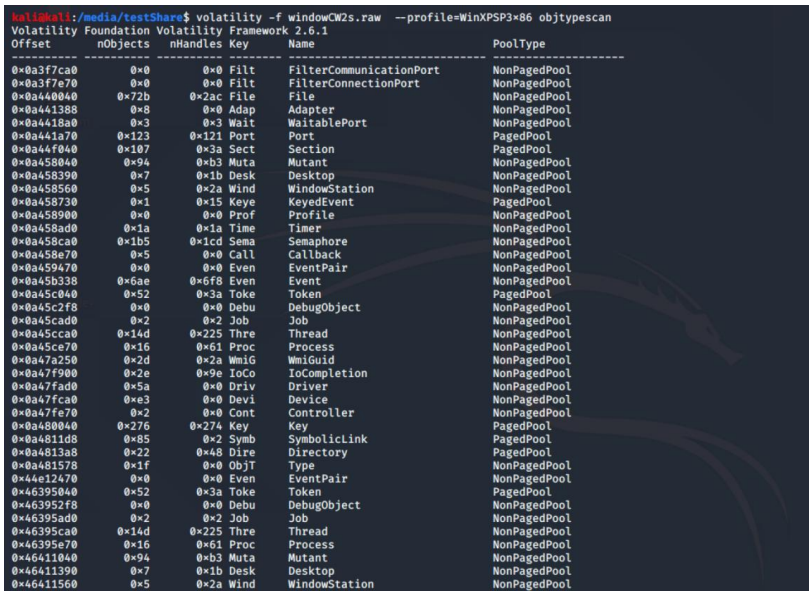


Figure 2: image of the different types of window objects in clean dump using plugin objtypescan

When running the plugin objtypescan in the clean and infected dump I got those outputs which can be seen in figure 1 and 2. Below is a table which I put all the window object which appeared, the description and if they are in the clean or infected dump.

Analysis of Windows Object Types Descriptions and Comparison Between Clean and Infected Memory Dumps

Windows Object	Description	Clean Dump	Infected Dump
FilterCommunicationPort	It's used for communication between process and it often in driver development or interprocess communication (Chevalier 2019)	Yes	Yes
FilterConnection Port	It represents the connection points for filter communication, and it establishes a communication between user mode applications and kernel mode drivers (Shafir 2023)	Yes	Yes
IoCompletion	It manages I/O completion ports which are used to efficiently handle multiple asynchronous operations by completing I/O requests for processing by worker threads (Sturtevant 2023)	Yes	Yes
Driver	It's a loaded device driver in the system which is responsible for managing hardware or implementing file systems (Matoušek 2005)	Yes	Yes

Device	It's a device object created by a driver to manage hardware or virtual device (Russinovich, Solomon, Ionescu 2014)	Yes	Yes
Controller	It's an abstraction for a hardware controller that manages one or more devices (2023)	Yes	Yes
Adapter	It's a network or hardware adapters which communicates between the operating system and the hardware components (Bogna 2021)	Yes	Yes
Key	It's a key object which is used to access and manage the window registry (Fisher 2023)	Yes	Yes
Profile	It shows the performance profiling object which is used to collect and analyse the system performance data (2024)	Yes	Yes
Section	It's a section object which is used for memory management which can include shared memory (*Allievi 2024)*	Yes	Yes
Desktop	It's a desktop object which is a user interface which has the windows and menus on it (Kirvan 2023)	Yes	Yes
Window Station	It contains a group pf desktop object and manages the input, output and global string identifiers (Haines 2024)	Yes	Yes
KeyedEvent	It's used for threads synchronisation based on the keys (2024)	Yes	Yes
Timer	This is used for to schedule the execution of the code at a specific time or after an interval (Peter 2018)	Yes	Yes
Semaphore	It's a synchronization primitive which controls access to a resource by multiple threads. (2024)	Yes	Yes
Callback	It allows the driver or application to register a function to be in response to a specific event (Johnson 2023)	Yes	Yes
Mutant	It's a synchronization mechanism which is used to control access by multiple threads (Cohen 2024)	Yes	Yes
EventPair	It's a synchronization between user mode and kernel mode components (Probert 2006)	Yes	Yes
Event	A synchronization which is used to signal the occurrence of an event to waiting threads (Probert 2006)	Yes	Yes
Process	It contains information about running processes which includes threads, handle table and security context (Ligh, Case Levy, Walters 2014)	Yes	Yes

Debug Object	It's used by debuggers to control and monitor processes (Heusser 2024)	Yes	Yes
Job	It allows groups of processes managed by a unit which includes setting limit on resources and handling their termination (2024)	Yes	Yes
Thread	It's the basic unit of CPU utilization which contains the threads context, scheduling information and stack. ((Ligh, Case Levy, Walters 2014)	Yes	Yes
WmiGuid	It's a GUID object and it's used to identify WMI data blocks and events (Buckbee 2023)	Yes	Yes
File	It provides access to files, devices and can see the information like file position and access rights (2024)	Yes	Yes
WaitablePort	It represents a port object which allows process to wait for messages and signals (2024)	Yes	Yes
Port	It allows processes to send and receive messages or data (2024)	Yes	Yes
Token	It's a security token which defines the access rights and privileges of a process or thread (Kirvan 2024)	Yes	Yes
SymbolicLink	It acts a shortcut or reference it's another file, directory or device (2024)	Yes	Yes
Directory	It organises and stores object in a window kernel (2024)	Yes	Yes
Type	It defines the properties, behaviour and constraints for each kernel objects (2024)	Yes	Yes

Table 2a: list of the window objects and if they appear in both dumps

When analysing the clean and infected dump the instances of Window objects means if it how many times it's been repeated and if an object like the mutant has been repeated many times this can suggest that it has malware, and it needs further investigation (Zeltser 2012). In figure 1 you can see the n0bjects column and that is what I will be using to calculate the instances, and this can be shown in the table below. My aim of comparing both instances in both dumps is to show how frequently the window objects both showed up and if they show significant difference this can show that malicious activity has gone, and it needs further investigation.

The examination of the memory dumps identifies several significant irregularities that raise the possibility of malware activity. The sudden increase in Device instances (Clean: 3, Infected: 344) could indicate malware interacting with hardware, fabricating device objects to pose as genuine hardware processes, or establishing persistent communication. Similarly, the decline in Key occurrences (Clean: 630, Infected: 557) suggests potential registry interference, where malware may modify or remove system

keys to conceal its existence or disrupt regular processes. Furthermore, the significant decrease in File occurrences (Clean: 1,835, Infected: 1,466) is concerning, as it could reflect malware erasing data, intercepting file access, or restricting access to critical files

The decrease in Semaphore objects (Clean: 437, Infected: 279) and Thread instances (Clean: 333, Infected: 309) could be a sign of malware interfering with synchronization and process execution. Likewise, the decrease of Port instances (Clean: 291, Infected: 238) raises the possibility of network communication manipulation. On the other hand, the rise in SymbolicLink objects (Clean: 133, Infected: 143) and Directory instances (Clean: 34, Infected: 57) suggests the development of hidden directories and efforts to reroute system operations

Comparison of Windows Object Instances Between Clean and Infected Memory Dumps

Windows Object	Number of instances in clean dump	Number of instances in infected Dump
FilterCommunicationPort	0	0
FilterConnection Port	0	0
IoCompletion	46	38
Driver	90	89
Device	3	344
Controller	2	2
Adapter	8	10
Key	630	557
Profile	0	0
Section	263	229
Desktop	7	7
Window Station	5	5
KeyedEvent	1	1
Timer	26	31
Semaphore	437	279
Callback	5	5
Mutant	148	147
EventPair	0	0
Event	1710	1496
Process	22	17
Debug Object	0	0
Job	2	1
Thread	333	309

WmiGuid	45	30
File	1835	1,466
WaitablePort	3	3
Port	291	238
Token	82	62
SymbolicLink	133	143
Directory	34	57
Type	31	31

Table 2b: the instances of each window object in both dumps

2. List the different Windows Station objects in both memory dumps and scan them.

How many of them can you find? What are their names? (10%)

The Windows operating system's Windows Station object is a kernel object in charge of controlling GUI elements and organizing input and output devices. Desktops use it as a container to construct windows, menus, and other visual components. While non-interactive Windows stations, like Service, manage background processes and services. Interactive stations, like WinSta0, enable user interactions via input devices like the keyboard and mouse. These items are essential for upholding access control and session separation. (Boutnaru 2023). I'll use the wndscan plugin to examine the Window Station objects in both memory dumps. By using memory forensic techniques, this tool can retrieve information straight from the memory dump, including the window's memory location, related process ID (PID), window title, and screen coordinates. It provides a thorough understanding of how Window Station objects are being used within the system by searching the Windows operating system's memory structures for and interpreting GUI-related data. (Batur, 2023).

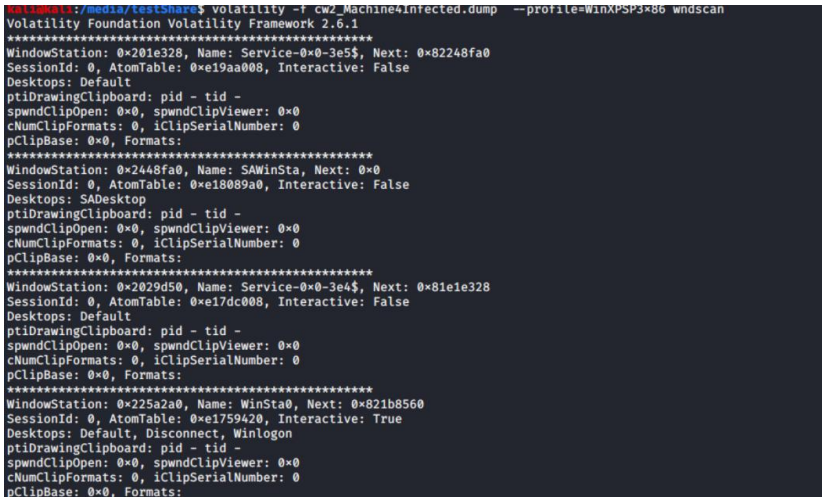


Figure 3: image of the Window objects in the infected dump using the plugin wndscan

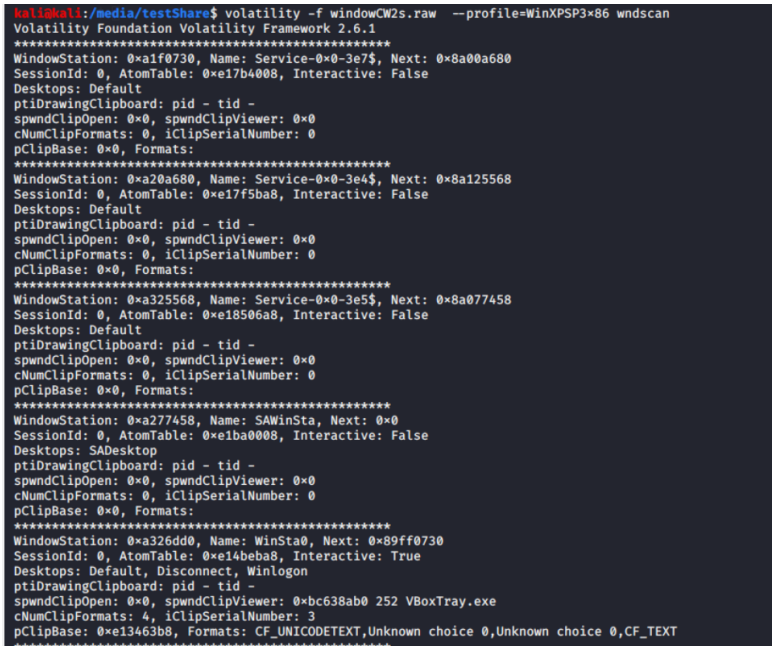


Figure 4: image of the Window objects in the clean dump using the plugin wndscan

As you can see in figure 3 and 4 it shows the window station object in clean and infected dump and below is the table which shows that. Window Station can be used for suspicious activity for authorised access to interactive desktops like Winsta0 and hijack user sessions and apart from there being missing station objects in the infected dump which can imply there is suspicious activity but in the infected dump the Winsta0 clipboard the entry CF_UNICODETEXT which shows the user can store or transfer text which is in exploited by malware to extract sensitive information.

Comparison of Window Station Object Counts in Clean and Infected Memory Dumps

Name of Window Station Object	How many in clean dump	How many in infected dump
SAWinSta	3	1
WinSta0	3	1
Service-0x0-3e5$,	2	1
Service-0x0-3e7$	3	1
Service-0x0-3e4$,	2	1

Table 4a: the number of times the window station appeared in both dumps

3. Identify every process that has an associated user, name the user, and discuss the level of privileges of each user in both memory dumps. (10%)

By linking each process to its corresponding user account and examining the privilege levels of these users, it is possible to identify processes within two memory dumps. As processes with higher privilege levels (such as Systems or Administrator) have more access to vital system resources and can be targets or routes for malicious behaviour as this is crucial for forensic investigations. (Robinson, Fishbein 2024). I am going to run the plugin getsids and this will show the process name, Process ID(PID), Security Identifies (SID) and the type of privilege each process has. (Ligh, Case Levy, Walters 2014)

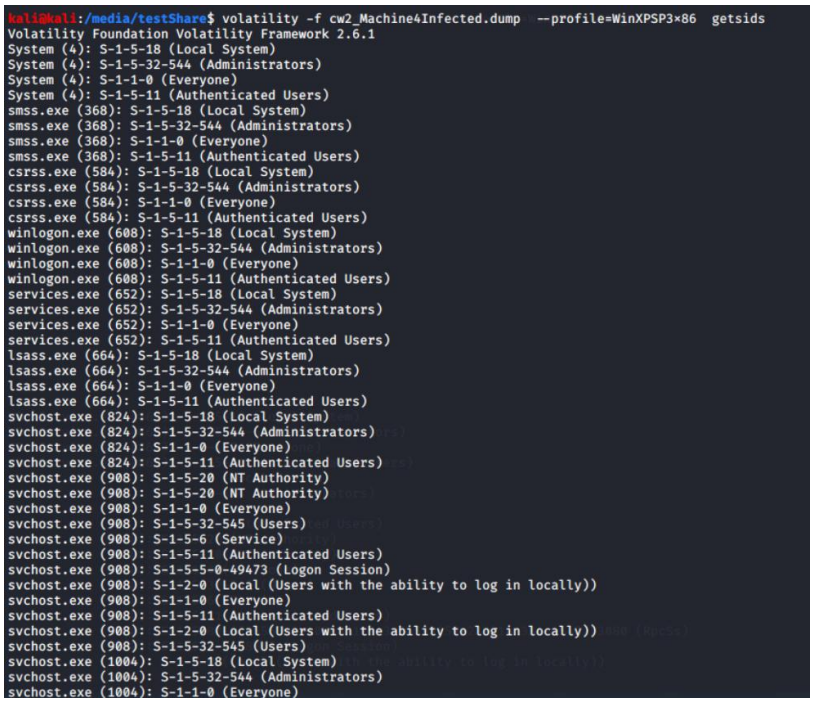


Figure 5: image of finding of process name,PID,SID,and type off privilege using the plugin getsids in the infected dump

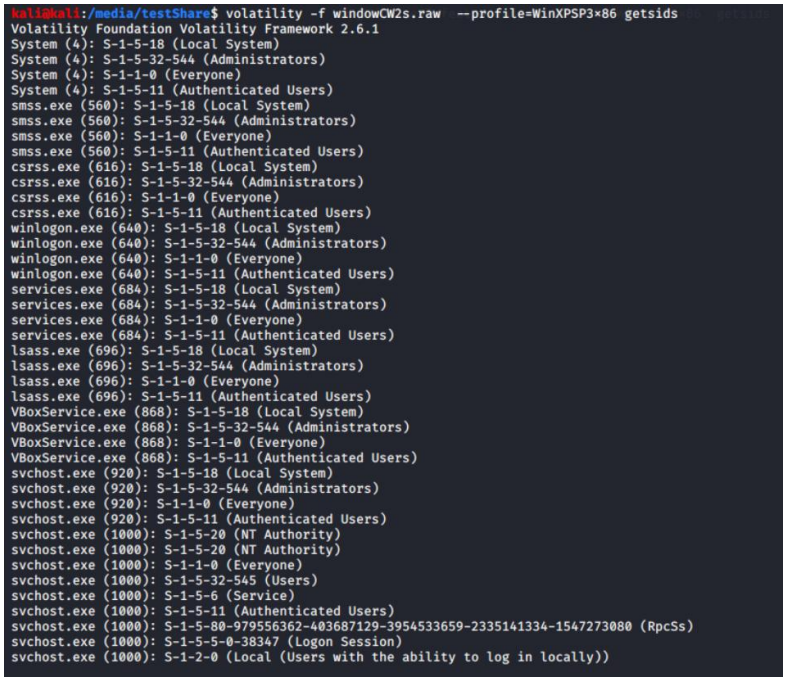


Figure 6: image of finding of process name,PID,SID,and type off privilege using the plugin getsids in the clean dump

In figure 5 and 6 you can see the outputs of the gettsids plugin which I ran and below is the table which I put all the data in.

Analysis of process privileges in clean and infected dump

Process Name	Associated user	Level of Privilege	Clean Dump	Infected Dump
System	S-1-5-18 (Local System)	High	Yes	Yes
System	S-1-5-32-544 (Administrators)	High	Yes	Yes
System	S-1-1-0 (Everyone)	Low	Yes	Yes
System	System (4): S-1-5-11 (Authenticated Users)	Medium	Yes	Yes
smss.exe	S-1-5-18 (Local System)	High	Yes	Yes
smss.exe	S-1-5-32-544 (Administrators)	High	Yes	Yes
smss.exe	S-1-1-0 (Everyone)	Low	Yes	Yes
smss.exe	S-1-5-11 (Authenticated Users)	Medium	Yes	Yes
csrss.exe	S-1-5-18 (Local System)	High	Yes	Yes
csrss.exe	S-1-5-32-544 (Administrators)	High	Yes	Yes
csrss.exe	S-1-1-0 (Everyone)	Low	Yes	Yes

csrss.exe	S-1-5-11 (Authenticated Users)	Medium	Yes	Yes
winlogon.exe	S-1-5-18 (Local System)	High	Yes	Yes
winlogon.exe	S-1-5-32-544 (Administrators)	High	Yes	Yes
winlogon.exe	S-1-1-0 (Everyone)	Low	Yes	Yes
winlogon.exe	S-1-5-11 (Authenticated Users)	Medium	Yes	Yes
services.exe	S-1-5-18 (Local System)	High	Yes	Yes
services.exe	S-1-5-32-544 (Administrators)	High	Yes	Yes
services.exe	S-1-1-0 (Everyone)	Low	Yes	Yes
services.exe	S-1-5-11 (Authenticated Users)	Medium	Yes	Yes
lsass.exe	S-1-5-18 (Local System)	High	Yes	Yes
lsass.exe	S-1-5-32-544 (Administrators)	High	Yes	Yes
lsass.exe	S-1-1-0 (Everyone)	Low	Yes	Yes
lsass.exe	S-1-5-11 (Authenticated Users)	Medium	Yes	Yes
VBoxService.exe	S-1-5-18 (Local System)	High	Yes	No
VBoxService.exe	S-1-5-32-544 (Administrators)	High	Yes	No
VBoxService.exe	S-1-1-0 (Everyone)	Low	Yes	No
VBoxService.exe	S-1-5-11 (Authenticated Users)	Medium	Yes	No

Table 6a : the process and there level of privilege and their associated user accounts

4. In the provided memory dump, enumerate the enabled privileges for every process that is not a critical process of the system. Indicate whether these privileges are indicators of compromise or not and explain why. (10%)

By spotting odd or unexpected privilege combinations, process privilege analysis is crucial for spotting illegal or possible harmful activity. The proper functioning of the operating system depends on core system processes, such as csrss.exe, smss.exe, and lsass.exe, which manage tasks including thread handling, session management, and security policy enforcement. As is typical in a protected system environment, these processes typically need enhanced privileges. On the other hand, privileges like SeDebugPrivilege and SeLoadDriverPrivilege shouldn't be needed by non-essential processes, which are frequently connected to user-installed apps or auxiliary services.

Forensic analysts can spot signs of compromise, including privilege escalation or misuse, which could indicate the presence of malware, code injection, or unauthorized system alterations. (Fox 2023). The plugin which I am going to run is the privs plugin and by running this I will be able to see privilege name and the attributes which include present, enabled or enabled by default. (Ligh, Case Levy, Walters 2014) This is going to be run in the infected dump as this is what I was given.

spoolsv.exe

The Windows Print Spooler service, spoolsv.exe, oversees handling printing tasks and corresponds with printer drivers (Velazco.Haag,Splunk 2024).Using the privs plugin there were some enabled privileges which were identified. SeDebugPrivilege makes it possible to access and modify other processes' memory, which is a common technique for inserting malicious code or obtaining private information. Device drivers can be loaded and unloaded using the SeLoadDriverPrivilege, which is frequently used to install malicious kernel drivers or rootkits. SeTcbPrivilege is a crucial route for privilege escalation since it also enables the process to mimic other users which includes administrators. Attackers can also read sensitive data, bypass access restrictions, and alter system files using privileges like SeBackupPrivilege and SeRestorePrivilege. The enabled privileges in spoolsv.exe show that it's been comprised as its only meant to be used for printing jobs and not using it for malicious activity.

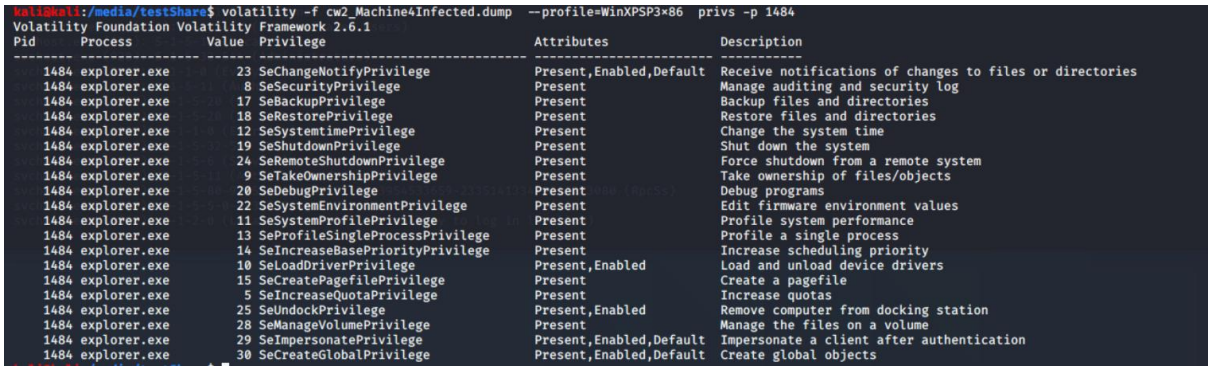
```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump  --profile=WinXPSP3x86  privs -p 1512
Volatility Foundation Volatility Framework 2.6.1
Pid      Process          Value  Privilege                         Attributes               Description
-------- ---------------- ------ --------------------------------- ------------------------ -----------
    1512 spoolsv.exe           7 SeTcbPrivilege                    Present,Enabled,Default  Act as part of the operating system
    1512 spoolsv.exe           2 SeCreateTokenPrivilege            Present                  Create a token object
    1512 spoolsv.exe           9 SeTakeOwnershipPrivilege          Present                  Take ownership of files/objects
    1512 spoolsv.exe          15 SeCreatePagefilePrivilege         Present,Enabled,Default  Create a pagefile
    1512 spoolsv.exe           4 SeLockMemoryPrivilege             Present,Enabled,Default  Lock pages in memory
    1512 spoolsv.exe           3 SeAssignPrimaryTokenPrivilege     Present                  Replace a process-level token
    1512 spoolsv.exe           5 SeIncreaseQuotaPrivilege          Present                  Increase quotas
    1512 spoolsv.exe          14 SeIncreaseBasePriorityPrivilege   Present,Enabled,Default  Increase scheduling priority
    1512 spoolsv.exe          16 SeCreatePermanentPrivilege        Present,Enabled,Default  Create permanent shared objects
    1512 spoolsv.exe          20 SeDebugPrivilege                  Present,Enabled,Default  Debug programs
    1512 spoolsv.exe          21 SeAuditPrivilege                  Present,Enabled,Default  Generate security audits
    1512 spoolsv.exe           8 SeSecurityPrivilege               Present                  Manage auditing and security log
    1512 spoolsv.exe          22 SeSystemEnvironmentPrivilege      Present                  Edit firmware environment values
    1512 spoolsv.exe          23 SeChangeNotifyPrivilege           Present,Enabled,Default  Receive notifications of changes to files or directories
    1512 spoolsv.exe          17 SeBackupPrivilege                 Present                  Backup files and directories
    1512 spoolsv.exe          18 SeRestorePrivilege                Present                  Restore files and directories
    1512 spoolsv.exe          19 SeShutdownPrivilege               Present                  Shut down the system
    1512 spoolsv.exe          10 SeLoadDriverPrivilege             Present,Enabled          Load and unload device drivers
    1512 spoolsv.exe          13 SeProfileSingleProcessPrivilege   Present,Enabled,Default  Profile a single process
    1512 spoolsv.exe          12 SeSystemtimePrivilege             Present                  Change the system time
    1512 spoolsv.exe          25 SeUndockPrivilege                 Present,Enabled          Remove computer from docking station
    1512 spoolsv.exe          28 SeManageVolumePrivilege           Present                  Manage the files on a volume
    1512 spoolsv.exe          29 SeImpersonatePrivilege            Present,Enabled,Default  Impersonate a client after authentication
    1512 spoolsv.exe          30 SeCreateGlobalPrivilege           Present,Enabled,Default  Create global objects
```

Figure 7: image of spoolsv.exe in infected dump using the plugin privs

explorer.exe

The main function of the Windows Explorer process, explorer.exe, is to provide the graphical user interface (GUI), which includes desktop navigation and file management (Glen, Lewis 2023). Using the privs plugin there were some enabled privileges which were identified. The operating system uses virtual memory pagefiles, which are created by the SeCreatePagefilePrivilege, to swap data to disk and increase physical memory. Although this privilege is usually linked to valid system functions, including controlling

memory usage or enhancing efficiency, attackers may use it maliciously. This access could be used by an attacker to conceal dangerous payloads in the pagefile, alter virtual memory, or overwrite private information. Also, the pagefile can be used to store and retrieve data without immediately leaving traces in physical memory, it might enable the attacker to bypass some security measures in a subtle way. The process explorer.exe shouldn't have that that as high enabled privilege and raises some concern and it can be comprised.



```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump  --profile=WinXPSP3x86  privs -p 1484
Volatility Foundation Volatility Framework 2.6.1
Pid      Process          Value  Privilege                       Attributes              Description
-------- ---------------- ------ ------------------------------- ----------------------- -----------
    1484 explorer.exe         23 SeChangeNotifyPrivilege         Present,Enabled,Default Receive notifications of changes to files or directories
    1484 explorer.exe          8 SeSecurityPrivilege             Present                 Manage auditing and security log
    1484 explorer.exe         17 SeBackupPrivilege               Present                 Backup files and directories
    1484 explorer.exe         18 SeRestorePrivilege              Present                 Restore files and directories
    1484 explorer.exe         12 SeSystemtimePrivilege           Present                 Change the system time
    1484 explorer.exe         19 SeShutdownPrivilege             Present                 Shut down the system
    1484 explorer.exe         24 SeRemoteShutdownPrivilege       Present                 Force shutdown from a remote system
    1484 explorer.exe          9 SeTakeOwnershipPrivilege        Present                 Take ownership of files/objects
    1484 explorer.exe         20 SeDebugPrivilege                Present                 Debug programs
    1484 explorer.exe         22 SeSystemEnvironmentPrivilege    Present                 Edit firmware environment values
    1484 explorer.exe         11 SeSystemProfilePrivilege        Present                 Profile system performance
    1484 explorer.exe         13 SeProfileSingleProcessPrivilege Present                 Profile a single process
    1484 explorer.exe         14 SeIncreaseBasePriorityPrivilege Present                 Increase scheduling priority
    1484 explorer.exe         10 SeLoadDriverPrivilege           Present,Enabled         Load and unload device drivers
    1484 explorer.exe         15 SeCreatePagefilePrivilege       Present                 Create a pagefile
    1484 explorer.exe          5 SeIncreaseQuotaPrivilege        Present                 Increase quotas
    1484 explorer.exe         25 SeUndockPrivilege               Present,Enabled         Remove computer from docking station
    1484 explorer.exe         28 SeManageVolumePrivilege         Present                 Manage the files on a volume
    1484 explorer.exe         29 SeImpersonatePrivilege          Present,Enabled,Default Impersonate a client after authentication
    1484 explorer.exe         30 SeCreateGlobalPrivilege         Present,Enabled,Default Create global objects
```

Figure 8: image of explorer.exe in infected dump using the plugin privs

reader_sl.exe

The reader_sl.exe process is linked to Adobe Reader's Speed Launcher and is intended to preload content for quicker PDF access and enhanced application functionality (Pilici 2023). Using the privs plugin there was some enabled privileges which was identified. SeCreateGlobalPrivilege's involvement in this process raises serious suspicions and may be a sign of compromise. This permission makes it possible to create global objects that are accessible by other processes and function beyond user sessions, including shared memory, mutexes, or events. By taking advantage of this, attackers can create persistence, which allows malicious programs to continue operating even after the system reboots. They might also create mutexes that prevent normal programs like antivirus software from operating or exploit global objects to store payloads and help other malware communicate with other processes. The existence of this permission strongly implies that the process may have been compromised and repurposed for illegal action and even though reader_sl.exe is a lightweight utility that does not need to generate global objects for its intended function.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump  --profile=WinXPSP3x86  privs -p 1640
Volatility Foundation Volatility Framework 2.6.1
Pid      Process          Value  Privilege                       Attributes              Description
-------- ---------------- ------ ------------------------------- ----------------------- -----------
    1640 reader_sl.exe        23 SeChangeNotifyPrivilege         Present,Enabled,Default Receive notifications of changes to files or directories
    1640 reader_sl.exe         8 SeSecurityPrivilege             Present                 Manage auditing and security log
    1640 reader_sl.exe        17 SeBackupPrivilege               Present                 Backup files and directories
    1640 reader_sl.exe        18 SeRestorePrivilege              Present                 Restore files and directories
    1640 reader_sl.exe        12 SeSystemtimePrivilege           Present                 Change the system time
    1640 reader_sl.exe        19 SeShutdownPrivilege             Present                 Shut down the system
    1640 reader_sl.exe        24 SeRemoteShutdownPrivilege       Present                 Force shutdown from a remote system
    1640 reader_sl.exe         9 SeTakeOwnershipPrivilege        Present                 Take ownership of files/objects
    1640 reader_sl.exe        20 SeDebugPrivilege                Present                 Debug programs
    1640 reader_sl.exe        22 SeSystemEnvironmentPrivilege    Present                 Edit firmware environment values
    1640 reader_sl.exe        11 SeSystemProfilePrivilege        Present                 Profile system performance
    1640 reader_sl.exe        13 SeProfileSingleProcessPrivilege Present                 Profile a single process
    1640 reader_sl.exe        14 SeIncreaseBasePriorityPrivilege Present                 Increase scheduling priority
    1640 reader_sl.exe        10 SeLoadDriverPrivilege           Present,Enabled         Load and unload device drivers
    1640 reader_sl.exe        15 SeCreatePagefilePrivilege       Present                 Create a pagefile
    1640 reader_sl.exe         5 SeIncreaseQuotaPrivilege        Present                 Increase quotas
    1640 reader_sl.exe        25 SeUndockPrivilege               Present,Enabled         Remove computer from docking station
    1640 reader_sl.exe        28 SeManageVolumePrivilege         Present                 Manage the files on a volume
    1640 reader_sl.exe        29 SeImpersonatePrivilege          Present,Enabled,Default Impersonate a client after authentication
    1640 reader_sl.exe        30 SeCreateGlobalPrivilege         Present,Enabled,Default Create global objects
```

Figure 9: image of reader_sl.exe in infected dump using the plugin privs

alg.exe

The Application Layer Gateway Service, or alg.exe, is a valid Windows operating system process. Its main duties include enabling network connectivity for programs like internet browsers and FTP clients and supporting third-party protocol plug-ins (Boutnaru 2023). Using the privs plugin there was one enabled privilege which were identified. The alg.exe process has the SeShutdownPrivilege enabled, which enables it to start a system shutdown or reboot. For a process like alg.exe, which is mostly connected to the Application Layer Gateway service for internet connection sharing and firewall functions, this permission is not common, even though it can occasionally be acceptable in particular situations. This privilege's existence is concerning because malicious individuals may use it to force a shutdown or reboot, install harmful modifications, evade detection, or interfere with system functionality. This behaviour might be a sign of compromise or privilege escalation, particularly if alg.exe is discovered operating from unusual paths or with unexpected parent processes.

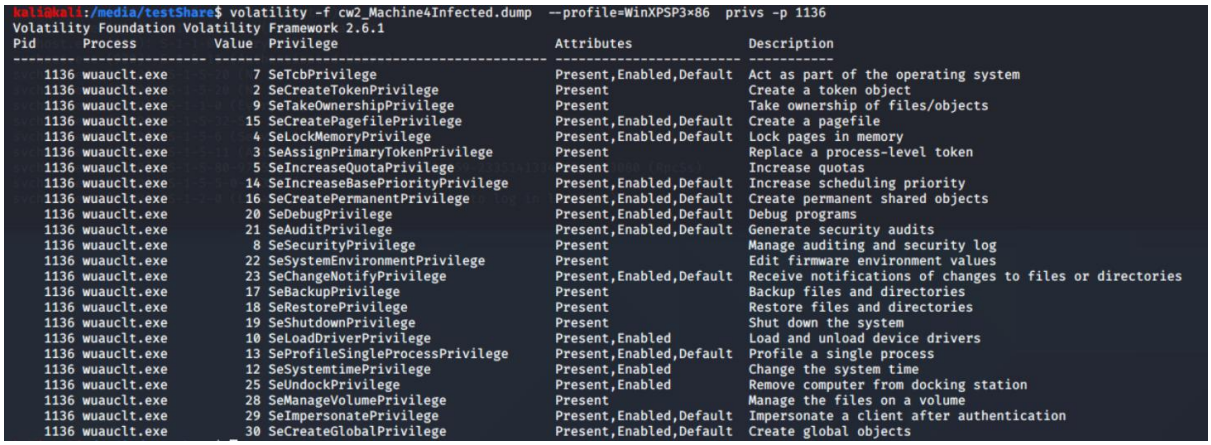
```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump  --profile=WinXPSP3x86  privs -p 788
Volatility Foundation Volatility Framework 2.6.1
Pid      Process          Value  Privilege                       Attributes              Description
-------- ---------------- ------ ------------------------------- ----------------------- -----------
     788 alg.exe              21 SeAuditPrivilege                Present                 Generate security audits
     788 alg.exe               5 SeIncreaseQuotaPrivilege        Present                 Increase quotas
     788 alg.exe               3 SeAssignPrimaryTokenPrivilege   Present                 Replace a process-level token
     788 alg.exe              23 SeChangeNotifyPrivilege         Present,Enabled,Default Receive notifications of changes to files or directories
     788 alg.exe              19 SeShutdownPrivilege             Present                 Shut down the system
     788 alg.exe              25 SeUndockPrivilege               Present                 Remove computer from docking station
     788 alg.exe              29 SeImpersonatePrivilege          Present,Enabled,Default Impersonate a client after authentication
     788 alg.exe              30 SeCreateGlobalPrivilege         Present,Enabled,Default Create global objects
```

Figure 10: image of alge.exe in infected dump using the plugin privs

wuauclt.exe

The Windows Update AutoUpdate Client process is called wuauclt.exe. It is a valid Windows system process that oversees looking for and downloading Windows operating system updates (Anna 2024). Using the privs plugin several enabled privileges were identified. SeTcbPrivilege is a high-risk privilege that is frequently misused by attackers to pose as privileged users and escalate privileges, even though it is not required for wuauclt.exe to perform its proper function as a Windows Update Client. Like this, SeDebugPrivilege is another high-risk privilege that permits access to and

control over other processes' memory; it is frequently used to insert malicious code or alter active processes because it can be misused to install malicious drivers or rootkits. SeLoadDriverPrivilege, which permits the loading of kernel-mode drivers, is especially suspicious in non-critical processes. SeImpersonatePrivilege is also a common target for lateral movement or privilege escalation attacks because it allows impersonation of higher-privileged users.



```
kali㉿kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump  --profile=WinXPSP3x86  privs -p 1136
Volatility Foundation Volatility Framework 2.6.1
Pid      Process          Value  Privilege                       Attributes              Description
-------- ---------------- ------ ------------------------------- ----------------------- -----------
    1136 wuauclt.exe           7 SeTcbPrivilege                  Present,Enabled,Default  Act as part of the operating system
    1136 wuauclt.exe           2 SeCreateTokenPrivilege          Present                  Create a token object
    1136 wuauclt.exe           9 SeTakeOwnershipPrivilege        Present                  Take ownership of files/objects
    1136 wuauclt.exe          15 SeCreatePagefilePrivilege       Present,Enabled,Default  Create a pagefile
    1136 wuauclt.exe           4 SeLockMemoryPrivilege           Present,Enabled,Default  Lock pages in memory
    1136 wuauclt.exe           3 SeAssignPrimaryTokenPrivilege   Present                  Replace a process-level token
    1136 wuauclt.exe           5 SeIncreaseQuotaPrivilege        Present                  Increase quotas
    1136 wuauclt.exe          14 SeIncreaseBasePriorityPrivilege Present,Enabled,Default  Increase scheduling priority
    1136 wuauclt.exe          16 SeCreatePermanentPrivilege      Present,Enabled,Default  Create permanent shared objects
    1136 wuauclt.exe          20 SeDebugPrivilege                Present,Enabled,Default  Debug programs
    1136 wuauclt.exe          21 SeAuditPrivilege                Present,Enabled,Default  Generate security audits
    1136 wuauclt.exe           8 SeSecurityPrivilege             Present                  Manage auditing and security log
    1136 wuauclt.exe          22 SeSystemEnvironmentPrivilege    Present                  Edit firmware environment values
    1136 wuauclt.exe          23 SeChangeNotifyPrivilege         Present,Enabled,Default  Receive notifications of changes to files or directories
    1136 wuauclt.exe          17 SeBackupPrivilege               Present                  Backup files and directories
    1136 wuauclt.exe          18 SeRestorePrivilege              Present                  Restore files and directories
    1136 wuauclt.exe          19 SeShutdownPrivilege             Present                  Shut down the system
    1136 wuauclt.exe          10 SeLoadDriverPrivilege           Present,Enabled          Load and unload device drivers
    1136 wuauclt.exe          13 SeProfileSingleProcessPrivilege Present,Enabled,Default  Profile a single process
    1136 wuauclt.exe          12 SeSystemtimePrivilege           Present,Enabled          Change the system time
    1136 wuauclt.exe          25 SeUndockPrivilege               Present,Enabled          Remove computer from docking station
    1136 wuauclt.exe          28 SeManageVolumePrivilege         Present                  Manage the files on a volume
    1136 wuauclt.exe          29 SeImpersonatePrivilege          Present,Enabled,Default  Impersonate a client after authentication
    1136 wuauclt.exe          30 SeCreateGlobalPrivilege         Present,Enabled,Default  Create global objects
```

Figure 11: image of wuauclt.exe in infected dump using the plugin privs

5. Enumerate the handles and symbolic links of each memory dump and describe 5 handles and symbolic links that are different. How many handles and symbolic links are in total in both memory dumps? (10%)

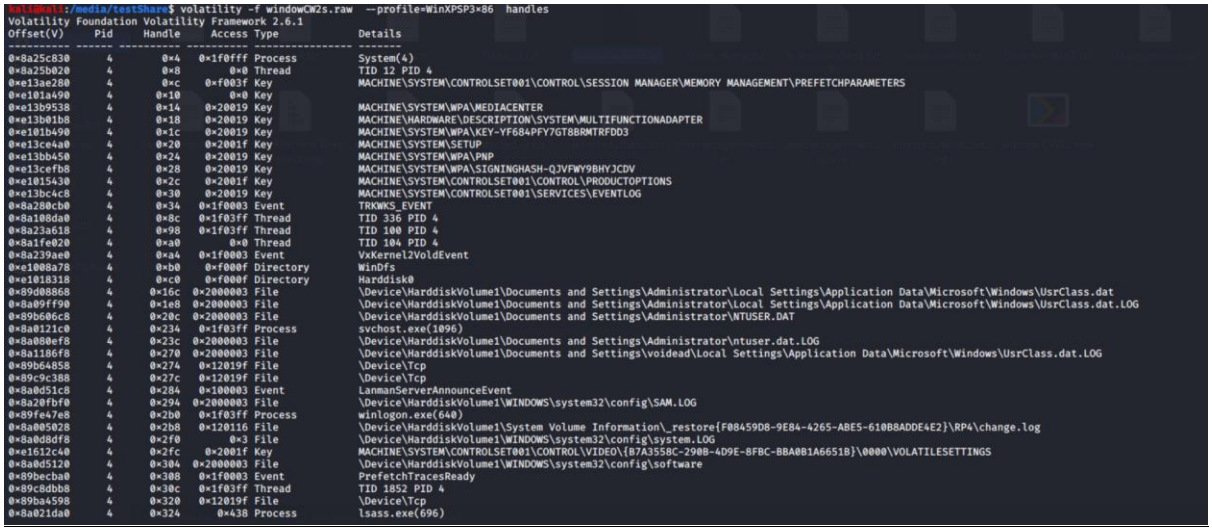
The operating system uses handles, which are references to control access to resources such as registry keys, files, processes, and threads. Without having direct access, they give processes a means of interacting with system resources. To find questionable or malevolent activity, the handles plugin analyses open handles in memory dump, revealing information such as object type, related process, and access privileges. File-system objects known as symbolic links serve as shortcuts or pointers to other files, directories, or devices. They give resource management flexibility by enabling the operating system to reroute access from one path or resource name to another. Device mappings, registry paths, and filesystem redirection are common uses for symbolic links. Nonetheless, they can uncover efforts to conceal or reroute system activity in memory forensics, which makes them helpful in identifying malware or unapproved setups (. Ligh, Case Levy, Walters 2014) The plugin which I am going to run is symlinkscan which shows the detailed list of links, showing the symbolic link name and where the file or link points too.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw  --profile=WinXPSP3x86  symlinkscan
Volatility Foundation Volatility Framework 2.6.1
Offset(P)           #Ptr   #Hnd Creation time                From                 To
------------------ ------ ------ ------------------------------ -------------------- ----------------------------------------------------------
0x000000000a9f2590      1      0 2024-11-14 09:36:50 UTC+0000   RdpDrDvMgr           \Device\RdpDrDvMgr
0x000000000a9f2610      1      0 2024-11-14 09:36:50 UTC+0000   PTILINK3             \Device\ParTechInc2
0x000000000a9f58f0      1      0 2024-11-14 09:36:49 UTC+0000   FltMgr               \FileSystem\Filters\FltMgr
0x000000000a9fe290      1      0 2024-11-14 09:36:48 UTC+0000   DmLoader             \Device\DmLoader
0x000000000aa2e270      1      0 2024-11-14 09:36:47 UTC+0000   DosDevices           \??
0x000000000aa2f5d8      1      0 2024-11-14 09:36:51 UTC+0000   SystemRoot           \Device\Harddisk0\Partition1\WINDOWS
0x000000000aa33ef0      1      0 2024-11-14 09:36:49 UTC+0000   VBoxGuest            \Device\VBoxGuest
0x000000000aa66298      1      0 2024-11-14 09:36:49 UTC+0000   STORAGE#V ... 91efb8b} \Device\HarddiskVolume1
0x000000000aa811f0      1      0 2024-11-14 09:36:48 UTC+0000   FtControl            \Device\FtControl
0x000000000aa81248      1      0 2024-11-14 09:36:48 UTC+0000   DmTrace              \Device\DmControl\DmTrace
0x000000000aa81298      1      0 2024-11-14 09:36:48 UTC+0000   DmIoDaemon           \Device\DmControl\DmIoDaemon
0x000000000aa816f8      1      0 2024-11-14 09:36:47 UTC+0000   Global               \GLOBAL??
0x000000000aa81c70      1      0 2024-11-14 09:36:48 UTC+0000   ScsiPort0            \Device\Ide\IdePort0
0x000000000aa89290      1      0 2024-11-14 09:36:49 UTC+0000   multi(0)d ... ition(2) \Device\Harddisk0\Partition2
0x000000000aa899b8      1      0 2024-11-14 09:36:50 UTC+0000   Volume{d8 ... 172696f} \Device\CdRom0
0x000000000aac5a10      1      0 2024-11-14 09:36:48 UTC+0000   ScsiPort1            \Device\Ide\IdePort1
0x000000000aac71b8      1      0 2024-11-14 09:36:49 UTC+0000   Volume{d8 ... 172696f} \Device\HarddiskVolume1
0x000000000aac7378      1      0 2024-11-14 09:36:50 UTC+0000   INTELPRO_ ... 340EF57} \Device\INTELPRO_{F482B08F-B60E-471C-9699-493DD340EF57}
0x000000000aace240      1      0 2024-11-14 09:36:48 UTC+0000   Root#ftdi ... 91efb8b} \Device\00000004
0x000000000ab012f0      1      0 2024-11-14 09:36:49 UTC+0000   Partition1           \Device\HarddiskVolume1
0x000000000ab01b78      1      0 2024-11-14 09:36:49 UTC+0000   multi(0)d ... rdisk(0) \Device\Harddisk0\Partition0
0x000000000adbdc78      1      0 2024-11-14 09:36:49 UTC+0000   IDE#DiskV ... 91efb8b} \Device\Ide\IdeDeviceP0T0L0-3
0x000000000adbfd98      1      0 2024-11-14 09:36:49 UTC+0000   C:                   \Device\HarddiskVolume1
0x000000000adf6270      1      0 2024-11-14 09:36:47 UTC+0000   ACPI#Fixe ... 9062857} \Device\0000003c
0x000000000adfb2e8      1      0 2024-11-14 09:36:48 UTC+0000   MountPointManager    \Device\MountPointManager
0x000000000adfb360      1      0 2024-11-14 09:36:49 UTC+0000   multi(0)d ... ition(4) \Device\Harddisk0\Partition4
0x000000000adfc8c0      1      0 2024-11-14 09:36:51 UTC+0000   UNC                  \Device\Mup
0x000000000adfd1f0      1      0 2024-11-14 09:36:49 UTC+0000   NDIS                 \Device\Ndis
0x000000000adfd5d8      1      0 2024-11-14 09:36:52 UTC+0000   Local                \BaseNamedObjects
0x000000000ae291f0      1      0 2024-11-14 09:36:52 UTC+0000   LCD                  \Device\VideoPdo0
0x000000000ae2c1b0      1      0 2024-11-14 09:36:50 UTC+0000   Root#SYST ... 4c10000} \Device\00000036
0x000000000ae2d668      1      0 2024-11-14 09:36:48 UTC+0000   Root#dmio ... 91efb8b} \Device\00000003
0x000000000ae2e6a0      1      0 2024-11-14 09:36:49 UTC+0000   multi(0)d ... ition(3) \Device\Harddisk0\Partition3
0x000000000ae2eca0      1      0 2024-11-14 09:36:52 UTC+0000   Global               \BaseNamedObjects
0x000000000ae33c48      1      0 2024-11-14 09:36:48 UTC+0000   DmConfig             \Device\DmControl\DmConfig
0x000000000ae35198      1      0 2024-11-14 09:36:49 UTC+0000   FltMgrMsg            \FileSystem\Filters\FltMgrMsg
0x000000000ae35768      1      0 2024-11-14 09:36:48 UTC+0000   Scsi1:               \Device\Ide\IdePort1
0x000000000ae37400      1      0 2024-11-14 09:36:48 UTC+0000   DmInfo               \Device\DmControl\DmInfo
0x000000000ae53a38      1      0 2024-11-14 09:36:50 UTC+0000   Root#MS_P ... fc3358c} \Device\00000032
```

Figure 12: image of clean dump using the plugin symlinkscan

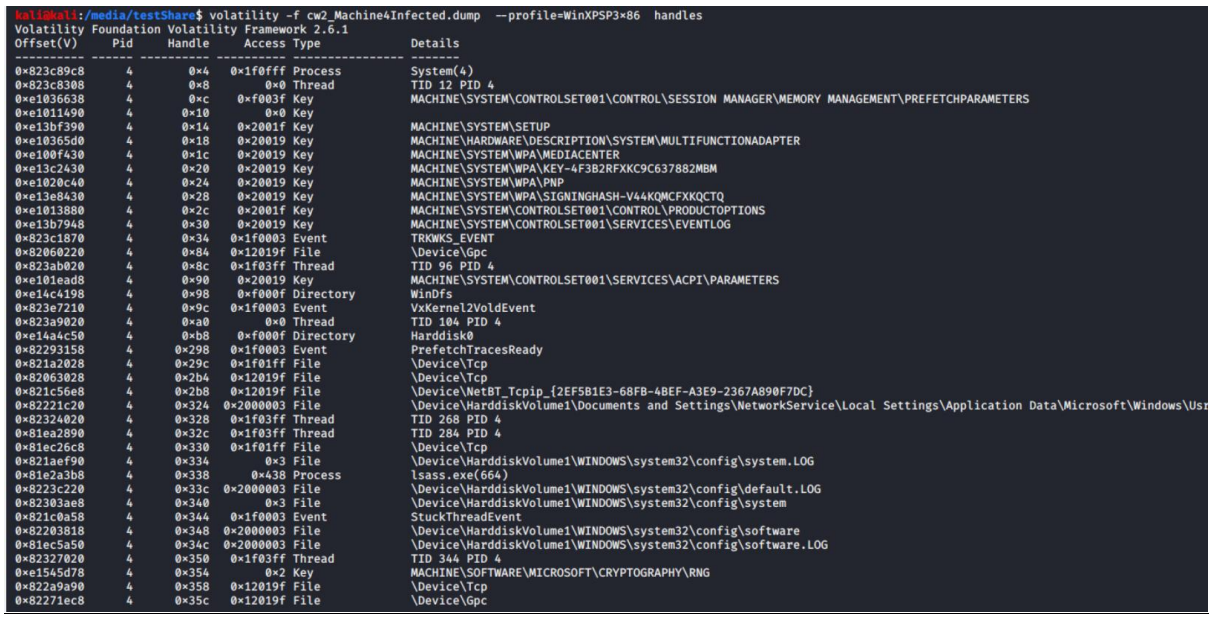
```
kali@kali:/media/testShare$ volatility -f cw2_Machine41nfected.dump  --profile=WinXPSP3x86  symlinkscan
Volatility Foundation Volatility Framework 2.6.1
Offset(P)           #Ptr   #Hnd Creation time                From                 To
------------------ ------ ------ ------------------------------ -------------------- ----------------------------------------------------------
0x00000000029f5518      1      0 2012-07-22 02:42:24 UTC+0000   Global               \GLOBAL??
0x00000000029f6b10      1      0 2012-07-22 02:42:32 UTC+0000   HID#Vid_0 ... 1000030} \Device\0000007b
0x00000000029f6be0      1      0 2012-07-22 02:42:32 UTC+0000   HID#Vid_0 ... 91405dd} \Device\0000007b
0x00000000029fd748      1      0 2012-07-22 02:42:24 UTC+0000   DosDevices           \??
0x00000000029ff470      1      0 2012-07-22 02:42:31 UTC+0000   SystemRoot           \Device\Harddisk0\Partition1\WINDOWS
0x0000000002a301c8      1      0 2012-07-22 02:42:35 UTC+0000   Global               \Global??
0x0000000002a30870      1      0 2012-07-22 02:42:31 UTC+0000   IPNAT                \Device\IPNAT
0x0000000002a45118      1      0 2012-07-22 02:42:29 UTC+0000   IDE#DiskV ... 91efb8b} \Device\Ide\IdeDeviceP0T0L0-3
0x0000000002a4f2a8      1      0 2012-07-22 02:42:25 UTC+0000   WMIDataDevice        \Device\WMIDataDevice
0x0000000002a8e108      1      0 2012-07-22 02:42:31 UTC+0000   NUL                  \Device\Null
0x0000000002ac40c8      1      0 2012-07-22 02:42:26 UTC+0000   ACPI#Fixe ... 9062857} \Device\00000037
0x0000000002b40dd8      1      0 2012-07-22 02:42:27 UTC+0000   Scsi0:               \Device\Ide\IdePort0
0x0000000002e39d28      1      0 2012-07-22 02:42:32 UTC+0000   Session              \Sessions\BNOLINKS
0x0000000002e49aa0      1      0 2012-07-22 02:42:31 UTC+0000   Ip                   \Device\Ip
0x0000000002e8a098      1      0 2012-07-22 02:42:30 UTC+0000   HCD1                 \Device\USBFDO-1
0x0000000002e8a0e8      1      0 2012-07-22 02:42:30 UTC+0000   A:                   \Device\Floppy0
0x0000000002e8c980      1      0 2012-07-22 02:42:29 UTC+0000   multi(0)d ... ition(3) \Device\Harddisk0\Partition3
0x0000000002e8ca20      1      0 2012-07-22 02:42:29 UTC+0000   multi(0)d ... ition(2) \Device\Harddisk0\Partition2
0x0000000003067e50      1      0 2012-07-22 02:42:27 UTC+0000   ScsiPort0            \Device\Ide\IdePort0
0x0000000003069540      1      0 2012-07-22 02:42:29 UTC+0000   Volume{d8 ... 172696f} \Device\HarddiskVolume1
0x000000000307d950      1      0 2012-07-22 02:42:27 UTC+0000   DmTrace              \Device\DmControl\DmTrace
0x00000000003088cb0     1      0 2012-07-22 02:42:27 UTC+0000   MountPointManager    \Device\MountPointManager
0x00000000003088dd8     1      0 2012-07-22 02:42:29 UTC+0000   STORAGE#V ... 91efb8b} \Device\HarddiskVolume1
0x000000000308b578      1      0 2012-07-22 02:42:27 UTC+0000   DmConfig             \Device\DmControl\DmConfig
0x000000000308b5c8      1      0 2012-07-22 02:42:27 UTC+0000   DmLoader             \Device\DmLoader
0x00000000030d8530      1      0 2012-07-22 02:42:29 UTC+0000   PhysicalDrive0       \Device\Harddisk0\DR0
0x00000000030dae88      1      0 2012-07-22 02:42:27 UTC+0000   CompositeBattery     \Device\CompositeBattery
0x00000000030ec8f0      1      0 2012-07-22 02:42:30 UTC+0000   Root#RDP_ ... 91405dd} \Device\0000002c
0x00000000030ec980      1      0 2012-07-22 02:42:30 UTC+0000   ACPI#PNP0 ... 91405dd} \Device\0000006a
0x00000000030ec9d8      1      0 2012-07-22 02:42:30 UTC+0000   PCI#VEN_1 ... 9223196} \Device\NTPNP_PCI0042
0x00000000030ecaf8      1      0 2012-07-22 02:42:30 UTC+0000   Root#MS_P ... fc3358c} \Device\0000002a
0x00000000030ecd88      1      0 2012-07-22 02:42:29 UTC+0000   Partition1           \Device\HarddiskVolume1
0x0000000003105f20      1      0 2012-07-22 02:42:30 UTC+0000   COM2                 \Device\Serial1
0x0000000003155920      1      0 2012-07-22 02:42:31 UTC+0000   IPSECDev             \Device\IPSEC
0x0000000003155b10      1      0 2012-07-22 02:42:29 UTC+0000   multi(0)d ... ition(4) \Device\Harddisk0\Partition4
0x00000000031c0c18      1      0 2012-07-22 02:42:27 UTC+0000   DmInfo               \Device\DmControl\DmInfo
```

Figure 13: image of infected dump using the plugin symlinkscan



```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw  --profile=WinXPSP3x86  handles
Volatility Foundation Volatility Framework 2.6.1
Offset(V)    Pid    Handle     Access Type          Details
---------- ------ ---------- ---------- ---------------- -------
0x8a25c830      4        0x4   0x1f0fff Process          System(4)
0x8a25b020      4        0x8        0x0 Thread           TID 12 PID 4
0xe13ae280      4        0xc    0xf003f Key              MACHINE\SYSTEM\CONTROLSET001\CONTROL\SESSION MANAGER\MEMORY MANAGEMENT\PREFETCHPARAMETERS
0xe101a490      4       0x10        0x0 Key
0xe13b9538      4       0x14    0x20019 Key              MACHINE\SYSTEM\WPA\MEDIACENTER
0xe13b81b8      4       0x18    0x20019 Key              MACHINE\HARDWARE\DESCRIPTION\SYSTEM\MULTIFUNCTIONADAPTER
0xe101b490      4       0x1c    0x20019 Key              MACHINE\SYSTEM\WPA\KEY-YF684PFY7GT8BRMTRFDD3
0xe13ce4a0      4       0x20    0x2001f Key              MACHINE\SYSTEM\SETUP
0xe13bb450      4       0x24    0x20019 Key              MACHINE\SYSTEM\WPA\PNP
0xe13cefb8      4       0x28    0x20019 Key              MACHINE\SYSTEM\WPA\SIGNINGHASH-QJVFWY9BHYJCDV
0xe1015430      4       0x2c    0x2001f Key              MACHINE\SYSTEM\CONTROLSET001\CONTROL\PRODUCTOPTIONS
0xe13bc4c8      4       0x30    0x20019 Key              MACHINE\SYSTEM\CONTROLSET001\SERVICES\EVENTLOG
0x8a280cb0      4       0x34   0x1f0003 Event            TRKWKS_EVENT
0x8a108da0      4       0x8c   0x1f03ff Thread           TID 336 PID 4
0x8a23a618      4       0x98   0x1f03ff Thread           TID 100 PID 4
0x8a1fe020      4       0xa0        0x0 Thread           TID 104 PID 4
0x8a239ae0      4       0xa4   0x1f0003 Event            VxKernel2VoldEvent
0xe1008a78      4       0xb0    0xf000f Directory        WinDfs
0xe1018318      4       0xc0    0xf000f Directory        Harddisk0
0x89d08868      4      0x16c  0x2000003 File             \Device\HarddiskVolume1\Documents and Settings\Administrator\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
0x8a09ff90      4      0x1e8  0x2000003 File             \Device\HarddiskVolume1\Documents and Settings\Administrator\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat.LOG
0x89b606c8      4      0x20c  0x2000003 File             \Device\HarddiskVolume1\Documents and Settings\Administrator\NTUSER.DAT
0x8a121c0       4      0x234   0x1f03ff Process          svchost.exe(1096)
0x8a080ef8      4      0x23c  0x2000003 File             \Device\HarddiskVolume1\Documents and Settings\Administrator\ntuser.dat.LOG
0x8a1186f8      4      0x270  0x2000003 File             \Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat.LOG
0x89b64858      4      0x274   0x12019f File             \Device\Tcp
0x89c9c388      4      0x27c   0x12019f File             \Device\Tcp
0x8a0d51c8      4      0x284   0x100003 Event            LanmanServerAnnounceEvent
0x8a20fbf0      4      0x294  0x2000003 File             \Device\HarddiskVolume1\WINDOWS\system32\config\SAM.LOG
0x89fe47e8      4      0x2b0   0x1f03ff Process          winlogon.exe(640)
0x8a05020       4      0x2b8   0x120116 File             \Device\HarddiskVolume1\System Volume Information\_restore{F08459D8-9E84-4265-ABE5-610B8ADDE4E2}\RP4\change.log
0x8a0d8df8      4      0x2f0        0x3 File             \Device\HarddiskVolume1\WINDOWS\system32\config\system.LOG
0xe1612c40      4      0x2fc    0x2001f Key              MACHINE\SYSTEM\CONTROLSET001\CONTROL\VIDEO\{B7A3558C-290B-4D9E-8FBC-BBA0B1A6651B}\0000\VOLATILESETTINGS
0x8a0d5120      4      0x304  0x2000003 File             \Device\HarddiskVolume1\WINDOWS\system32\config\software
0x89becba0      4      0x308   0x1f0003 Event            PrefetchTracesReady
0x89c8dbb8      4      0x30c   0x1f03ff Thread           TID 1852 PID 4
0x89ba4598      4      0x320   0x12019f File             \Device\Tcp
0x8a021da0      4      0x324       0x438 Process         lsass.exe(696)
```

Figure 14: image of clean dump using the plugin handles



```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump  --profile=WinXPSP3x86  handles
Volatility Foundation Volatility Framework 2.6.1
Offset(V)    Pid    Handle     Access Type          Details
---------- ------ ---------- ---------- ---------------- -------
0x823c89c8      4        0x4   0x1f0fff Process          System(4)
0x823c8308      4        0x8        0x0 Thread           TID 12 PID 4
0xe1036638      4        0xc    0xf003f Key              MACHINE\SYSTEM\CONTROLSET001\CONTROL\SESSION MANAGER\MEMORY MANAGEMENT\PREFETCHPARAMETERS
0xe1011490      4       0x10        0x0 Key
0xe13bf390      4       0x14    0x2001f Key              MACHINE\SYSTEM\SETUP
0xe10365d0      4       0x18    0x20019 Key              MACHINE\HARDWARE\DESCRIPTION\SYSTEM\MULTIFUNCTIONADAPTER
0xe100f430      4       0x1c    0x20019 Key              MACHINE\SYSTEM\WPA\MEDIACENTER
0xe13c2430      4       0x20    0x20019 Key              MACHINE\SYSTEM\WPA\KEY-4F3B2RFXKC9C637882MBM
0xe1020c40      4       0x24    0x20019 Key              MACHINE\SYSTEM\WPA\PNP
0xe13e8430      4       0x28    0x20019 Key              MACHINE\SYSTEM\WPA\SIGNINGHASH-V44KQMCFXKQCTQ
0xe1013880      4       0x2c    0x2001f Key              MACHINE\SYSTEM\CONTROLSET001\CONTROL\PRODUCTOPTIONS
0xe13b7948      4       0x30    0x20019 Key              MACHINE\SYSTEM\CONTROLSET001\SERVICES\EVENTLOG
0x823c1870      4       0x34   0x1f0003 Event            TRKWKS_EVENT
0x82060220      4       0x84   0x12019f File             \Device\Gpc
0x823ab020      4       0x8c   0x1f03ff Thread           TID 96 PID 4
0xe101ead8      4       0x90    0x20019 Key              MACHINE\SYSTEM\CONTROLSET001\SERVICES\ACPI\PARAMETERS
0xe14c4198      4       0x98    0xf000f Directory        WinDfs
0x823e7210      4       0x9c   0x1f0003 Event            VxKernel2VoldEvent
0x823a9020      4       0xa0        0x0 Thread           TID 104 PID 4
0xe14a4c50      4       0xb8    0xf000f Directory        Harddisk0
0x82293158      4      0x298   0x1f0003 Event            PrefetchTracesReady
0x821a2028      4      0x29c   0x1f01ff File             \Device\Tcp
0x82063028      4      0x2b4   0x12019f File             \Device\Tcp
0x821c56e8      4      0x2b8   0x12019f File             \Device\NetBT_Tcpip_{2EF5B1E3-68FB-4BEF-A3E9-2367A890F7DC}
0x82221c20      4      0x324  0x2000003 File             \Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\Usr
0x82324020      4      0x328   0x1f03ff Thread           TID 268 PID 4
0x81ea2890      4      0x32c   0x1f03ff Thread           TID 284 PID 4
0x81ec26c8      4      0x330   0x1f01ff File             \Device\Tcp
0x821aef90      4      0x334        0x3 File             \Device\HarddiskVolume1\WINDOWS\system32\config\system.LOG
0x81e2a3b8      4      0x338      0x438 Process          lsass.exe(664)
0x8223c220      4      0x33c  0x2000003 File             \Device\HarddiskVolume1\WINDOWS\system32\config\default.LOG
0x82303ae8      4      0x340        0x3 File             \Device\HarddiskVolume1\WINDOWS\system32\config\system
0x821c0a58      4      0x344   0x1f0003 Event            StuckThreadEvent
0x82203818      4      0x348  0x2000003 File             \Device\HarddiskVolume1\WINDOWS\system32\config\software
0x81ec5a50      4      0x34c  0x2000003 File             \Device\HarddiskVolume1\WINDOWS\system32\config\software.LOG
0x82327020      4      0x350   0x1f03ff Thread           TID 344 PID 4
0xe1545d78      4      0x354        0x2 Key              MACHINE\SOFTWARE\MICROSOFT\CRYPTOGRAPHY\RNG
0x822a9a90      4      0x358   0x12019f File             \Device\Tcp
0x82271ec8      4      0x35c   0x12019f File             \Device\Gpc
```

Figure 15: image of infected dump using the plugin handles`

Symbolic link in clean dump

Offset (P)	Ptr	Hnd	Creation Time	From	To
0x000000000a9f2590	1	0	2024-11-14 09:36:50 UTC+0000	RdpDrDvMgr	\Device\RdpDrDvMgr
0x000000000a9f2610	1	0	2024-11-14 09:36:50 UTC+0000	PTILINK3	\Device\ParTechInc2
0x000000000a9f58f0	1	0	2024-11-14 09:36:49 UTC+0000	FltMgr	\FileSystem\Filters\FltMgr

x000000000a9fe290	1	0	2024-11-14 09:36:48 UTC+0000	DmLoader	\Device\DmLoader
0x000000000aa2e270	1	0	2024-11-14 09:36:47 UTC+0000	DosDevices	??
0x000000000aa2f5d8	1	0	2024-11-14 09:36:51 UTC+0000	SystemRoot	\Device\Harddisk0\Partition1\WINDOWS
0x000000000aa33ef0	1	0	2024-11-14 09:36:49 UTC+0000	VBoxGuest	\Device\VBoxGuest
0x000000000aa66298	1	0	2024-11-14 09:36:49 UTC+0000	STORAGE#V...91efb8b}	\Device\HarddiskVolume1
0x000000000aa811f0	1	0	2024-11-14 09:36:48 UTC+0000	FtControl	\Device\FtControl
0x000000000aa81248	1	0	2024-11-14 09:36:48 UTC+0000	DmTrace	\Device\DmControl\DmTrace
0x000000000aa81298	1	0	2024-11-14 09:36:48 UTC+0000	DmIoDaemon	\Device\DmControl\DmIoDaemon
0x000000000aa816f8	1	0	2024-11-14 09:36:47 UTC+0000	Global	\GLOBAL??
0x000000000aa81c70	1	0	2024-11-14 09:36:48 UTC+0000	ScsiPort0	\Device\Ide\IdePort0
0x000000000aa89290	1	0	2024-11-14 09:36:49 UTC+0000	multi(0)d...ition(2)	\Device\Harddisk0\Partition2
0x000000000aa899b8	1	0	2024-11-14 09:36:50 UTC+0000	Volume{d8...172696f}	\Device\CdRom0
0x000000000aac5a10	1	0	2024-11-14 09:36:48 UTC+0000	ScsiPort1	\Device\Ide\IdePort1
0x000000000aac71b8	1	0	2024-11-14 09:36:49 UTC+0000	Volume{d8...172696f}	\Device\HarddiskVolume1

0x000000000aac7378	1	0	2024-11-14 09:36:50 UTC+0000	INTELPRO_...340EF57}	\Device\INTELPRO_{F482B08F-B60E-471C-9699-493DD340EF57}
0x000000000aace240	1	0	2024-11-14 09:36:48 UTC+0000	Root#ftdi...91efb8b}	\Device\00000004
0x000000000ab012f0	1	0	2024-11-14 09:36:49 UTC+0000	Partition1	\Device\HarddiskVolume1
0x000000000ab01b78	1	0	2024-11-14 09:36:49 UTC+0000	multi(0)d...rdisk(0)	\Device\Harddisk0\Partition0
0x000000000adbdc78	1	0	2024-11-14 09:36:49 UTC+0000	IDE#DiskV...91efb8b}	\Device\Ide\IdeDeviceP0T0L0-3
0x000000000adbfd98	1	0	2024-11-14 09:36:49 UTC+0000	C:	\Device\HarddiskVolume1
0x000000000adf6270	1	0	2024-11-14 09:36:47 UTC+0000	ACPI#Fixe...9062857}	\Device\0000003c
0x000000000adfb2e8	1	0	2024-11-14 09:36:48 UTC+0000	MountPointManager	\Device\MountPointManager
0x000000000adfb360	1	0	2024-11-14 09:36:49 UTC+0000	multi(0)d...ition(4)	\Device\Harddisk0\Partition4
0x000000000adfc8c0	1	0	2024-11-14 09:36:51 UTC+0000	UNC	\Device\Mup
0x000000000adfd1f0	1	0	2024-11-14 09:36:49 UTC+0000	NDIS	\Device\Ndis
0x000000000adfd5d8	1	0	2024-11-14 09:36:52 UTC+0000	Local	\BaseNamedObjects
0x000000000ae291f0	1	0	2024-11-14 09:36:52 UTC+0000	LCD	\Device\VideoPdo0
0x000000000ae2c1b0	1	0	2024-11-14 09:36:50 UTC+0000	Root#SYST...4c10000}	\Device\00000036

0x000000000ae2d668	1	0	2024-11-14 09:36:48 UTC+0000	Root#dmio...91efb8b}	\Device\00000003
0x000000000ae2e6a0	1	0	2024-11-14 09:36:49 UTC+0000	multi(0)d...ition(3)	\Device\Harddisk0\Partition3
0x000000000ae2eca0	1	0	2024-11-14 09:36:52 UTC+0000	Global	\BaseNamedObjects
0x000000000ae33c48	1	0	2024-11-14 09:36:48 UTC+0000	DmConfig	\Device\DmControl\DmConfig
0x000000000ae35198	1	0	2024-11-14 09:36:49 UTC+0000	FltMgrMsg	\FileSystem\Filters\FltMgrMsg
0x000000000ae35768	1	0	2024-11-14 09:36:48 UTC+0000	Scsi1:	\Device\Ide\IdePort1
0x000000000ae37400	1	0	2024-11-14 09:36:48 UTC+0000	DmInfo	\Device\DmControl\DmInfo
0x000000000ae53a38	1	0	2024-11-14 09:36:50 UTC+0000	Root#MS_P...fc3358c}	\Device\00000032
0x000000000ae54b58	1	0	2024-11-14 09:36:51 UTC+0000	PCI#VEN_8...9223196}	\Device\NTPNP_PCI0006
0x000000000ae55198	1	0	2024-11-14 09:36:48 UTC+0000	CompositeBattery	\Device\CompositeBattery
0x000000000ae560d0	1	0	2024-11-14 09:36:50 UTC+0000	NdisWan	\Device\NdisWan
0x000000000ae58530	1	0	2024-11-14 09:36:47 UTC+0000	WMIDataDevice	\Device\WMIDataDevice
0x000000000ae5a958	1	0	2024-11-14 09:36:50 UTC+0000	ACPI#Genu...29dbdd0}	\Device\00000040
0x000000000ae8c460	1	0	2024-11-14 09:36:49 UTC+0000	PhysicalDrive0	\Device\Harddisk0\DR0

0x000000000aec4440	1	0	2024-11-14 09:36:49 UTC+0000	multi(0)d...ition(1)	\Device\Harddisk0\Partition1
0x000000000aec6998	1	0	2024-11-14 09:36:50 UTC+0000	ACPI#PNP0...91405dd}	\Device\00000046
0x000000000af01778	1	0	2024-11-14 09:36:49 UTC+0000	Partition0	\Device\Harddisk0\DR0
0x000000000af03260	1	0	2024-11-14 09:36:48 UTC+0000	Scsi0:	\Device\Ide\IdePort0
0x000000000afc0b98	1	0	2024-11-14 09:36:50 UTC+0000	Root#SYST...77afcde}	\Device\00000036
0x000000000b040900	1	0	2024-11-14 09:36:50 UTC+0000	Root#SYST...4bf0407}	\Device\00000036
0x000000000b4365a0	1	0	2024-11-14 09:36:50 UTC+0000	CdRom0	\Device\CdRom0
0x000000000b4fa898	1	0	2024-11-14 09:36:51 UTC+0000	VBoxMiniRdrDN	\Device\VBoxMiniRdr

Table 15a: list of the symbolic links in the clean dump

Symbolic links in infected dump

Offset (P)	Ptr	Hnd	Creation Time (UTC)	From	To
x00000000029f5518	1	0	2012-07-22 02:42:24	Global	\GLOBAL??
0x00000000029f6b10	1	0	2012-07-22 02:42:32	HID#Vid_0...1000030}	\Device\0000007b
0x00000000029f6be0	1	0	2012-07-22 02:42:32	HID#Vid_0...91405dd}	\Device\0000007b
0x00000000029fd748	1	0	2012-07-22 02:42:24	DosDevices	??
0x00000000029ff470	1	0	2012-07-22 02:42:31	SystemRoot	\Device\Harddisk0\Partition1\WINDOWS
0x0000000002a301c8	1	0	2012-07-22 02:42:35	Global	\Global??
0x0000000002a30870	1	0	2012-07-22 02:42:31	IPNAT	\Device\IPNAT

0x0000000002a45118	1	0	2012-07-22 02:42:29	IDE#DiskV...91efb8b}	\Device\Ide\IdeDeviceP0T0L0-3
0x0000000002a4f2a8	1	0	2012-07-22 02:42:25	WMIDataDevice	\Device\WMIDataDevice
0x0000000002a8e108	1	0	2012-07-22 02:42:31	NUL	\Device\Null
x00000000029f5518	1	0	2012-07-22 02:42:24	Global	\GLOBAL??
0x00000000029f6b10	1	0	2012-07-22 02:42:32	HID#Vid_0...1000030}	\Device\0000007b
0x00000000029f6be0	1	0	2012-07-22 02:42:32	HID#Vid_0...91405dd}	\Device\0000007b
0x00000000029fd748	1	0	2012-07-22 02:42:24	DosDevices	??
0x00000000029ff470	1	0	2012-07-22 02:42:31	SystemRoot	\Device\Harddisk0\Partition1\WINDOWS
0x0000000002a301c8	1	0	2012-07-22 02:42:35	Global	\Global??
0x0000000002a30870	1	0	2012-07-22 02:42:31	IPNAT	\Device\IPNAT
0x0000000002a45118	1	0	2012-07-22 02:42:29	IDE#DiskV...91efb8b}	\Device\Ide\IdeDeviceP0T0L0-3
0x0000000002a4f2a8	1	0	2012-07-22 02:42:25	WMIDataDevice	\Device\WMIDataDevice
0x0000000002a8e108	1	0	2012-07-22 02:42:31	NUL	\Device\Null
0x0000000002ac40c8	1	0	2012-07-22 02:42:26	ACPI#Fixe...9062857}	\Device\00000037
0x0000000002b40dd8	1	0	2012-07-22 02:42:27	Scsi0:	\Device\Ide\IdePort0
0x0000000002e39d28	1	0	2012-07-22 02:42:32	Session	\Sessions\BNOLINKS
0x0000000002e49aa0	1	0	2012-07-22 02:42:31	Ip	\Device\Ip
0x0000000002e8a098	1	0	2012-07-22 02:42:30	HCD1	\Device\USBFDO-1
0x0000000002e8a0e8	1	0	2012-07-22 02:42:30	A:	\Device\Floppy0
0x0000000002e8c980	1	0	2012-07-22 02:42:29	multi(0)d...ition(3)	\Device\Harddisk0\Partition3
0x0000000002e8ca20	1	0	2012-07-22 02:42:29	multi(0)d...ition(2)	\Device\Harddisk0\Partition2
0x0000000003067e50	1	0	2012-07-22 02:42:27	ScsiPort0	\Device\Ide\IdePort0
0x0000000003069540	1	0	2012-07-22 02:42:29	Volume{d8...172696f}	\Device\HarddiskVolume1
0x0000000003088cb0	1	0	2012-07-22 02:42:27	MountPointManager	\Device\MountPointManager
0x0000000003088dd8	1	0	2012-07-22 02:42:29	STORAGE#V...91efb8b}	\Device\HarddiskVolume1
0x000000000308b578	1	0	2012-07-22 02:42:27	DmConfig	\Device\DmControl\DmConfig
0x000000000308b5c8	1	0	2012-07-22 02:42:27	DmLoader	\Device\DmLoader

0x00000000030d8530	1	0	2012-07-22 02:42:29	PhysicalDrive0	\Device\Harddisk0\DR0
0x00000000030dae88	1	0	2012-07-22 02:42:27	CompositeBattery	\Device\CompositeBattery
0x00000000030ec8f0	1	0	2012-07-22 02:42:30	Root#RDP_...91405dd}	\Device\0000002c
0x00000000030ec980	1	0	2012-07-22 02:42:30	ACPI#PNP0...91405dd}	\Device\0000006a
0x00000000030ec9d8	1	0	2012-07-22 02:42:30	PCI#VEN_1...9223196}	\Device\NTPNP_PCI0042
0x00000000030ecaf8	1	0	2012-07-22 02:42:30	Root#MS_P...fc3358c}	\Device\0000002a
0x00000000030ecd88	1	0	2012-07-22 02:42:29	Partition1	\Device\HarddiskVolume1
0x0000000003105f20	1	0	2012-07-22 02:42:30	COM2	\Device\Serial1
0x0000000003155920	1	0	2012-07-22 02:42:31	IPSECDev	\Device\IPSEC
0x0000000003155b10	1	0	2012-07-22 02:42:29	multi(0)d...ition(4)	\Device\Harddisk0\Partition4
0x00000000031c0c18	1	0	2012-07-22 02:42:27	DmInfo	\Device\DmControl\DmInfo
0x00000000032fa660	1	0	2012-07-22 02:42:30	PTILINK3	\Device\ParTechInc2
0x00000000032fa970	1	0	2012-07-22 02:42:29	multi(0)d...ition(1)	\Device\Harddisk0\Partition1
0x0000000033571f0	1	0	2012-07-22 02:42:27	DmIoDaemon	\Device\DmControl\DmIoDaemon
0x000000000344a458	1	0	2012-07-22 02:42:30	HCD0	\Device\USBFDO-0
0x00000000036b4fe0	1	0	2012-07-22 02:42:27	Root#ftdi...91efb8b}	\Device\00000004
0x0000000003088cb0	1	0	2012-07-22 02:42:27	MountPointManager	\Device\MountPointManager
0x0000000003088dd8	1	0	2012-07-22 02:42:29	STORAGE#V...91efb8b}	\Device\HarddiskVolume1
0x000000000308b578	1	0	2012-07-22 02:42:27	DmConfig	\Device\DmControl\DmConfig
0x000000000308b5c8	1	0	2012-07-22 02:42:27	DmLoader	\Device\DmLoader
0x00000000030d8530	1	0	2012-07-22 02:42:29	PhysicalDrive0	\Device\Harddisk0\DR0
0x00000000030dae88	1	0	2012-07-22 02:42:27	CompositeBattery	\Device\CompositeBattery
0x00000000030ec8f0	1	0	2012-07-22 02:42:30	Root#RDP_...91405dd}	\Device\0000002c
0x00000000030ec980	1	0	2012-07-22 02:42:30	ACPI#PNP0...91405dd}	\Device\0000006a
0x00000000030ec9d8	1	0	2012-07-22 02:42:30	PCI#VEN_1...9223196}	\Device\NTPNP_PCI0042
0x00000000030ecaf8	1	0	2012-07-22 02:42:30	Root#MS_P...fc3358c}	\Device\0000002a
0x00000000030ecd88	1	0	2012-07-22 02:42:29	Partition1	\Device\HarddiskVolume1

0x0000000003105f20	1	0	2012-07-22 02:42:30	COM2	\Device\Serial1
0x0000000003155920	1	0	2012-07-22 02:42:31	IPSECDev	\Device\IPSEC
0x0000000003155b10	1	0	2012-07-22 02:42:29	multi(0)d...ition(4)	\Device\Harddisk0\Partition4
0x00000000031c0c18	1	0	2012-07-22 02:42:27	DmInfo	\Device\DmControl\DmInfo
0x00000000032fa660	1	0	2012-07-22 02:42:30	PTILINK3	\Device\ParTechInc2
0x00000000032fa970	1	0	2012-07-22 02:42:29	multi(0)d...ition(1)	\Device\Harddisk0\Partition1
0x00000000033571f0	1	0	2012-07-22 02:42:27	DmIoDaemon	\Device\DmControl\DmIoDaemon
0x000000000344a458	1	0	2012-07-22 02:42:30	HCD0	\Device\USBFDO-0
0x00000000036b4fe0	1	0	2012-07-22 02:42:27	Root#ftdi...91efb8b}	\Device\00000004
0x000000000370c540	1	0	2012-07-22 02:42:29	C:	\Device\HarddiskVolume1
0x000000000370cc28	1	0	2012-07-22 02:42:27	FtControl	\Device\FtControl
0x000000000370cd50	1	0	2012-07-22 02:42:29	FltMgrMsg	\FileSystem\Filters\FltMgrMsg
0x000000000370d150	1	0	2012-07-22 02:42:32	Global	\BaseNamedObjects
0x00000000037e7358	1	0	2012-07-22 02:42:29	NDIS	\Device\Ndis
0x00000000037e7750	1	0	2012-07-22 02:42:27	Root#dmio...91efb8b}	\Device\00000003
0x00000000038822 48	1	0	2012-07-22 02:42:29	multi(0)d...rdisk(0)	\Device\Harddisk0\Partition0
0x0000000003882d20	1	0	2012-07-22 02:42:28	Scsi1:	\Device\Ide\IdePort1
0x0000000003882dd8	1	0	2012-07-22 02:42:28	ScsiPort1	\Device\Ide\IdePort1
0x0000000003a19110	1	0	2012-07-22 02:42:29	Partition0	\Device\Harddisk0\DR0
0x0000000003b7d440	1	0	2012-07-22 02:42:29	FltMgr	\FileSystem\Filters\FltMgr
0x0000000003d8b878	2	1	2012-07-22 02:42:32	0	\BaseNamedObjects
0x0000000003df8998	1	0	2012-07-22 02:42:29	CdRom0	\Device\CdRom0
0x000000000413dbc8	1	0	2012-07-22 02:42:32	HID#Vid_0...1000030}	\Device\0000007a
0x0000000004170d60	1	0	2012-07-22 02:42:30	PTILINK1	\Device\ParTechInc0
0x0000000004170f20	1	0	2012-07-22 02:42:30	PTILINK2	\Device\ParTechInc1
0x0000000004175c18	1	0	2012-07-22 02:42:32	Local	\BaseNamedObjects
0x0000000004193e78	1	0	2012-07-22 02:42:30	{2EF5B1E3...890F7DC}	\Device{2EF5B1E3-68FB-4BEF-A3E9-2367A890F7DC}

0x0000000004193fe0	1	0	2012-07-22 02:42:30	PCI#VEN_8...1e6af27}	\Device\NTPNP_PCI0040
0x000000000419da18	1	0	2012-07-22 02:42:31	PRN	\DosDevices\LPT1
0x00000000041aa860	1	0	2012-07-22 02:42:32	HID#Vid_0...91405dd}	\Device\0000007a
0x00000000041c8940	1	0	2012-07-22 02:42:32	USB#Vid_0...fb951ed}	\Device\USBPDO-2
0x00000000041ca030	1	0	2012-07-22 02:42:30	Root#SYST...4bf0407}	\Device\0000002e
0x00000000041e90b0	1	0	2012-07-22 02:42:30	{EF92BFD5...D2E9067}	\Device{EF92BFD5-E444-4AA8-AFC1-A3EF5D2E9067}
0x00000000041eb8e0	1	0	2012-07-22 02:42:30	RdpDrDvMgr	\Device\RdpDrDvMgr
0x00000000041f2210	1	0	2012-07-22 02:42:30	PCI#VEN_1...5c10000}	\Device\NTPNP_PCI0042
0x00000000041f2260	1	0	2012-07-22 02:42:30	USB#ROOT_...906bed8}	\Device\USBPDO-0
0x00000000042158e0	1	0	2012-07-22 02:42:30	{B947BCC8...30FEC50}	\Device{B947BCC8-F245-4517-8F26-31F0B30FEC50}
0x000000000424b9b8	1	0	2012-07-22 02:42:30	D:	\Device\CdRom0
0x00000000042528 40	1	0	2012-07-22 02:42:31	PIPE	\Device\NamedPipe
0x00000000042739c8	1	0	2012-07-22 02:42:30	Root#MS_P...fc3358c}	\Device\00000026
0x00000000042755 68	1	0	2012-07-22 02:42:30	Volume{d8...172696f}	\Device\Floppy0
0x00000000042b20 80	1	0	2012-07-22 02:42:30	Volume{d8...172696f}	\Device\CdRom0
0x00000000042da8e0	1	0	2012-07-22 02:42:30	ACPI#PNP0...91405dd}	\Device\00000069
0x00000000042e1030	1	0	2012-07-22 02:42:30	Root#SYST...4c10000}	\Device\0000002e
0x00000000047520 60	1	0	2012-07-22 02:42:30	{A9876EE5...6781267}	\Device{A9876EE5-95B0-4AC0-9730-6C9826781267}
0x0000000004758c60	1	0	2012-07-22 02:42:30	Root#RDP_...91405dd}	\Device\0000002d
0x00000000047643 78	1	0	2012-07-22 02:42:30	NDISWANIP	\Device\NdisWanIp
0x00000000047780 30	1	0	2012-07-22 02:42:30	PSched	\Device\PSched
0x000000000477d620	1	0	2012-07-22 02:42:30	multi(0)d...fdisk(0)	\Device\Floppy0
0x000000000477f5a0	1	0	2012-07-22 02:42:31	WanArp	\Device\WANARP
0x00000000048015 08	1	0	2012-07-22 02:42:32	USB#Vid_0...906bed8}	\Device\USBPDO-3
0x0000000004ab8278	1	0	2012-07-22 02:42:30	IDE#CdRom...91efb8b}	\Device\Ide\IdeDeviceP1T0L0-e
0x0000000005c73990	1	0	2012-07-22 02:42:30	Root#MS_L...fc3358c}	\Device\00000024
0x0000000005c77150	1	0	2012-07-22 02:42:30	{D400802F...1970147}	\Device{D400802F-DB5A-4A71-B884-860BB1970147}

0x0000000005c78428	1	0	2012-07-22 02:42:30	Root#SYST...9223196}	\Device\0000002e
0x0000000005cbb450	1	0	2012-07-22 02:42:30	Root#SYST...9223196}	\Device\0000002e
0x00000000072bc398	1	0	2012-07-22 02:42:30	PCI#VEN_1...1e6af27}	\Device\NTPNP_PCI0043
0x000000000731f148	1	0	2012-07-22 02:42:30	LEGACY#JO...90f57da}	\Device\00000075
0x0000000007326a60	1	0	2012-07-22 02:42:30	Root#MS_P...fc3358c}	\Device\00000029
0x00000000073283 60	1	0	2012-07-22 02:42:30	Root#MS_P...fc3358c}	\Device\00000027
0x00000000073283c0	1	0	2012-07-22 02:42:30	Root#SYST...77afcde}	\Device\0000002e
0x00000000073284 20	1	0	2012-07-22 02:42:30	FDC#GENER...91efb8b}	\Device\FloppyPDO0
0x00000000073295 68	1	0	2012-07-22 02:42:30	Root#SYST...4c10000}	\Device\0000002e
0x000000000732a3f0	1	0	2012-07-22 02:42:31	UNC	\Device\Mup
0x000000000732a5a8	1	0	2012-07-22 02:42:30	{9F518110...E3131B7}	\Device{9F518110-3877-431A-A69B-14663E3131B7}
0x000000000732a5f8	1	0	2012-07-22 02:42:30	ACPI#PNP0...e301f73}	\Device\0000006d
0x000000000732d2e0	1	0	2012-07-22 02:42:31	MAILSLOT	\Device\MailSlot
0x000000000732e4e8	1	0	2012-07-22 02:42:30	Root#SYST...4c10000}	\Device\0000002e
0x00000000073312e0	1	0	2012-07-22 02:42:31	IPMULTICAST	\Device\IPMULTICAST
0x00000000073316e0	1	0	2012-07-22 02:42:30	ACPI#PNP0...be10318}	\Device\0000006d
0x00000000073331 28	1	0	2012-07-22 02:42:30	COM1	\Device\Serial0
0x00000000073335f0	1	0	2012-07-22 02:42:30	ACPI#PNP0...e301f73}	\Device\0000006e
0x00000000073376b0	1	0	2012-07-22 02:42:30	PCI#VEN_1...9223196}	\Device\NTPNP_PCI0042
0x00000000073379 08	1	0	2012-07-22 02:42:30	Root#SYST...9223196}	\Device\0000002e
0x00000000073379a0	1	0	2012-07-22 02:42:30	USB#ROOT_...906bed8}	\Device\USBPDO-1
0x00000000073398 48	1	0	2012-07-22 02:42:30	ACPI#Genu...29dbdd0}	\Device\00000035
0x000000000733b468	1	0	2012-07-22 02:42:30	ACPI#PNP0...be10318}	\Device\0000006e
0x000000000733b800	1	0	2012-07-22 02:42:30	LPT1	\Device\Parallel0
0x000000000733b858	1	0	2012-07-22 02:42:30	DISPLAY2	\Device\Video1
0x000000000733d4a0	1	0	2012-07-22 02:42:30	{272517F3...A6291F8}	\Device{272517F3-D392-4474-B9B6-C539DA6291F8}
0x00000000073482c0	1	0	2012-07-22 02:42:30	Root#MS_N...fc3358c}	\Device\00000025

0x00000000073485e0	1	0	2012-07-22 02:42:30	LPTENUM#M...8753ed1}	\Device\Parallel0
0x00000000073488d8	1	0	2012-07-22 02:42:31	Tcp	\Device\Tcp
0x0000000007386240	1	0	2012-07-22 02:42:31	AUX	\DosDevices\COM1
0x0000000007386bd8	1	0	2012-07-22 02:42:30	DISPLAY1	\Device\Video0
0x00000000073a65b8	1	0	2012-07-22 02:42:30	PCI#VEN_1...fc3358c}	\Device\NTPNP_PCI0041
0x00000000073a6810	1	0	2012-07-22 02:42:30	Root#SYST...fc3358c}	\Device\0000002e
0x00000000073b5cf0	1	0	2012-07-22 02:42:30	Root#SYST...4c10000}	\Device\0000002e
0x00000000073b65c0	1	0	2012-07-22 02:42:31	Shadow	\Device\LanmanRedirector
0x00000000073b6cb0	1	0	2012-07-22 02:42:31	DISPLAY3	\Device\Video2
0x00000000073fa270	1	0	2012-07-22 02:42:30	Root#SYST...9223196}	\Device\0000002e
0x00000000073fd630	1	0	2012-07-22 02:42:30	PCI#VEN_1...9223196}	\Device\NTPNP_PCI0042
0x00000000073fd878	1	0	2012-07-22 02:42:30	ACPI#PNP0...800845c}	\Device\0000006c
0x00000000073fddd0	1	0	2012-07-22 02:42:30	Root#SYST...8b03a8e}	\Device\0000002e
0x00000000073fe278	1	0	2012-07-22 02:42:30	Root#SYST...8775bf1}	\Device\0000002e
0x00000000769f958	2	1	2012-07-22 02:42:31	KnownDllPath	C:\WINDOWS\system32
0x00000000082c4600	1	0	2012-07-22 02:42:33	Global	\Global??
0x00000000087e6620	1	0	2012-07-22 02:42:33	Ndisuio	\Device\Ndisuio
0x0000000008f2a360	1	0	2012-07-22 02:42:33	Global	\Global??
0x000000000a3478c0	1	0	2012-07-22 02:42:37	SW#{a7c7a...8004788}	\Device\KSENUM#00000002
0x000000000a621890	1	0	2012-07-22 02:42:53	$VDMLPT1	\Device\ParallelVdm0
0x000000000bb21960	1	0	2012-07-22 02:42:37	SW#{a7c7a...8004788}	\Device\KSENUM#00000002
0x000000000bdc06b0	1	0	2012-07-22 02:42:37	sysaudio	\Device\sysaudio
0x000000000be9b8d8	1	0	2012-07-22 02:42:37	SW#{a7c7a...8004788}	\Device\KSENUM#00000002
0x000000000e2ce3e8	1	0	2012-07-22 02:42:37	SW#{a7c7a...8004788}	\Device\KSENUM#00000002

Table 15b: list of the symbolic links in the infected dump

Handles in clean dump

Offset (V)	Pid	Handle	Access	Type	Details
0x8a25c830	4	0x4	0x1f0fff	Process	System (4)
0x8a25b020	4	0x8	0x0	Thread	TID 12 PID 4
0xe13ae280	4	0xc	0xf003f	Key	MACHINE\SYSTEM\CONTROLSET001\CONTROL\SESSION MANAGER\MEMORY MANAGEMENT\PREFETCHPARAMETERS
0xe101a490	4	0x10	0x0	Key	
0xe13b9538	4	0x14	0x20019	Key	MACHINE\SYSTEM\WPA\MEDIACENTER
0xe13b01b8	4	0x18	0x20019	Key	MACHINE\HARDWARE\DESCRIPTION\SYSTEM\MULTIFUNCTIONADAPTER
0xe101b490	4	0x1c	0x20019	Key	MACHINE\SYSTEM\WPA\KEY-YF684PFY7GT8BRMTRFDD3
0xe13ce4a0	4	0x20	0x2001f	Key	MACHINE\SYSTEM\SETUP
0xe13bb450	4	0x24	0x20019	Key	MACHINE\SYSTEM\WPA\PNP
0xe13cefb8	4	0x28	0x20019	Key	MACHINE\SYSTEM\WPA\SIGNINGHASH-QJVFWY9BHYJCDV
0xe1015430	4	0x2c	0x2001f	Key	MACHINE\SYSTEM\CONTROLSET001\CONTROL\PRODUCTOPTIONS
0xe13bc4c8	4	0x30	0x20019	Key	MACHINE\SYSTEM\CONTROLSET001\SERVICES\EVENTLOG
0x8a280cb0	4	0x34	0x1f0003	Event	TRKWKS_EVENT
0x8a108da0	4	0x8c	0x1f03ff	Thread	TID 336 PID 4
0x8a23a618	4	0x98	0x1f03ff	Thread	TID 100 PID 4
0x8a1fe020	4	0xa0	0x0	Thread	TID 104 PID 4
0x8a239ae0	4	0xa4	0x1f0003	Event	VxKernel2VoldEvent
0xe1008a78	4	0xb0	0xf000f	Directory	WinDfs
0xe1018318	4	0xc0	0xf000f	Directory	Harddisk0
0x89d08868	4	0x16c	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\Administrator\Local Settings\Application Data\Microsoft\Windows\U...
0x8a09ff90	4	0x1e8	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\Administrator\Local Settings\Application Data\Microsoft\Windows\U...

0x89b606c8	4	0x20c	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\Administrator\NTUSER.DAT
0x8a0121c0	4	0x234	0x1f03ff	Process	svchost.exe(1096)
0x8a080ef8	4	0x23c	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\Administrator\ntuser.dat.LOG
0x8a1186f8	4	0x270	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Application Data\Microsoft\Windows\UsrClas...
0x89b64858	4	0x274	0x12019f	File	\Device\Tcp
0x89c9c388	4	0x27c	0x12019f	File	\Device\Tcp
0x8a0d51c8	4	0x284	0x100003	Event	LanmanServerAnnounceEvent
0x8a20fbf0	4	0x294	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\SAM.LOG
0x89fe47e8	4	0x2b0	0x1f03ff	Process	winlogon.exe(640)
0x8a005028	4	0x2b8	0x120116	File	\Device\HarddiskVolume1\System Volume Information_restore{F08459D8-9E84-4265-ABE5-610B8ADDE4E2}\RP4\change.log
0x8a0d8df8	4	0x2f0	0x3	File	\Device\HarddiskVolume1\WINDOWS\system32\config\system.LOG
0xe1612c40	4	0x2fc	0x2001f	Key	MACHINE\SYSTEM\CONTROLSET001\CONTROL\VIDEO{B7A3558C-290B-4D9E-8FBC-BBA0B1A6651B}\0000\VOLATILESETTINGS
0x8a0d5120	4	0x304	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\software
0x89becba0	4	0x308	0x1f0003	Event	PrefetchTracesReady
0x89c8dbb8	4	0x30c	0x1f03ff	Thread	TID 1852 PID 4
0x89ba4598	4	0x320	0x12019f	File	\Device\Tcp
0x8a021da0	4	0x324	0x438	Process	lsass.exe(696)
0x89bebd00	4	0x32c	0x1f03ff	Process	spoolsv.exe(1568)
0x8a0b6f90	4	0x334	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\voidead\NTUSER.DAT
0x8a0a3500	4	0x338	0x1f03ff	Process	svchost.exe(1684)
0x8a03bef8	4	0x340	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\voidead\ntuser.dat.LOG
0x8a204238	4	0x344	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Application Data\Microsoft\Windows\UsrClas...
0xe1125348	4	0x348	0xf000f	Directory	Http
0x8a021da0	4	0x34c	0x1f03ff	Process	lsass.exe(696)
0x8a0e9568	4	0x350	0x120116	File	\Device\Mup
0x89bebb638	4	0x354	0x1f03ff	Thread	TID 1780 PID 4

0x8a147d98	4	0x358	0x12019f	File	\Device\NTPNP_PCI0006\Topology
0x89b61ba0	4	0x35c	0x1f03ff	Thread	TID 1816 PID 4
0x89b866f0	4	0x360	0x20	File	\Device\RdpDr
0x8a08a5d8	4	0x364	0x1200a0	File	\Device\Udp
0x89b7ada0	4	0x368	0x1f03ff	Thread	TID 1952 PID 4
0x89bf1a20	4	0x36c	0x1f03ff	Thread	TID 1924 PID 4
0x89bebb3b8	4	0x370	0x1f03ff	Thread	TID 1844 PID 4
0x89b61920	4	0x374	0x1f03ff	Thread	TID 1288 PID 4
0x89cac2f0	4	0x378	0x20	File	\Device\VBoxMiniRdr
0x89ff4960	4	0x37c	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows
0x89ca8670	4	0x380	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\NetworkService\ntuser.dat.LOG
0xe16c9308	4	0x384	0x1f0001	Port	
0x89b2b8e8	4	0x388	0x1f03ff	Thread	TID 1936 PID 4
0x8a1632c8	4	0x38c	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\software.LOG
0x8a15f930	4	0x390	0x12019f	File	\Device\Tcp
0x8a1640f0	4	0x394	0x12019f	File	\Device\Gpc
0x8a1a96c0	4	0x398	0x3	File	\Device\HarddiskVolume1\WINDOWS\system32\config\system
0x8a165d50	4	0x39c	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\default
0x8a165b80	4	0x3a0	0x12019f	File	\Device\Tcp
0xe18a4af0	4	0x3a4	0x2001f	Key	MACHINE\SYSTEM\CONTROLSET001\SERVICES\HTTP\PARAMETERS\URLACLINFO
0x8a19f7c8	4	0x3a8	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\SECURITY.LOG
0x8a0dd028	4	0x3ac	0x1200a0	File	\Device\Tcp
0x8a1638e8	4	0x3b0	0x12019f	File	\Device\Udp
0x8a0e1da0	4	0x3b4	0x1f03ff	Thread	TID 340 PID 4
0x8a160740	4	0x3b8	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\SAM
0x89fefb70	4	0x3bc	0x12019f	File	\Device\Tcp
0xe1687830	4	0x3c0	0x1f0001	Port	

0x89fe65a8	4	0x3c4	0x120116	File	\Device\Mup
0x8a1618b0	4	0x3c8	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\SECURITY
0x8a1666b8	4	0x3cc	0x12019f	File	\Device\Gpc
0x8a160028	4	0x3d0	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\default.LOG
0x89b2b3e8	4	0x3d4	0x1f03ff	Thread	TID 1948 PID 4
0x8a068e98	4	0x3d8	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\LocalService\ntuser.dat.LOG
0x89c9bca0	4	0x3dc	0x12019f	File	\Device\Tcp
0xe1686c00	4	0x3e0	0x2	Key	MACHINE\SOFTWARE\MICROSOFT\CRYPTOGRAPHY\RNG
0x89ca57b8	4	0x3e4	0x12019f	File	\Device\Tcp
0x89c9c8b0	4	0x3e8	0x12019f	File	\Device\Tcp
0x89c9d450	4	0x3ec	0x12019f	File	\Device\Tcp
0x8a03e558	4	0x3f0	0x1f03ff	Thread	TID 1700 PID 4
0xe152d8d8	4	0x3f4	0x4	Directory	WindowStations
0x89c9dce8	4	0x3f8	0x12019f	File	\Device\Tcp
0x8a0b7640	4	0x3fc	0x140003	File	\Device\HarddiskVolume1\pagefile.sys
0x89ca5b28	4	0x400	0x12019f	File	\Device\Tcp
0x8a0090a0	4	0x404	0x12019f	File	\Device\Tcp
0x8a07cde0	4	0x408	0xf0003	Desktop	Disconnect
0x8a0b2768	4	0x40c	0x12019f	File	\Device\NetBT_Tcpip_{F482B08F-B60E-471C-9699-493DD340EF57}
0x89ca02e8	4	0x410	0x12019f	File	\Device\Tcp
0x89fefc28	4	0x414	0x1f0003	Event	StuckThreadEvent
0x89ca5f90	4	0x418	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\NetworkService\NTUSER.DAT
0x8a079668	4	0x41c	0x12019f	File	\Device\Tcp
0x8a0794b0	4	0x420	0x12019f	File	\Device\Tcp
0x89ca0130	4	0x424	0x12019f	File	\Device\Tcp
0x8a0792f8	4	0x428	0x12019f	File	\Device\Tcp
0x8a005c68	4	0x42c	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat.LOG

0x89ca5970	4	0x434	0x12019f	File	\Device\Tcp
0x89ca5290	4	0x438	0x12019f	File	\Device\Tcp
0x89ca5028	4	0x43c	0x12019f	File	\Device\Tcp
0x89ca50d8	4	0x440	0x12019f	File	\Device\Tcp
0x89ca5448	4	0x444	0x12019f	File	\Device\Tcp
0x8a166b98	4	0x448	0x120089	File	\Device\Tcp
0x89c9d978	4	0x44c	0x12019f	File	\Device\Tcp
0x89ca5ce0	4	0x450	0x12019f	File	\Device\Tcp
0x89ca5600	4	0x454	0x12019f	File	\Device\Tcp
0x89c9cc20	4	0x458	0x12019f	File	\Device\Tcp
0x89c9d608	4	0x45c	0x12019f	File	\Device\Tcp
0x89c9bf90	4	0x460	0x12019f	File	\Device\Tcp
0x89c9d7c0	4	0x464	0x12019f	File	\Device\Tcp
0x89c9d298	4	0x468	0x12019f	File	\Device\Tcp
0x89c9db30	4	0x46c	0x12019f	File	\Device\Tcp
0x89c9dea0	4	0x470	0x12019f	File	\Device\Tcp
0x89c9ca68	4	0x474	0x12019f	File	\Device\Tcp
0x89c9be58	4	0x478	0x12019f	File	\Device\Tcp
0x89c9c540	4	0x47c	0x12019f	File	\Device\Tcp
0x89c9cf90	4	0x480	0x12019f	File	\Device\Tcp
0x89c9d0e0	4	0x484	0x12019f	File	\Device\Tcp
0x89c9a028	4	0x488	0x12019f	File	\Device\Tcp
0xe167b668	4	0x48c	0x1f0001	Port	SeRmCommandPort
0x89c9c1d0	4	0x490	0x12019f	File	\Device\Tcp
0x8a0321e0	4	0x494	0x12019f	File	\Device\Tcp
0x89bea028	4	0x498	0x12019f	File	\Device\Tcp
0x89c9c6f8	4	0x49c	0x12019f	File	\Device\Tcp

0x89b25180	4	0x4a0	0x12019f	File	\Device\Tcp
0x8a0aa8a8	4	0x4a4	0x12019f	File	\Device\Tcp
0x8a0ce2d8	4	0x4a8	0x12019f	File	\Device\Tcp
0x89c9bae8	4	0x4ac	0x12019f	File	\Device\Tcp
0x89c9b778	4	0x4b0	0x12019f	File	\Device\Tcp
0x89c9b5c0	4	0x4b4	0x12019f	File	\Device\Tcp
0x89c9ad18	4	0x4b8	0x12019f	File	\Device\Tcp
0x89c9ab60	4	0x4bc	0x12019f	File	\Device\Tcp
0x89c9b408	4	0x4c0	0x12019f	File	\Device\Tcp
0x89c9a7f0	4	0x4c4	0x12019f	File	\Device\Tcp
0x89c9a9a8	4	0x4c8	0x12019f	File	\Device\Tcp
0x89caa440	4	0x4cc	0x12019f	File	\Device\Tcp
0x8a126330	4	0x4d0	0x1f01ff	File	\Device\Ip
0x89c9b250	4	0x4d4	0x12019f	File	\Device\Tcp
0xe182e5e8	4	0x4d8	0x2001f	Key	MACHINE\SOFTWARE\MICROSOFT\WINDOWS\CURRENTVERSION\GROUP POLICY\STATE\MACHINE
0x89c9aea0	4	0x4dc	0x12019f	File	\Device\Tcp
0x89c2d848	4	0x4e0	0x1f0003	Event	
0x8a0797f0	4	0x4e4	0x12019f	File	\Device\Tcp
0x89c9a638	4	0x4e8	0x12019f	File	\Device\Tcp
0x89be3408	4	0x4ec	0x20	File	\Device\LanmanRedirector
0x8a0b3930	4	0x4f0	0x12019f	File	\Device\NetBT_Tcpip_{F482B08F-B60E-471C-9699-493DD340EF57}
0xe17e1160	4	0x4f4	0x2001f	Key	MACHINE\SYSTEM\CONTROLSET001\SERVICES\TCPIP\PARAMETERS\INTERFACES{F482B08F-B60E-471C-9699-493DD340EF57}
0x89c2c778	4	0x4f8	0x1f0003	Event	
0x89ffb440	4	0x4fc	0x12019f	File	\Device\Tcp
0x8a1595e8	4	0x500	0x12019f	File	\Device\Tcp
0x89c95e78	4	0x504	0x2000003	File	\Device\HarddiskVolume1\Documents and Settings\LocalService\Local Settings\Application Data\Microsoft\WindowsUsrClass.dat.LOG

Table 15 c: list of the handles in the clean dump

Handles in Infected dump

Offset	Pid	Handle	Access	Type	Details
0x823c89c8	4	0x4	0x1f0fff	Process	System(4)
0x823c8308	4	0x8	0x1f03ff	Thread	TID 12 PID 4
0xe1036638	4	0xc	0xf0003	Key	MACHINE\SYSTEM\CONTROLSET001\CONTROL\SESSION MANAGER\MEMORY MANAGEMENT\PREFETCHPARAMETERS
0xe13bf390	4	0x14	0x20019	Key	MACHINE\SYSTEM\SETUP
0xe100f340	4	0x18	0x20019	Key	MACHINE\HARDWARE\DESCRIPTION\SYSTEM\MULTIFUNCTIONADAPTER
0xe13fba88	4	0x1c	0x20019	Key	MACHINE\SYSTEM\WPA\MEDIACENTER
0xe102c240	4	0x20	0x20019	Key	MACHINE\SYSTEM\WPA\KEY-4F3B2RFXK9C637882MBM
0xe13b70a0	4	0x24	0x20019	Key	MACHINE\SYSTEM\WPA\PNP
0xe1038430	4	0x28	0x20019	Key	MACHINE\SYSTEM\WPA\SIGNINGHASH-V44KQMCFCKQTQ
0xe13b7948	4	0x2c	0x20019	Key	MACHINE\SYSTEM\CONTROLSET001\SERVICES\EVENTLOG
0xe102e678	4	0x30	0xf0003	Event	TRKWKS_EVENT
0x82060020	4	0x84	0x1201f	File	\Device\Gpc
0xe101ead8	4	0x88	0x1f03ff	Thread	TID 96 PID 4
0xe14c1498	4	0x98	0x20019	Key	MACHINE\SYSTEM\CONTROLSET001\SERVICES\ACPI\PARAMETERS
0xe103bd00	4	0x9c	0xf0001	Directory	WinDFS
0x82291358	4	0x298	0x1f0003	Event	PrefetchTracesReady
0x82063208	4	0x2b4	0x1201f	File	\Device\Tcp
0x82062808	4	0x2b8	0x1201f	File	\Device\NetBT_Tcpip_{2EF5B1E3-68FB-4BEF-A3E9-2367A890F7DC}
0x82221c20	4	0x2c0	0x200003	File	\Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat.LOG
0x82221608	4	0x2c4	0x1f03ff	Thread	TID 268 PID 4
0x82221e40	4	0x324	0x1f03ff	File	\Device\HarddiskVolume1\WINDOWS\system32\config\system.LOG
0x82221e48	4	0x328	0x1f03ff	Thread	TID 284 PID 4
0x82214a60	4	0x344	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\default.LOG
0x822021a0	4	0x34c	0x2000003	File	\Device\HarddiskVolume1\WINDOWS\system32\config\software

0x82232708	4	0x350	0x1f03ff	Thread	TID 344 PID 4
0xe1545d78	4	0x2	0x12019f	Key	MACHINE\SOFTWARE\MICROSOFT\CRYPTOGRAPHY\RNG
0x82221ec8	4	0x35c	0x12019f	File	\Device\Gpc

Table 15 d: list of the handles in the infected dump

Looking at figure 15, 16 .17 and 18 they show the outputs of the handles and symbolic links which were done in the infected and clean dump and the suspicious things which I found in a handle or symbolic link can be found at the table below.

5 handles and Symbolic Link and what's the difference between them

Number	Type	Object	Clean dump	Infected dump	Significance
1	Handle	MACHINE\SOFTWARE\MICROSOFT\CRYPTOGRAPHY\RNG	No	Yes	It suggest tampering with the cryptographic random number generator and weaking the encryption to get gain easier access into the system
2	Symbolic Link	\Device\USBPDO-1	No	Yes	It suggests that malware or infected payloads are being downloaded onto the system and there are two in the exact same time creation
3	Handle	\Device\HarddiskVolume1\WINDOWS\Debug\PASSWD.LOG	No	Yes	It suggests that this file contains the passwords of the system and the debugging information
4	Handle	\Device\Ndisuio	No	Yes	It suggest that packet sniffing may have occurred on the network and can capture sensitive information that the system sends
5	Symbolic Link	\Device\{2EF5B1E3-68FB-4BEF-A3E9-2367A890F7DC}	No	Yes	This suggest that it's a virtual device and this can be used to tamper with the system without the device being present

Table 15 e: the 5 handles and symbolic links that were seen to be suspicious and if they are in the clean or infected dump

Figure 16: image of number of symbolic links in clean dump

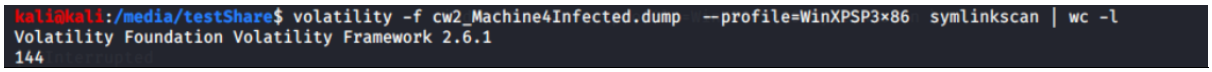


Figure 17: image of number of symbolic links in infected dump

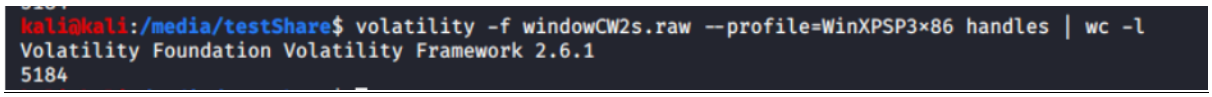


Figure 18: image of number of handles in clean dump

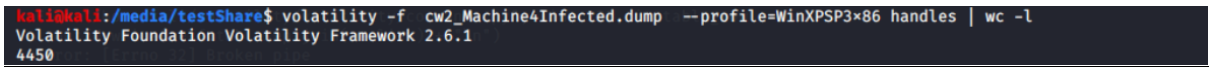


Figure 19: image of number of handles in infected dump

The number of handles and symbolic link that are missing in infected and clean dump shows that is suspicious activity and they have either been changed to another directory or there is more devices connected to the infected dump, and they are inserting potentially malicious code into the system.

Number of Handles and Symbolic links in clean and infected dump

Type	Clean Dump	Infected Dump	Total
Symbolic links	387	144	531
Handles	5184	4450	9,634

Table 19 a: the total number of handles and symbolic links in the infected and clean dump

6. Choose 5 processes that are not critical processes of the system and use the volatility shell to create a short script that identify their associated DLLs. Provide the Python code and explain it. (10%)

The 5 process that are not critical part of the system is explorer.exe, spoolsv.exe, wuauclt.exe, reader_sl.exe and alg.exe. Using volshell which is an interactive shell, and it allows to investigate memory dumps using python which can explore data structures. (2024). A DLLs (Dynamic Link Library) is a file which contains reusable code and data that multiple programs can run at the same time. (2024) The reason why we check is because one of the processes might behave as an unusual path which may indicate malware injecting or high jacking

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4.2NETWORK ANALYSIS AND SERVICES – **M00874013**

2.1 . From the provided memory dump, check the live sockets. Enumerate how many connections there are and where these connections are pointing. Distinguish between localhost connections, local network ones and public network connections.

What is a socket ? A socket is one endpoint of a two-way communication link between two programs running on a network. Sockets are bound to have port number so that the TCP layer can identify the application that the data is being detined to be sent to. For example : a client desktop would send request to a server to gain access to a webpage. The client creates a socket and sends a request to the server through that socket, once the server has received the request, the server then can send a response back to the client through such created socket which allows the two computers to communicate with eachother and transfer data between each other.

What is UDP:

UDP is also known as User Datagram Protocol. UDP is a communication protocol used across the internet for time-sensitive transmission or DNS lookup. Which could help speed up communication by not formally establishing a connection before data is transferred; allows data to be transferred quickly. UDP doesn’t check for if all packets have arrived to the destination which is at higher risk of data loss.

TCP:

Known as Transmission Control Protocol is a connection based protocol as it requires a connection to be made between the sender and receiver before data. TCP ensures that packets are delivered in the order that they been sent unlike UDP which doesn’t ensure this without any errors. If the packets happen to get lost or corrupted whilst in transmission TCP can retransmit the packet . which make TCP much reliable then UDP.

Sockets: This plugin is designed to enumerate active socket connections within a memory image, providing insights into network communication at the time of acquisition. It retrieves details such as protocol type, local and remote addresses, ports, and the owning process ID, aiding in the analysis of network activity and potential identification of malicious connections.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 sockets
Volatility Foundation Volatility Framework 2.6.1
Offset(V)       PID   Port  Proto Protocol        Address         Create Time
---------- -------- ------ ------ -------------- --------------- -----------
0x81ddb780      664    500     17 UDP            0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x82240d08     1484   1038      6 TCP            0.0.0.0         2012-07-22 02:44:45 UTC+0000
0x81dd7618     1220   1900     17 UDP            172.16.112.128  2012-07-22 02:43:01 UTC+0000
0x82125610      788   1028      6 TCP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x8219cc08        4    445      6 TCP            0.0.0.0         2012-07-22 02:42:31 UTC+0000
0x81ec23b0      908    135      6 TCP            0.0.0.0         2012-07-22 02:42:33 UTC+0000
0x82276878        4    139      6 TCP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x82277460        4    137     17 UDP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x81e76620     1004    123     17 UDP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x82172808      664      0    255 Reserved       0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x81e3f460        4    138     17 UDP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x821f0630     1004    123     17 UDP            172.16.112.128  2012-07-22 02:43:01 UTC+0000
0x822cd2b0     1220   1900     17 UDP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x82172c50      664   4500     17 UDP            0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x821f0d00        4    445     17 UDP            0.0.0.0         2012-07-22 02:42:31 UTC+0000
```

Figure 1 : volatility plugin 'sockets' this plugin checks all sockets

Figure [1] uses the volatility plugin 'sockets' this plugin checks all sockets that are listening for connections. After the plugin is ran the columns are displayed showing information which consist of : Offset , PID, Port , Protocol , Address and create Time . The offset columns represent where the memory offset for the sockets structure is lo0cated at. PID represents the process ID for each of the sockets. Port represents the prot number that each socket are using. Proto is used to display the error checked delivery over network. Protocol is used to display either TCP&UDP and reserved the socket is using. Address displays the IP address associated with each socket showing if their either Localhost/loopback to a local network ipd address and 0.0.0.0 represents socket listening for connections and lastly the create time shows when each sockets was created.

Connections : plugin is designed to enumerate active TCP connections within a memory image, providing insights into network communication at the time of acquisition. It retrieves details such as local and remote addresses, ports, and the owning process ID, aiding in the analysis of network activity and potential identification of malicious connections.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 connections
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  Local Address             Remote Address            Pid
---------- ------------------------ ------------------------ ---
0x81e87620 172.16.112.128:1038      41.168.5.140:8080         1484
```

Figure 2 : connections plugin, revealing a connection originating from the local network IP address

Figure [2] utilizes the connections plugin, revealing a connection originating from the local network IP address **172.16.112.128**, a private IP address operating on port **1038**. This connection is established with the remote IP address **41.168.5.140**, a public IP located in **Johannesburg, Gauteng, South Africa**, which uses port **8080**. Port 8080 is commonly associated with web server traffic, indicating that the user is accessing a

website hosted in Johannesburg. Further in-depth analysis of the remote address, conducted using the IPinfo service, is illustrated in Figure [3] below.

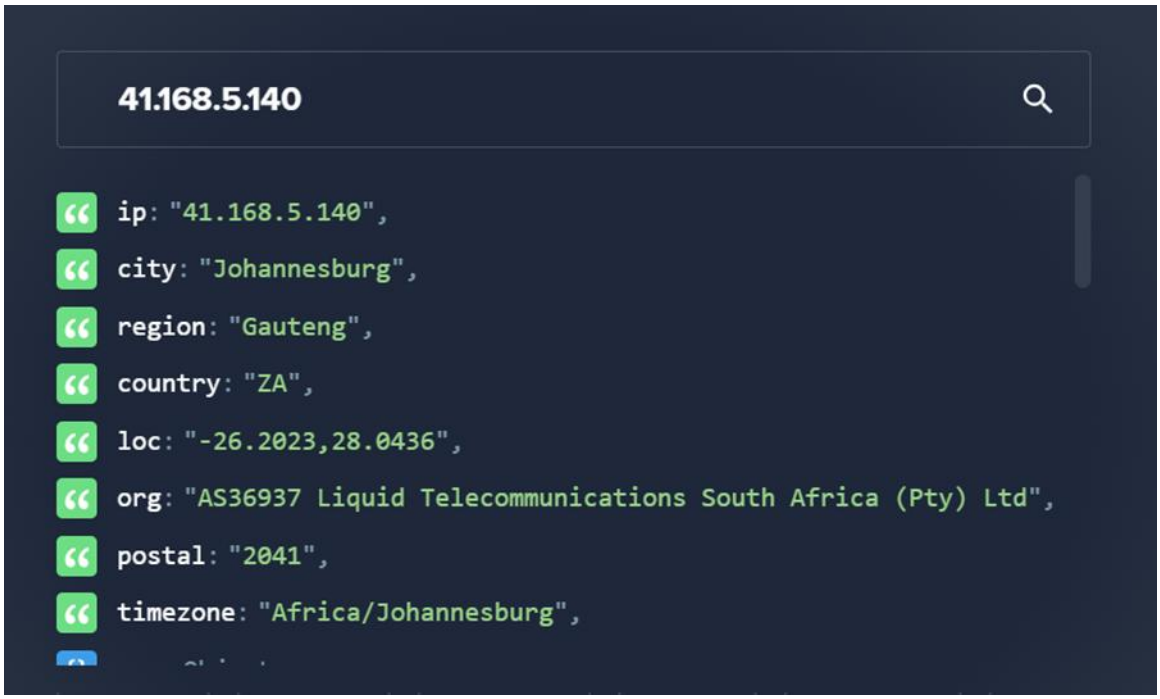


Figure 3: show the public IP address **41.168.5.140** being queried on the IPinfo website

The figures above show the public IP address **41.168.5.140** being queried on the IPinfo website to gather further details. The results indicate that the IP address is located in **Johannesburg, Gauteng, South Africa** and does not have an associated Domain Name Service (DNS). Additionally, running the IP address through IPinfo.io reveals that it is registered to **Liquid Telecommunication South Africa (PTY) LTD**, a company that rebranded in 2021 to **Liquid Intelligent Technologies**. This company specializes in delivering tailored digital solutions to private enterprises and SMEs across the continent, focusing primarily on telecommunications and satellite services worldwide.

Localhost (Loopback)	788	1028	6 (TCP)	127.0.0.1	Not Infected
Localhost (Loopback)	1220	4000	6 (TCP)	127.0.0.1	Not Infected
Local Network	1004	445	17 (UDP)	172.16.112.128	Unknown
Local Network	4	137	17 (UDP)	172.16.112.138	Unknown
Public Network	1220	4000	17 (UDP)	192.168.0.1	Unknown
Public Network	4	445	17 (UDP)	0.0.0.0	Unknown

Table 1 : showing either localhost, local network or public network which was found on figure 1

2.2 . From the provided memory dump, check the inactive sockets. Enumerate them and where these inactive connections are pointing. Distinguish between localhost connections, local network ones and public network connections.

Volatility plugin “Sockets” and “sockscan” and them can dump them into a text file which can be thoroughly gone through to help find the difference between all inactive and live sockets within the infected dump.

Sockets: This plugin is designed to enumerate active socket connections within a memory image, providing insights into network communication at the time of acquisition. It retrieves details such as protocol type, local and remote addresses, ports, and the owning process ID, aiding in the analysis of network activity and potential identification of malicious connections.

Sockscan: is designed to identify and enumerate active socket objects within a memory image by scanning for _ADDRESS_OBJECT structures associated with network sockets. This method allows for the detection of both active and previously terminated sockets, providing insights into network communications that may not be listed through standard enumeration techniques

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 sockets
Volatility Foundation Volatility Framework 2.6.1
Offset(V)       PID   Port  Proto Protocol        Address         Create Time
---------- -------- ------ ------ -------------- --------------- -----------
0x81ddb780      664    500     17 UDP            0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x82240d08     1484   1038      6 TCP            0.0.0.0         2012-07-22 02:44:45 UTC+0000
0x81dd7618     1220   1900     17 UDP            172.16.112.128  2012-07-22 02:43:01 UTC+0000
0x82125610      788   1028      6 TCP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x8219cc08        4    445      6 TCP            0.0.0.0         2012-07-22 02:42:31 UTC+0000
0x81ec23b0      908    135      6 TCP            0.0.0.0         2012-07-22 02:42:33 UTC+0000
0x82276878        4    139      6 TCP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x82277460        4    137     17 UDP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x81e76620     1004    123     17 UDP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x82172808      664      0    255 Reserved       0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x81e3f460        4    138     17 UDP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x821f0630     1004    123     17 UDP            172.16.112.128  2012-07-22 02:43:01 UTC+0000
0x822cd2b0     1220   1900     17 UDP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x82172c50      664   4500     17 UDP            0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x821f0d00        4    445     17 UDP            0.0.0.0         2012-07-22 02:42:31 UTC+0000
```

Figure 4: plugins “sockets” to detect all sockets that are listening for connections

Figure [4] uses the volatility plugins “sockets” to detect all sockets that are listening for connections.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 sockets > sockets.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$
```

Figure 5: sockets plugin, which outputs the results into a text file.

The above **Figure [5]** demonstrates the use of the sockets plugin, which outputs the results into a text file. This file serves as a valuable resource for further analysis, enabling the identification of both active and inactive sockets within the provided memory dump.

“sockscan” This plugin picks up residual and artifacts on previous sockets.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 sockscan
Volatility Foundation Volatility Framework 2.6.1
Offset(P)       PID   Port  Proto Protocol        Address         Create Time
---------- -------- ------ ------ -------------- --------------- -----------
0x01fd7618     1220   1900     17 UDP            172.16.112.128  2012-07-22 02:43:01 UTC+0000
0x01fdb780      664    500     17 UDP            0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x0203f460        4    138     17 UDP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x02076620     1004    123     17 UDP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x020c23b0      908    135      6 TCP            0.0.0.0         2012-07-22 02:42:33 UTC+0000
0x02325610      788   1028      6 TCP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
0x02372808      664      0    255 Reserved       0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x02372c50      664   4500     17 UDP            0.0.0.0         2012-07-22 02:42:53 UTC+0000
0x0239cc08        4    445      6 TCP            0.0.0.0         2012-07-22 02:42:31 UTC+0000
0x023f0630     1004    123     17 UDP            172.16.112.128  2012-07-22 02:43:01 UTC+0000
0x023f0d00        4    445     17 UDP            0.0.0.0         2012-07-22 02:42:31 UTC+0000
0x02440d08     1484   1038      6 TCP            0.0.0.0         2012-07-22 02:44:45 UTC+0000
0x02476878        4    139      6 TCP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x02477460        4    137     17 UDP            172.16.112.128  2012-07-22 02:42:38 UTC+0000
0x024cd2b0     1220   1900     17 UDP            127.0.0.1       2012-07-22 02:43:01 UTC+0000
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 sockscan > inactive_sockets.txt
Volatility Foundation Volatility Framework 2.6.1
```

Figure 6: volatility plugin sockscan

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 sockscan > inactive_sockets.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$
```

Figure 7

Both **Figure [6],[7]** above first showcase the use of the Volatility plugin sockscan, which, as mentioned earlier, lists all sockets listening for connections. The second figure demonstrates saving this data into a file named **"inactive_sockets"**. This step is performed to facilitate further analysis, enabling the examination of both active and inactive sockets within the provided memory dump.

Connections: plugin is useful for identifying and analysing inactive sockets by enumerating existing or previously established connections on a system. By inspecting these connections, the plugin helps determine their status and the destination they are pointing to

Network Forensics: Helps trace connections to understand the origin or destination of past communications, crucial for investigating intrusions.

Troubleshooting: Assists in diagnosing connectivity issues or verifying which services were previously active.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 connections
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  Local Address             Remote Address            Pid
---------- ------------------------ ------------------------ ---
0x81e87620 172.16.112.128:1038      41.168.5.140:8080        1484
kali@kali:/media/testShare$
```

Figure 8 : connections` plugin to display all external network connections

Figure [8]utilizes the `connections` plugin to display all external network connections, along with the ports being used. It provides details such as the offset, local address, remote address, and PID.

- Offset indicates the memory location where the connection object is stored.

- Local Address shows the local IP address and the port number associated with the connection.

- Remote Address displays the remote IP address and the corresponding port number used for the connection.

- PID (Process ID) identifies the process responsible for establishing the connection.

Connscan: plugin is a forensic tool often used to analyze network connections from a memory dump. It is particularly valuable in identifying inactive sockets—connections that are no longer actively used but are still recorded in memory.

Helps identify persistent malware that may establish connections and then drop them to remain undetected.

Reveals historical communication patterns, including connections that might indicate data exfiltration.

Differentiates between normal system activity and potentially malicious behaviors (e.g., connections to external unknown servers).

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 connscan
Volatility Foundation Volatility Framework 2.6.1
Offset(P)  Local Address             Remote Address            Pid
---------- ------------------------ ------------------------ ---
0x02087620 172.16.112.128:1038      41.168.5.140:8080         1484
0x023a8008 172.16.112.128:1037      125.19.103.198:8080       1484
kali@kali:/media/testShare$
```

Figure 9: `connscan` plugin to display all network connections, including the ports

Figure [9] uses the `connscan` plugin to display all network connections, including the ports that were utilized. Similar to previous plugins, it provides four key columns:

- Offset: Indicates where the memory for the connection object is stored.

- Local Address: Displays the local IP address and the port number associated with the connection.

- Remote Address: Shows the remote IP address involved in the connection along with the corresponding port number, capturing both active and terminated connections.

- PID: Identifies the process ID responsible for the connection.

The figure highlights both active and inactive connections within the infected memory dump. Notably, two connections share the same PID (1484) but use different ports: 1037 and 1038. The connection using port 1037 was terminated, followed by a new connection using port 1038. Both connections utilized port 8080, commonly associated with proxies or web servers.

The remote IP address 41.168.5.140:8080 traces back to Johannesburg, Gauteng, South Africa, as shown in Figure [3], while the IP address 125.19.103.198:8080 points to Delhi, India, as illustrated in Figure [11].

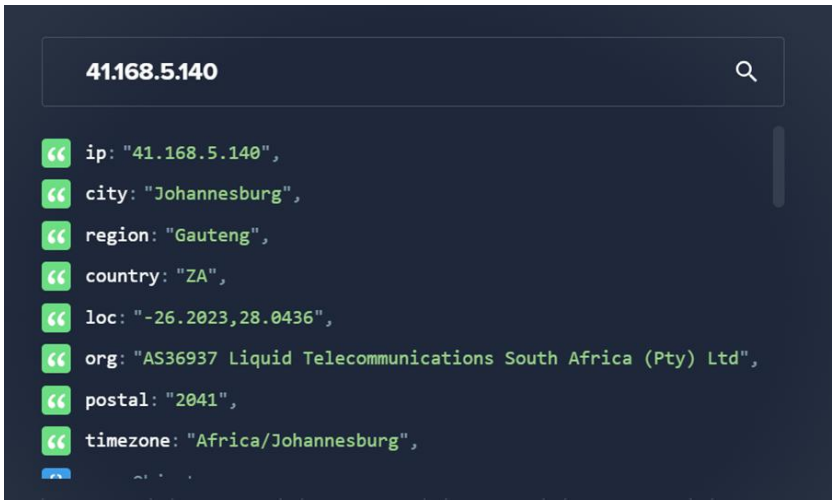


Figure 10: IP address 41.168.5.140:8080 traces back to Johannesburg, Gauteng, South Africa

Figure 11: IP address 125.19.103.198:8080 points to Delhi, India,

https://ipinfo.io/

The use of “awk” was used to remove the first column which is the physical offsfet value for the “sockets” and “sockscan” plugin is done as both plugins get there findings fom different areas from the memory dump as “sockets” gets results from the “tcpip.sys” module whilst “sockscan” get results from by scanning the entire memory dump looking for any patterns.

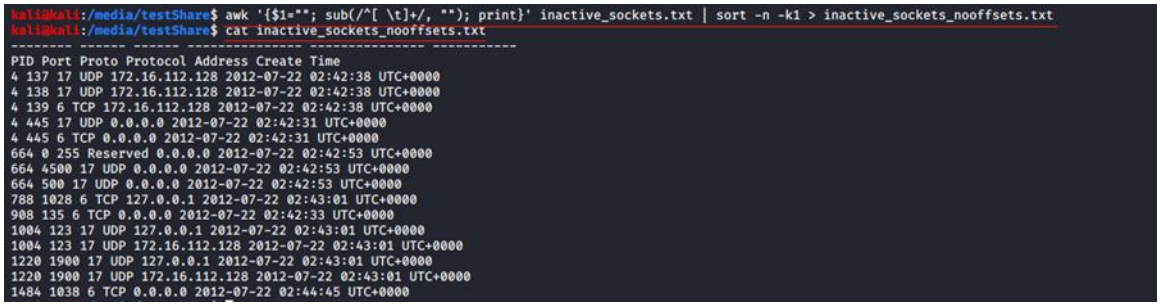


Figure 12: "live_sockets.txt" using the command "awk" which removes the physical offsets

Figure [12] shows the "live_sockets.txt" using the command "awk" which removes the physical offsets as explained above. Once this is completed the a table created below would show results of no active sockets and active sockets on the provided memory dump. Code explanation: awk

awk '{$1=""; sub(/^[\t]+/, ""); print}' inactive_sockets.txt | sort -n **-k1 > inactive_sockets_nooffsets.txt**

1. `awk '{$1=""; sub(/^[ \t]+/, ""); print}' inactive_sockets.txt`:

- Removes the first column (like PID numbers) from `inactive_sockets.txt`.

- Cleans up any extra spaces or tabs at the beginning of eachline.

2. `sort -n -k1`:

- Sorts the remaining lines numerically by the first column (

3. `> inactive_sockets_nooffsets.txt`:

- Saves the cleaned and sorted output into a new file called `inactive_sockets_nooffsets.txt`.

PID	Port	Protocol	Address	Status
664	500	17 (UDP)	0.0.0.0	Inactive
1484	1038	6 (TCP)	0.0.0.0	Inactive
788	1028	6 (TCP)	127.0.0.1	Active
908	135	6 (TCP)	0.0.0.0	Inactive
1220	4000	6 (TCP)	127.0.0.1	Active
1004	445	17 (UDP)	172.16.112.128	Active
4	445	6 (TCP)	0.0.0.0	Inactive
4	137	17 (UDP)	172.16.112.138	Active
4	4500	17 (UDP)	0.0.0.0	Inactive
1220	1900	17 (UDP)	127.0.0.1	Active
4	1900	17 (UDP)	172.16.112.128	Active

Table 2: showing the results found put in a table from figure 12

2.3. Explain what the DNS protocol is and its relevance for memory analysis. Recover the DNS file of both memory dumps and show them. Are the addresses the same? Why?

The **Domain Name System (DNS)** functions as the "phonebook" of the internet, translating **domain names** into **IP addresses** that browsers use to load web pages. Every device connected to the internet has a unique **IP address**, which other devices use to locate and communicate with it. DNS was developed to simplify web navigation, allowing users to connect to websites using easy-to-remember domain names instead of numerical IP addresses. Without DNS, users would need to memorize the IP addresses of every website they wish to visit, which would be highly impractical.

However, DNS also has its vulnerabilities. These include **DNS cache poisoning**, where malicious data is introduced into the DNS cache, and the creation of misleading domain names for **phishing attacks**. In the context of **memory analysis**, the DNS-related **"host.dat"** file is often examined for signs of malicious activity. This file can be manipulated to block access to legitimate websites or redirect users to malicious ones. Analyzing the **host.dat** file is crucial for detecting modifications that may compromise the system or user security.

- Plugin: filescan this scans the physical memory using pool tag scanning, scans a memory dump to identify and reconstruct files or file objects that were active or cached during system operation. It can help identify DNS-related log files that were opened at the time.
  Filescan works by searching through the memory dump for file related structures like : file objects, handles etc.

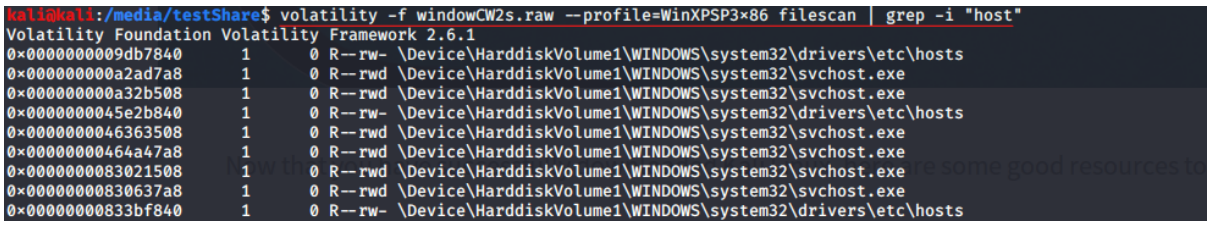


Figure 13: volatility plugin filescan

The above figure[13] shows the use of the volatility plugin “filescan” to show that the file path of the “host.dat” file with the given physical offset address and they the type of file it is. In the figure above [13] it also shows that the “host.dat” has read and write authority.

Dumpfiles: dumpfiles plugin is used in memory forensics to extract files from a memory dump. which can inclide files such as DNS cache data and other artifacts that may exist in memory. When investigating memory dumps for DNS records, the dumpfiles plugin is relevant because DNS queries and responses may be stored as temporary or cached files in the memory of a compromised system.

DNS Cache in Memory: When a system resolves DNS queries, these are often cached in memory for efficiency. If this data is captured in a memory dump, it can be extracted and analyzed using the dumpfiles plugin.

Validation and Analysis: Extracted DNS data can be validated to uncover previously accessed domains, which is crucial for understanding the attack timeline and connections.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 dumpfiles -Q 0x0000000009db7840 --dump-dir /media/testShare
Volatility Foundation Volatility Framework 2.6.1
DataSectionObject 0x09db7840   None   \Device\HarddiskVolume1\WINDOWS\system32\drivers\etc\hosts
kali@kali:/media/testShare$
```

Figure 14: dumping "host.dat"

The above figure [14] shows the dumping process of the "host.dat" within the clean dumping process. Which was done to check the content within the clean dump "host.dat"not then compare to "host.dat" of the infected dump which is done to ensure no manipulation of the "host.dat" which can show proof of any dns poisoning.

```
kali@kali:/media/testShare$ ls
cw2_Machine4Infected.dump  file.None.0x8a264530.dat  inactive_sockets_nooffsets.txt  inactive_sockets.txt  sockets.txt  windowCW2s.raw
kali@kali:/media/testShare$ cat /media/testShare/file.None.0x8a264530.dat
# Copyright (c) 1993-1999 Microsoft Corp.
#
# This is a sample HOSTS file used by Microsoft TCP/IP for Windows.
#
# This file contains the mappings of IP addresses to host names. Each
# entry should be kept on an individual line. The IP address should
# be placed in the first column followed by the corresponding host name.
# The IP address and the host name should be separated by at least one
# space.
#
# Additionally, comments (such as these) may be inserted on individual
# lines or following the machine name denoted by a '#' symbol.
#
# For example:
#
#      102.54.94.97     rhino.acme.com          # source server
#       38.25.63.10     x.acme.com              # x client host

127.0.0.1       localhost
kali@kali:/media/testShare$
```

Figure 15: host.dat content from clean dump

Figure [15] above shows the content of the "host.dat" file within the clean dump.

FIleScan: is used to **scan memory dumps** for file objects based on specific signatures. It helps identify files that were open or referenced by processes during the memory capture. Its relevenace to dns is due to the fact that DNS activity can be tied to specific processes or files found using filescan.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 filescan | grep -i "host"
Volatility Foundation Volatility Framework 2.6.1
0x000000000227bb60      1      0 R--rwd \Device\HarddiskVolume1\WINDOWS\system32\drivers\etc\hosts
0x000000000245a9b8      1      0 R--rwd \Device\HarddiskVolume1\WINDOWS\system32\svchost.exe
0x00000000024a7700      1      0 R--rwd \Device\HarddiskVolume1\WINDOWS\system32\svchost.exe
kali@kali:/media/testShare$
```

Figure 16:filescan plugin ran on infected dump

Figure [16] shows the filescan plugin being executed on the infected memory dump, revealing modifications to the **"host.dat"** file. The evidence of deletion is visible in the **Access** column, where the entry **"R—rwd"** includes a lowercase **"d"**, indicating that the file has been marked for deletion. This action may have been taken to erase traces of modifications by overwriting data within the file path **/Device/HarddiskVolume1/WINDOWS\system32\drivers\etc**, as illustrated in Figure [16].

In Windows operating systems, the **host.dat** file is a local plain text file that maps server hostnames to specific IP addresses. It serves as a method for resolving hostnames to IP addresses, bypassing DNS.

Mftparser: this plugin scans for potential master file table entries in the memory

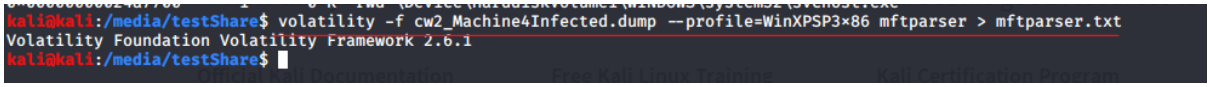


Figure 17: creation of the "mftprarser.txt"

Figure above shows how the volatility plugin was used to produce result which is outputted into a tex file called "mftparser.txt"

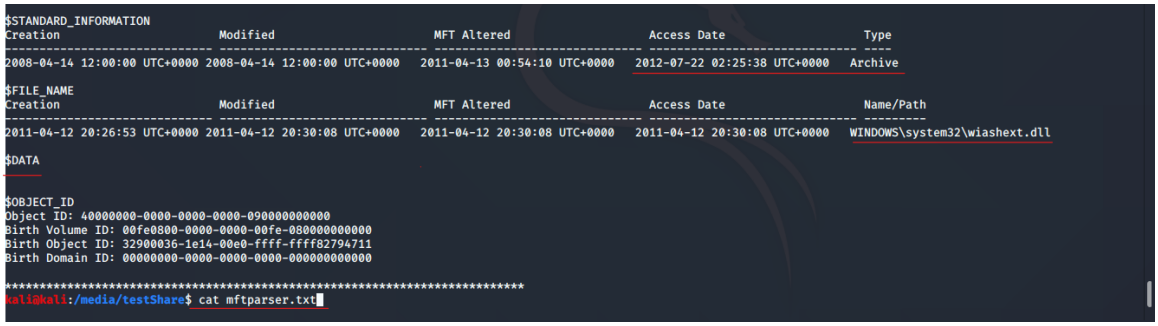


Figure 18: results of the mftparser

The above Figure [18] displays the results of the Volatility plugin mftparser, which parses the Master File Table (MFT) entries from the memory dump. The output provides key metadata about the file WINDOWS\system32\wiashext.dll under the "Name/Path" field. This location indicates the file resides in the critical System32 directory, which is a common target for attackers attempting to place or manipulate malicious files.

The timestamps in the STANDARD_INFORMATION and $FILE_NAME fields provide critical insights into the file's lifecycle:

- Creation Date: The file was created on 2008-04-14 at 12:00:00 UTC.
- Modified Date: It was last modified on 2008-04-14 at 12:00:00 UTC.
- MFT Altered: The entry was altered on 2011-04-12 at 00:54:10 UTC, suggesting possible manipulation or activity involving this file.
- Access Date: The file was last accessed on 2012-07-22 at 02:25:38 UTC, shortly before being archived or deleted.

The $DATA field is empty, which typically holds file content in hexadecimal format. The absence of data confirms that the file has been deleted or the content is no longer retrievable from memory.

Attempts to use the MFT entry offset to recover the file were unsuccessful, further supporting that the file content is no longer available in the memory dump.

- The file name wiashext.dll appears to be associated with the Windows Image Acquisition (WIA) service. While this is a legitimate DLL, its presence in System32 combined with the deletion activity may warrant further investigation to rule out tampering or abuse by malware.
- The Object ID and associated identifiers (Birth Volume ID, Birth Object ID) confirm the unique attributes of the file within the system but do not provide additional file content.
- Importance:

1. File Path: The path (`WINDOWS\system32\wiashext.dll`) highlights a potential area of concern, as the System32 folder is a high-value target.

2. Timestamps: The timeline reveals access and modification activity, which could point to malicious behavior or system changes.

3. Empty $DATA: Confirms that the file's content is unrecoverable, indicating deletion or tampering.

4. Failed Recovery: Attempts to recover the file using its MFT offset failed, reinforcing the likelihood that the file was deleted.

2.4 Scan the services of both memory dumps and highlight those services that are different. How many services have each memory dump? Select 5 services of the provided memory dump and describe them.

Plugin description : Svcscan : is used to identify and display the Windows services present in a memory dump. which is critical tool in memory forensics for understanding services that were active, stopped, or even hidden during the time the memory was captured. This plugin extracts valuable details such as: service name , display name, pid, service type, service state ,binary path. svscan also helps uncover hidden or hidden services

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 svcscan | grep 'Service Name' > infected_name_service.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$
```

Figure 19: grepping whilst using svscan

Figure [19] demonstrates the use of a Volatility plugin on the infected memory dump, with the **grep** command employed to filter results specifically related to the **"service name"**. The filtered output is then saved into a text file named **"infected_name_service"**. This file serves as a resource for further analysis, allowing investigators to compare the results against a clean memory dump to identify anomalies or discrepancies.

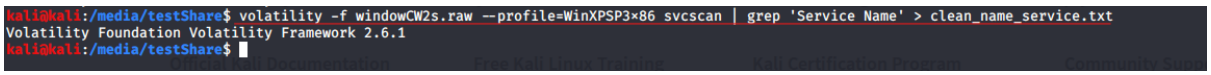


Figure [19] illustrates the use of the Volatility plugin svcscan executed on a clean memory dump. The **grep** command is applied to filter results related to the **"service name"**, and the output is saved to a text file named **"clean_name_service.txt"**. This file is essential for further analysis, enabling a comparison between the clean and infected services to identify any discrepancies or malicious activity.

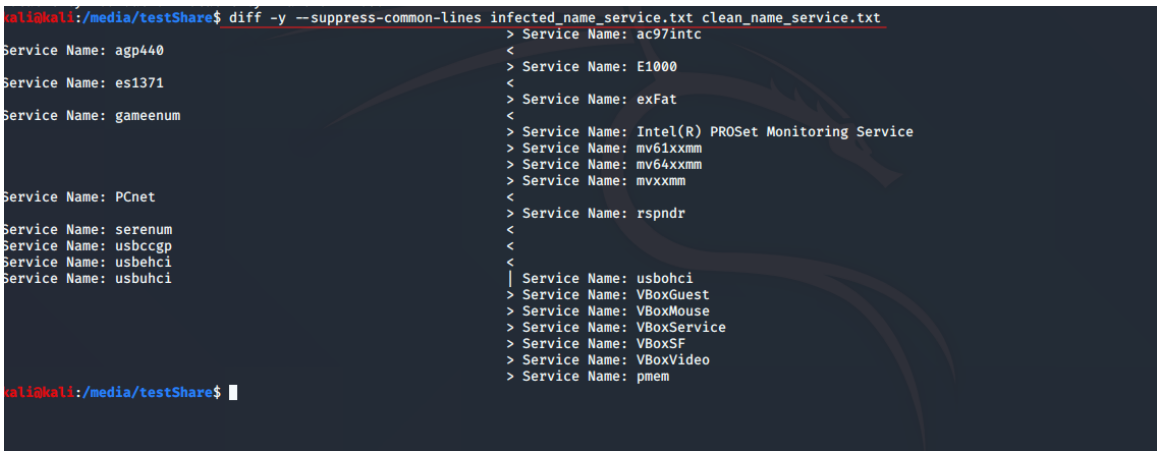


Figure 20: results of service in infected and clean dump

The figure above shows a side by side comparison of the different services that are seen in the infected dump and cannot be found on the clean dump. Figure [] also shows us that there are 15 services which are in the clean that cannot be found on the infected dump.

Service Name (Infected)	Service Name (Clean)
agp440	ac97intc
es1371	E1000
gameenum	exFat

PCnet	Intel(R) PROSet Monitoring Service
serenum	mv61xxmm
usbccgp	VBoxGuest
usbuhci	VBoxMouse
	VBoxService
	VBoxSF
	VBoxVideo
	pmem
	Mv64xxmm
	mvxmm
	rspndr
	usbohci

The above table [3] dislays and shows the difference between service found in the infected and the clean memory dump.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 svcscan | grep -c 'Service Name'
Volatility Foundation Volatility Framework 2.6.1
244
```

Figure 21: total services in infected dump

Figure [21] displays the total number of services identified in the infected memory dump, which amounts to **244**. This result was obtained by running the appropriate command and using the **grep** option **-c** to count the matching lines, providing the total number of services found.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 svcscan | grep -c 'Service Name'
Volatility Foundation Volatility Framework 2.6.1
251
kali@kali:/media/testShare$
```

Figure 22: Total service inclean dump

The above figure [22] shows the number of services found within the clean memory dump which is “251”. Which was done by grepping “-c” which prints out the results.

Agp440

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 svcscan | grep 'agp440' -C 4
Volatility Foundation Volatility Framework 2.6.1
Offset: 0x382268
Order: 8
Start: SERVICE_BOOT_START
Process ID: -
Service Name: agp440
Display Name: Intel AGP Bus Filter
Service Type: SERVICE_KERNEL_DRIVER
Service State: SERVICE_RUNNING
Binary Path: \Driver\agp440

Offset: 0x3822f8
Order: 9
Start: SERVICE_DISABLED
kali@kali:/media/testShare$
```

Figure 23: svscan plugin –C4

Figure [23] shows the svcscan plugin executed against the infected memory dump, with the results filtered using **grep** for the service name and the **-C 4** option, which prints four lines of context around the match. This output highlights the relevant information associated with the specified Windows service.

In this case, the results pertain to the **'agp440'** service, which has a display name of **'Intel AGP Bus Filter'**. The **agp440** service is a critical component of the Windows operating system, as it serves as a driver—a small software program that enables the system to communicate with hardware or connected devices.

'agp550' manage the communication with the Accelerated Graphics Port with the central processing unit. 'AGP440' is located at "\Driver\agp440" folder path .

Gameenum

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 svcscan | grep 'gameenum' -C 4
Volatility Foundation Volatility Framework 2.6.1
Offset: 0x384488
Order: 69
Start: SERVICE_DEMAND_START
Process ID: -
Service Name: gameenum
Display Name: Game Port Enumerator
Service Type: SERVICE_KERNEL_DRIVER
Service State: SERVICE_RUNNING
Binary Path: \Driver\gameenum

Offset: 0x384518
Order: 70
Start: SERVICE_DEMAND_START
kali@kali:/media/testShare$
```

Figure 24 :svscan plugin being executed on gameeenum

Figure [24] displays the results for the Windows service **'gameenum'**, which has the display name **"Game Port Enumerator"**. This service is located in the file path **\Driver\gameenum** and can be stopped through the Control Panel. The **'gameenum'** service driver is responsible for managing gaming controllers connected via the game port, a legacy hardware interface commonly found on older desktop PCs.

Serenum

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 svcscan | grep 'serenum' -C 4
Volatility Foundation Volatility Framework 2.6.1
Offset: 0x3885e8
Order: 186
Start: SERVICE_DEMAND_START
Process ID: -
Service Name: serenum
Display Name: Serenum Filter Driver
Service Type: SERVICE_KERNEL_DRIVER
Service State: SERVICE_RUNNING
Binary Path: \Driver\serenum

Offset: 0x388678
Order: 187
Start: SERVICE_SYSTEM_START
```

Figure 25: svscan being executed on serenum

Figure [25] presents the results for the Windows service **'serenum'**, which has the display name **"Serenum Filter Driver"**. This service is a kernel-mode driver located in the file path **\Driver\serenum**. The **'serenum'** driver serves as a crucial bridge between

hardware and software, enabling the detection of **Plug and Play** devices such as modems and other peripherals.

Usbccgp

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 svcscan | grep 'usbccg' -C 4
Volatility Foundation Volatility Framework 2.6.1
Offset: 0x389b28
Order: 224
Start: SERVICE_DEMAND_START
Process ID: -
Service Name: usbccgp
Display Name: Microsoft USB Generic Parent Driver
Service Type: SERVICE_KERNEL_DRIVER
Service State: SERVICE_STOPPED
Binary Path: -
kali@kali:/media/testShare$
```

Figure 26: svscan executed on usbccg

Figure [26] shows the results for the service **'usbccg'**, which has the display name **"Microsoft USB Generic Parent Driver"**. This is a kernel-level driver, as indicated in the figure. The **'usbccg'** service is a built-in component of all versions of Microsoft Windows. It serves as a universal driver for most USB controllers, enabling them to interface with the operating system. This functionality allows the computer to communicate with hardware or connected devices via USB ports.

PCnet

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 svcscan | grep 'PCnet' -C 4
Volatility Foundation Volatility Framework 2.6.1
Offset: 0x386ee0
Order: 145
Start: SERVICE_DEMAND_START
Process ID: -
Service Name: PCnet
Display Name: AMD PCNET Compatable Adapter Driver
Service Type: SERVICE_KERNEL_DRIVER
Service State: SERVICE_RUNNING
Binary Path: \Driver\PCnet

Offset: 0x386f68
Order: 146
Start: SERVICE_DEMAND_START
kali@kali:/media/testShare$
```

Figure 27:svscan executed on pcnet

The figure [27] above shows the result related to the service called ‘PCnet’ and it’s a kernel driver.. This service display name is “AMD PCNET Compatible Adapter Driver”. PCnet detects the edge structure by estimating the phase congruency of different scale of frequency components. And the service path is “\Driver\PCnet”.

2.5.Using Yara, identify any HTTP or HTTPS connection inside of the memory dump. Enumerate the URLs that you have found. Which ones are suspicious and why?

Yarascan- a volatility plugin that is used to scan process or kernel memory with yara signatures. Yarascan helps to identify and classify malware samples and makes it possible to create description based on binary patterns and can be used in command line.

```
kali@kali:/media/testShare$ cat /media/testShare/http_and_https.yar
rule http{
    strings:
        $http="http://"
        $https="https://"
    condition:
        $http or $https
}
```

Figure 28: creation of Yara

Figure [28] showcases a **Yara** scanning rule created using Python. This rule is designed to scan the provided (infected) memory dump for any **HTTP** and **HTTPS** content. It specifically searches for strings that may contain **"http"** or **"https"** within the memory dump.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 yarascan -y "http_and_https.yar" > http_https.txt
Volatility Foundation Volatility Framework 2.6.1
```

Figure 29:Yara being executed on infected dump

The above figure [29] displays shows the plugin ran “http_and_htpps.yar” against the infected dump and the results are saved to a text file called “http_https.txt” which will used for further analysis .

```
Rule: http
Owner: Process explorer.exe Pid 1484
0x01d44277  68 74 74 70 3a 2f 2f 31 38 38 2e 34 30 2e 30 2e   http://188.40.0.
0x01d44287  31 33 38 3a 38 30 38 30 2f 7a 62 2f 76 5f 30 31   138:8080/zb/v_01
0x01d44297  5f 61 2f 69 6e 2f 63 70 2e 70 68 70 00 00 0e 00   _a/in/cp.php....
0x01d442a7  00 00 84 00 00 00 1f b8 c0 c3 01 bb 2d 16 00 00   ............-...
0x01d442b7  83 00 00 00 19 16 00 00 00 00 00 00 19 00 00 00   ................
0x01d442c7  2a 61 63 63 6f 75 6e 74 2e 61 75 74 68 6f 72 69   *account.authori
0x01d442d7  7a 65 2e 6e 65 74 2f 2a 00 f0 15 00 00 00 00 00   ze.net/*........
0x01d442e7  00 08 00 00 00 ef 15 00 00 3c 68 65 61 64 2a 3e   .........<head*>
0x01d442f7  00 3c 73 74 79 6c 65 20 74 79 70 65 3d 22 74 65   .<style type="te
0x01d44307  78 74 2f 63 73 73 22 3e 0d 0a 62 6f 64 79 20 7b   xt/css">..body.{
0x01d44317  20 76 69 73 69 62 69 6c 69 74 79 3a 20 68 69 64   .visibility: hid
```

Figure 30: results of the http on notepad after it was made into a txt.file

Figure [30] presents one of the many results saved in the **"http_and_https.txt"** file. The output reveals that **PID 1484** established an **HTTPS** connection to the URL http://188.40.0.138:8080\zb\v_01_a\in\cp.php. This connection is flagged as potentially suspicious because it uses a direct **IP address** instead of a **Domain Name**

Service (DNS), and it communicates over **port 8080**, which is often associated with proxy or web server traffic.

HTTP URL	Domain	Frequency
http://ocsp.verisign.com	.com	2
http://crl.microsoft.com	.com	3
http://www.microsoft.com	.com	4
http://www.verisign.com	.com	2
http://cr.oft.com	.com	1
http://www.trustcenter.de	.de	5
http://www.certplus.com	.com	4
http://crl.verisign.com	.com	2
http://www.usertrust.com	.com	6
http://www.usertrust.com1	.com1	7
http://www/valicert.com	.com	6
http://certplus.com	.com	1
http://ca.sia.it	.it	3
http://www.usertrust.com1+0	.com1+0	2
http://www.entrust.net	.net	1
http://wwwdigsittrust.com	.com	1
http://www.usertrust.com1604	.com1604	2
http://support.microsoft.com	.com	2
http://%s/%s.wpad.dat	.dat	4
http://www.chase.com	.com	2
http://188.40.0.138:8080/zb/v_01_a/in/cp.php	cp.php	8

Table [5] The table displays all HTTP website connections identified within the infected memory dump. It includes the HTTP URLs, their corresponding domains, and the frequency of visits for each website.

One particular URL, http://188.40.0.138:8080/zb/v_01_a/in/cp.php, appears 8 times in the analysis. This frequent occurrence makes it suspicious, as legitimate URLs usually appear fewer times unless heavily accessed.

Unlike the other URLs that have associated **DNS entries**, this URL directly uses an **IP address** instead of a domain name. This is unusual because legitimate websites typically rely on domain names, while malware or suspicious connections often use IP addresses to avoid detection.

Additionally, the URL connects through **port 8080**, which is not the standard HTTP port (port 80). Port 8080 is commonly associated with **proxy servers**, which can be used to obfuscate or redirect traffic. This raises further suspicion that the URL may be part of

malicious activity, such as command-and-control (C2) communication or exfiltration of sensitive data.

A **proxy server** acts as a gateway between users and the internet, providing privacy, web filtering, and firewall protection against online threats. However, proxies can also be exploited for malicious purposes, such as proxy attacks, to conceal harmful activities or evade detection. This further highlights the suspicious nature of the connection in question.

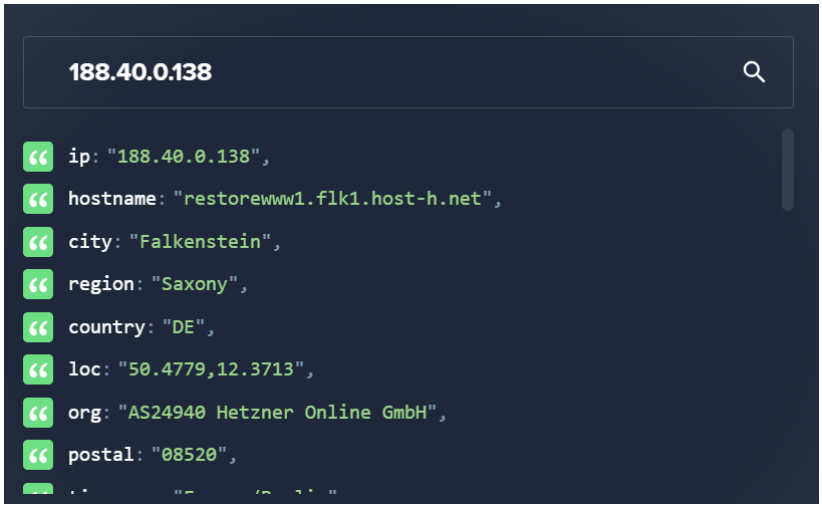


Figure 31: findings of the ip address

The figure [31] above shows information about the ip address “188.40.0.138” and this ip address is located at Falkenstein, Saxony,Germany.

HTTPS URL	Domain	Frequency
https://ca.sia.it	.it	2
https://www.netlock.net	.net	6
https://www.verisign.com	.com	9
https://www.microsoft.com	.com	7
https://crl.microsoft.com	.com	6
https://support.microsoft.com	.com	2
https://ajax.googleapis.com	.com	126
https://account.authorise.net	.net	4
https://mfasa.chase.com	.com	2
https://chaseonline.com	.com	27
https://www.chase.com	.com	7

https://onlinebanking.tdbank.com	.com	4

Table [6] lists all **HTTPS URLs** visited within the infected memory dump, along with the frequency of connections to each website. It is observed that "**https://ajax.googleapis.com**" has been accessed **126 times**.

The URL **https://ajax.googleapis.com** serves as an API loader, simplifying the use of multiple Google AJAX APIs on a single webpage. It can, for example, add dynamic features like a search box to a website.

Based on the provided memory dump, there is evidence suggesting that the user may have initially connected to websites over the less secure **HTTP protocol** before subsequently switching to **HTTPS** for the same websites. This behavior is unusual and raises suspicion, as HTTP connections pose significant security risks compared to HTTPS.

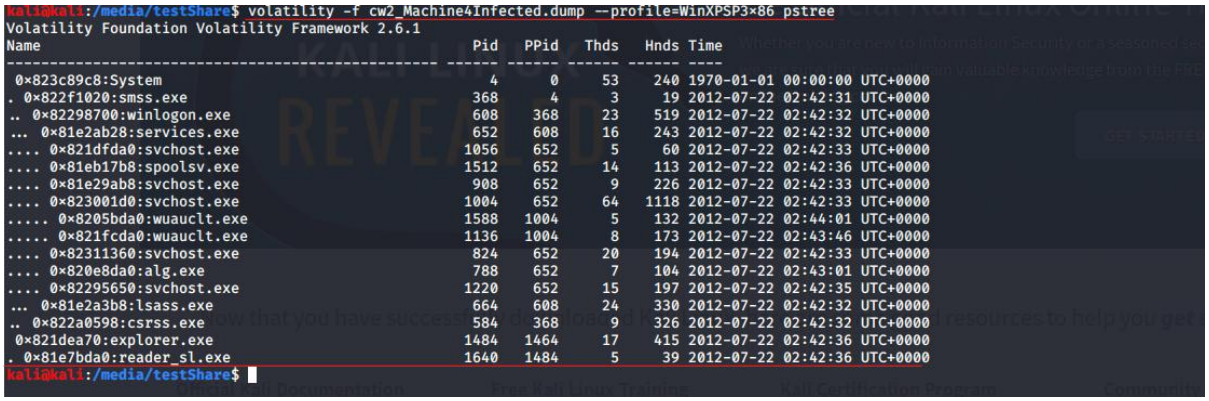


Figure 32:volatility plugin pstree being executed on the infected dump

Figure [32] demonstrates the use of the pstree plugin, which displays all processes in a hierarchical tree format, showing each process along with its parent and child processes. As illustrated in the figure, **PID 1484** is the parent process of **PID 1640**, with the tree structure clearly indicating the parent-child relationship where child processes appear beneath their respective parent processes.

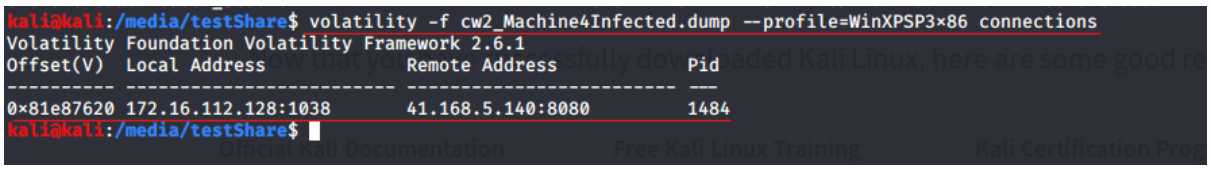


Figure 33:connections plugin executed on infected dump

The figure [33] above shows the plugin “connections” . when this was ran it provided 4 column offset, local address, Remote Address, PID.

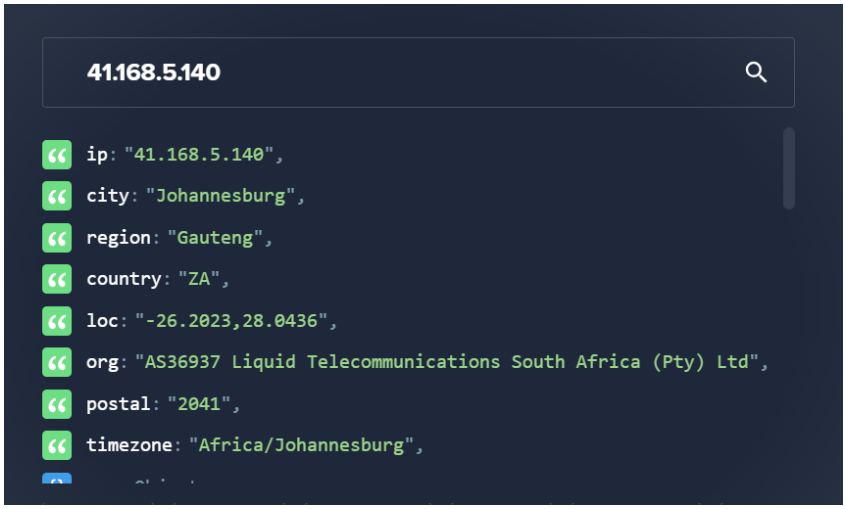


Figure 34:ipaddress findings

https://ipinfo.io/41.168.5.140

The above figure displays the result of the ip on ipinfo and this ip address “41.168.5.1402 has been suspicious on more than 2 database.

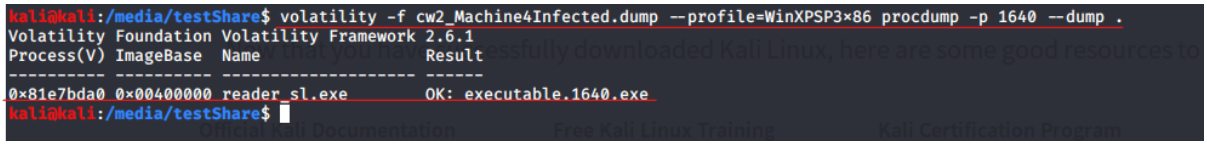


Figure 35:procdump plugin being executed on infected dump

Figure [35] showcases the use of the Volatility plugin `procdump`, which outputs four key columns:

1. Process: Displays the identifier (PID) of the process from which the executable is being dumped.

2. Imagebase: Indicates the base address in memory where the executable is loaded.

3. Name: Shows the name of the process being dumped.

4. Results: Displays the name of the newly created dumped file.

In this instance, PID 1640, named "READER_SL.EXE", is identified as a child process of PID 1484. The process PID 1640 has been successfully dumped, and the resulting file is saved as "executable.1640.exe".

Memdump: is used to extract specific processes' memory contents from a memory dump. While Memdump itself doesn’t directly analyze HTTP/HTTPS connections, it can be used to **dump process memory** where network-related artifacts, including URLs, HTTP requests, and HTTPS connections, might be located. Use the memdump plugin to extract the memory of processes that might have network activity, such as browsers

and **Phishing Investigations**: Extracted URLs may indicate browser activity pointing to phishing sites.

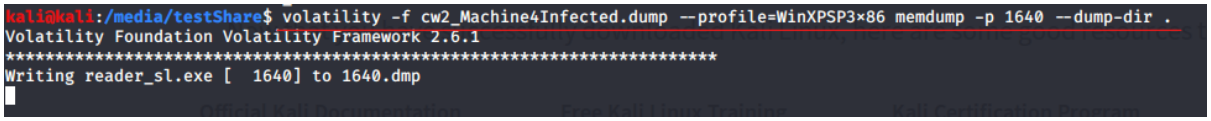


Figure 36:memdump plugin being executed on infected dump

Figure [36] demonstrates the use of the Volatility plugin **memdump**, targeting **PID 1640**. The output generated is saved as **1640.dmp**. The **memdump** plugin was utilized to extract the memory content of the **reader_sl.exe** process, allowing further analysis using commands like **strings** and **cat** to examine its contents in detail.

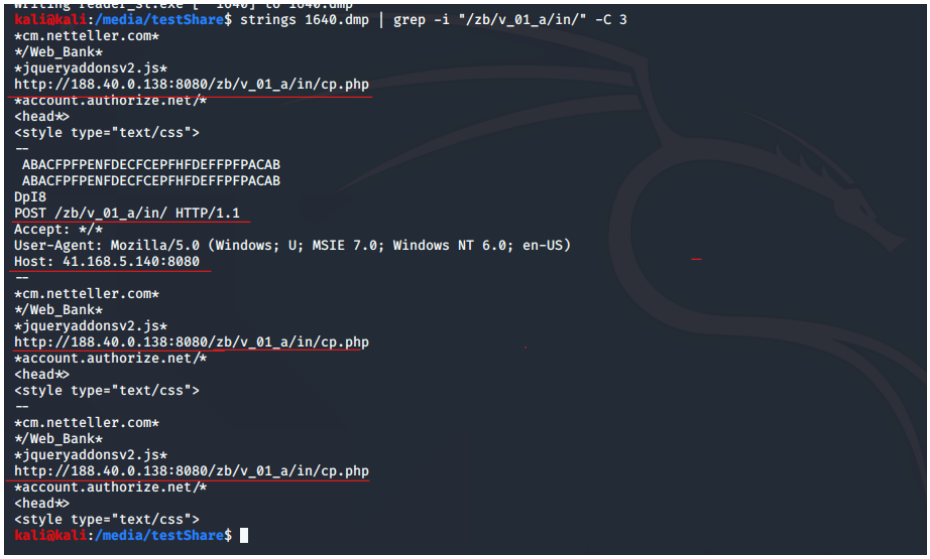


Figure 37: 1640.dmp memory dump being analyzed using the **strings** command

The figure above shows the **1640.dmp** memory dump being analyzed using the **strings** command, with a focus on content related to **HTTP URL extensions**. The results reveal the URL **http://188.40.0.138:8080/zb/v_o1_a/cp.php**, indicating that information is being transmitted to a **"web bank"** endpoint.

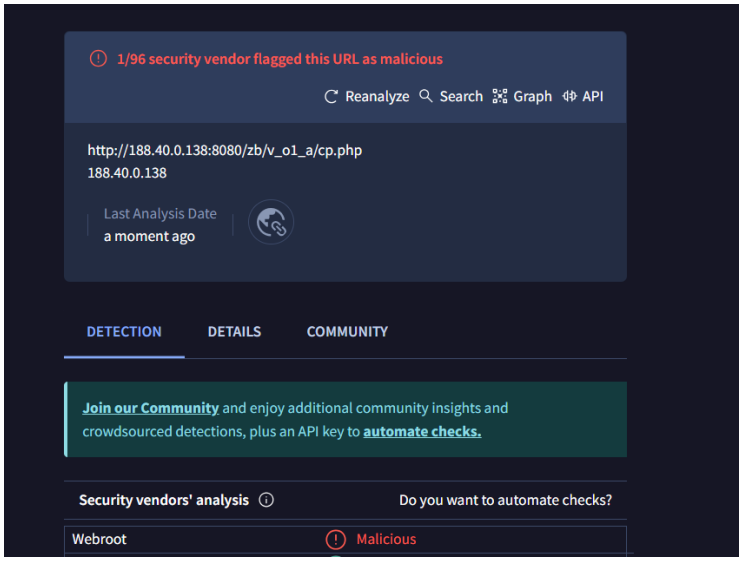


Figure 38:ip address findings

Figure [38] shows that the HTTP URL, identified using **VirusTotal** and **yarascan**, has been flagged as malicious. The URL was subsequently scanned for viruses using **Webroot**, confirming its suspicious nature.

Figure 39:strings search for ".com"

The figure [39] above is searching for ".com" domains within the "1640.dmp" memory dump and it will also save the output as "grep_com.txt" which would show all that is being connected for gathering information.

Figure 40:grepping "bank"

Figure [40] illustrates the use of **grep** with the keyword **"bank"**, which reveals all URLs pointing to major banking websites.

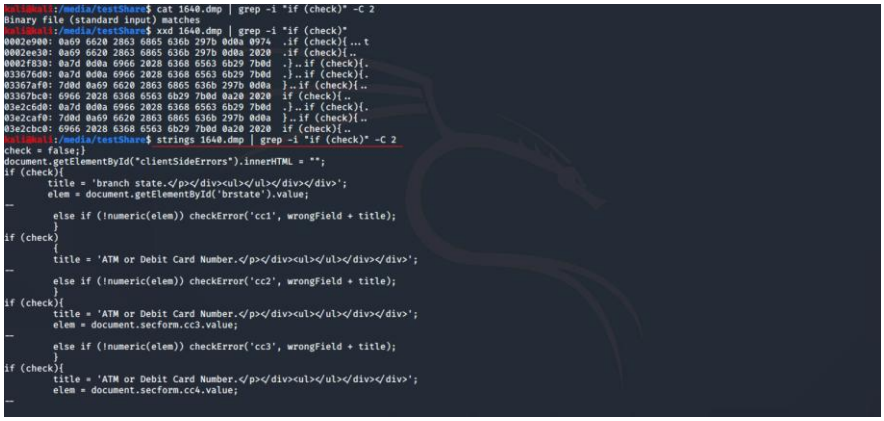


Figure 41: 1640.dmp memory dump being analyzed using the strings command

Figure [41] shows the results of using **1640.dmp** memory dump being analyzed using the **strings** command displaying the surrounding lines of code. The results indicate that **PID 1640** (associated with **reader_sl.exe**) is executing checks on specific field names within websites, such as those related to **debit card information** and **card numbers**.

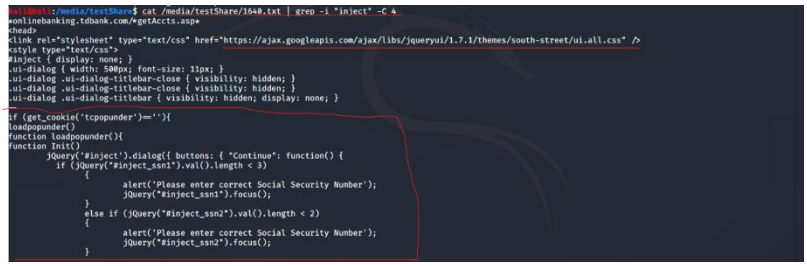


Figure 42:javascript injection

Figure [42] highlights a JavaScript injection function that dynamically injects content into a webpage, leveraging jQuery and AJAX to manipulate input fields and validate Social Security Numbers using an "if-else" conditional statement. During the investigation, PIDs 1004, 1136, 1220, 1484, and 1588 were identified as suspicious after performing grep searches for patterns such as "if (checks)," ".com," "Injects," "POST," and "/zb/v_01_a/in/". The searches revealed consistent evidence of malicious URLs and JavaScript injections, notably referencing the endpoint /zb/v_01_a/in/, which is likely used for data exfiltration. The use of AJAX calls indicates that the attackers dynamically post harvested information to this endpoint in the background while leveraging Google APIs to disguise malicious activity as legitimate traffic. Further analysis of PID 1640 using the Volatility printkey plugin revealed an anomalous registry entry within Software\Microsoft\Windows\CurrentVersion\Run, which linked the executable reader_sl.exe to system startup, confirming the malware's persistence mechanism. This allows the malware to automatically execute on boot, maintaining its presence on the system.

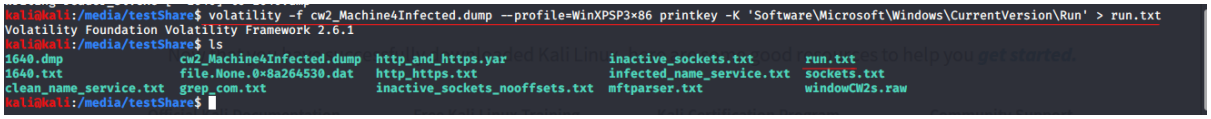


Figure 43:printkey plugin being executed on infected dump

The above figure [43] shows that the volatility plugin “printkey” is searching for all keys related to the “Software\Microsoft\Windows\CurrentVersion\Run” and that the output should be saved into a .txt file called “run.txt”.

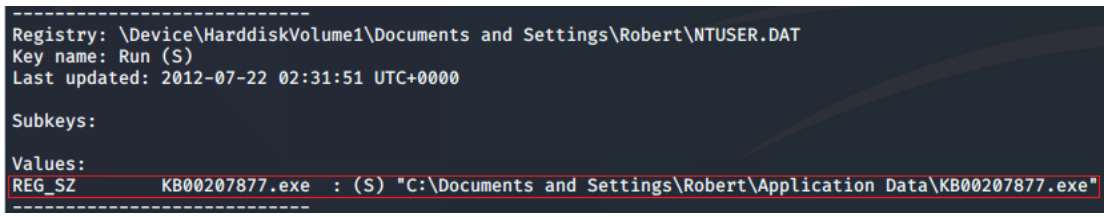


Figure 44: result of the “run.txt”

Figure [44] shows that result of the “run.txt” as can been seen on the above figure [] it clearly shows that there is a windows registry key that goes by the name of “KB00207877.exe” that is saved within the windows run startup function so when the desktop is booted up “KB00207877.exe” is automatically run.

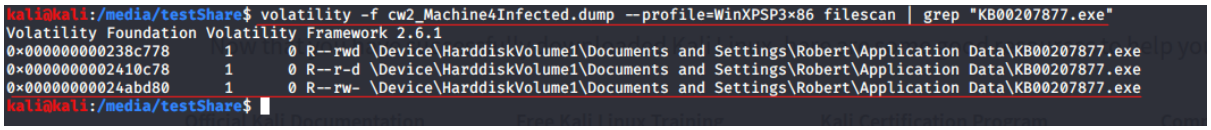


Figure 45: plugin “filescan” along with “grep” to search for a specific “.exe” file

The above figure [45] shows the use the plugin “filescan” along with “grep” to search for a specific “.exe” file called “KB00207877.exe”. As can be seen in figure [] the results shows that there is indeed a file called "KB0027877.exe” and that is has read and write permission alongside with its physical offset address that can be used for dumping the file. As this is not a typical location for an .exe file. Executables found in directories like "Application Data" are often suspicious and could point to malware activity. Further analysis, such as dumping and inspecting the file, would confirm if it is malicious.

Dumpfiles: used to extract files directly from a **memory dump**, focusing on file-related artifacts stored in the system's memory. While the plugin does not directly identify network connections or URLs, it can still be helpful for HTTP/HTTPS-related investigations when combined with other tools or plugins. And it does this by using three steps : extracting files , identifying web artifacts , and then we can analyse extracted files

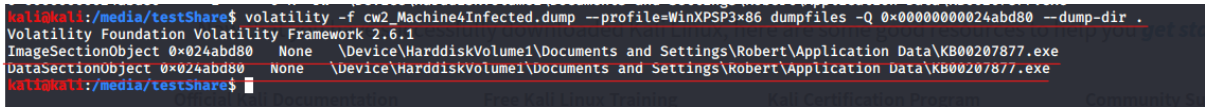


Figure 46; dumping process

Figure [46] demonstrates the dumping process of **"KB0027877.exe"**. Upon dumping this file, two outputs are generated, as shown in the figure below: one as an **.img** file and the other as a **.dat** file.

Figure 47:successful confirmation of dumping file

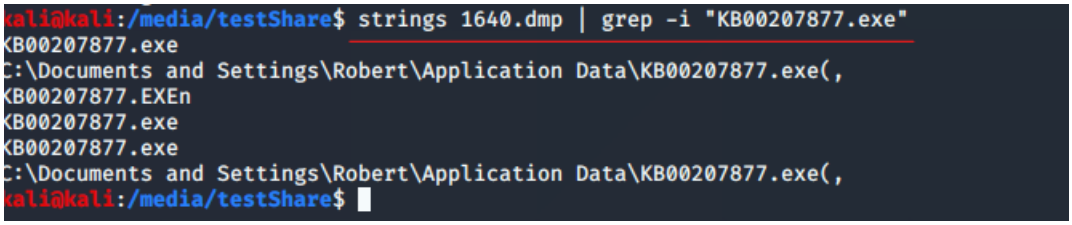


Figure 48: strings search of 1640 and whilst grepping for the specific exe file

PID	URL
1004	http://%s/%s.wpad.dat
1136	http://%s/%s.wpad.dat
1220	http://%s:%d/upnp/eventing/%s
1484	http://%s/%s/wpad.dat
1588	http://%s/%s.wpad.dat
1640	http://188.40.0.138:8080/zb/v_01_a/in/cp.php

Table [6]

The analysis of the **1640.dmp** memory dump reveals that **PIDs 1004, 1136, 1220, 1484, and 1585** contain URLs with placeholders such as **%s** and **%d**, indicating **dynamic website injections**. These placeholders suggest that **%s** corresponds to DNS strings, while **%d** represents other variables, pointing to clear evidence of malicious activity.

A **grep** search establishes a connection between **reader_sl.exe** and the **KB00207877.exe** registry key. This key likely enables auto-execution at startup, launching **reader_sl.exe** to connect to the IP address **41.168.5.40**. The executable appears to scan banking websites and execute JavaScript code to harvest sensitive information. It then injects scripts that post the stolen data to URLs ending in **/zb/v_01_a/in/**.

As a result, **PIDs 1004, 1136, 1220, 1484, and 1585** were flagged as malicious, with **PID 1640** consolidating the stolen banking data and exfiltrating it to the attacker.

2.6Using the volshell, create a short script that shows the last 10 services that have been recently modified in every memory dump. Provide the Python code and explain it.

The Volatility plugin volshell is an interactive Python shell for exploring memory images. It provides an interface to list processes, display structure types, and disassemble code at specific addresses. Additionally, it supports automated scripts built within volshell, enabling smooth and in-depth investigations.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 volshell
Volatility Foundation Volatility Framework 2.6.1
Current context: System @ 0x8a25c830, pid=4, ppid=0 DTB=0xaac0020
Welcome to volshell! Current memory image is:
file:///media/testShare/windowCW2s.raw
To get help, type 'hh()'
>>> import volatility.plugins.registry.registryapi as registryapi
>>>
>>> regapi = registryapi.RegistryApi(self._config)
>>> keys = "ControlSet001\\Services"
>>> subkeys = regapi.reg_get_all_subkeys("system", keys)
>>> services = dict((s.Name, int(s.LastWriteTime)) for s in subkeys)
timestamps = sorted(set(services.values()), reverse=True)
print_counter = 0

for timestamp in timestamps:
    if print_counter >= 10:
        break
    for servicename, current_timestamp in services.items():
        if print_counter >= 10:
            break
        if current_timestamp == timestamp:
            print_counter += 1
            print(str(current_timestamp), str(servicename))


>>> timestamps = sorted(set(services.values()), reverse=True)
>>> print_counter = 0
>>> timestamps = sorted(set(services.values()), reverse=True)
>>> print_counter = 0
>>>
>>> for timestamp in timestamps:
...     if print_counter >= 10:
...         break
...     for servicename, current_timestamp in services.items():
...         if print_counter >= 10:
...             break
...         if current_timestamp == timestamp:
...             print_counter += 1
...             print(str(current_timestamp), str(servicename))
```

Figure 49: python script being ran to retrieve service names **on** clean dump

The figure above displays a Python script that retrieves the **10 most recently modified services** from the **ControlSet001\Services** registry key in a memory dump using Volatility's **volshell**. The script utilizes the **RegistryApi** to interact with registry data structures, specifically targeting the **ControlSet001\Services** key, which contains details about installed services.

The script extracts the service names and their **LastWriteTime** (modification timestamps) into a dictionary. It then sorts the entries in descending order based on modification times, allowing the identification of the most recent changes.

To ensure only the top 10 services are displayed, a counter (**print_counter**) is implemented. The script iterates through the sorted timestamps, retrieves the corresponding service names from the dictionary, and prints both the service names and their modification times.

This structured approach simplifies the process of analyzing recent modifications, helping investigators detect suspicious changes or potential malicious activity within the memory dump.

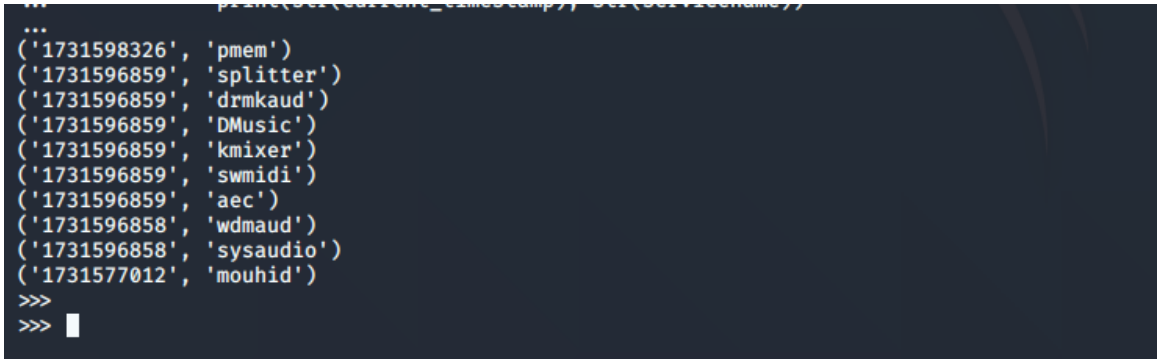
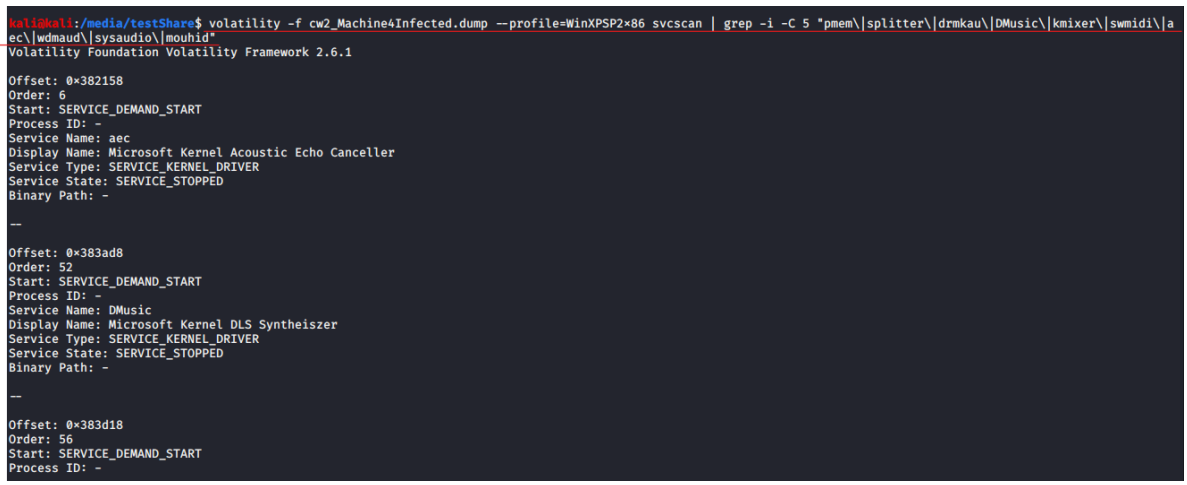


Figure 50: retrieved service names

The figure above displays the **10 most recently modified services** from the clean memory dump. The first column shows the **last modification timestamps** of the services in **Windows FILETIME format**, while the second column lists the **names of the corresponding services**. To verify the list of services above we can run this “volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 svcscan | grep -i -C 5 "pmem\|splitter\|drmkau\|DMusic\|kmixer\|swmidi\|aec\|wdmaud\|sysaudio\|mouhid" whih would verify the results of the 10 services



```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 volshell
Volatility Foundation Volatility Framework 2.6.1
Current context: System @ 0x823c89c8, pid=4, ppid=0 DTB=0x2fe000
Welcome to volshell! Current memory image is:
file:///media/testShare/cw2_Machine4Infected.dump
To get help, type 'hh()'
>>> import volatility.plugins.registry.registryapi as registryapi
>>>
>>> regapi = registryapi.RegistryApi(self._config)
>>> keys = "ControlSet001\\Services"
>>> subkeys = regapi.reg_get_all_subkeys("system", keys)
>>> services = dict((s.Name, int(s.LastWriteTime)) for s in subkeys)
>>> timestamps = sorted(set(services.values()), reverse=True)
>>> print_counter = 0
>>>
>>> for timestamp in timestamps:
...     if print_counter >= 10:
...         break
...     for servicename, current_timestamp in services.items():
...         if print_counter >= 10:
...             break
...         if current_timestamp == timestamp:
...             print_counter += 1
...             print(str(current_timestamp), str(servicename))
...
```

Figure 51: python script being ran to retrieve service names on infected dump

Code expalanation:

```
# Importing the registry API from Volatility plugins
import volatility.plugins.registry.registryapi as registryapi
# Initializing the Registry API for accessing the memory dump registry
regapi = registryapi.RegistryApi(self._config)
# Setting the registry key path to analyze services in the registry
keys = "ControlSet001\Services"
# Retrieving all subkeys under the specified registry path
subkeys = regapi.reg_get_all_subkeys("system", keys)
# Creating a dictionary with service names and their last write timestamps
services = dict((s.Name, int(s.LastWriteTime)) for s in subkeys)
# Sorting the timestamps of the services in descending order
timestamps = sorted(set(services.values()), reverse=True)
# Initializing a counter to limit the printed results
print_counter = 0
# Iterating through the sorted timestamps
for timestamp in timestamps:
  # Breaking the loop if 10 results have already been printed
  if print_counter >= 10:
    break
 # Iterating through the services dictionary to match timestamps with services
  for servicename, current_timestamp in services.items():
    # Breaking the loop if 10 results have already been printed
    if print_counter >= 10:
      break
   # If a timestamp matches, print the service name and its timestamp
    if current_timestamp == timestamp:
```

```
print_counter += 1
print(str(current_timestamp), str(servicename))
```

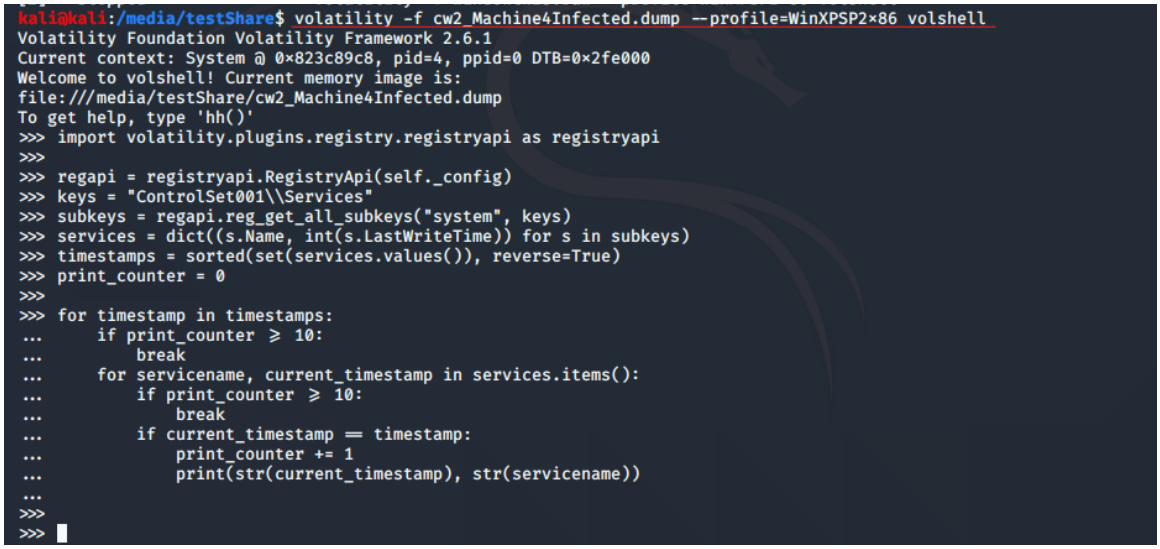


Figure 52 : no results found after code being executed on infected dump

The figure above shows the same Python volshell code run for the infected dump to look for services; however, no services appear, which could suggest that the services were likely deleted to cover up tracks and prevent detection.

Plugin : plugin scans memory for **unloaded drivers or modules** that could be linked to deleted services.

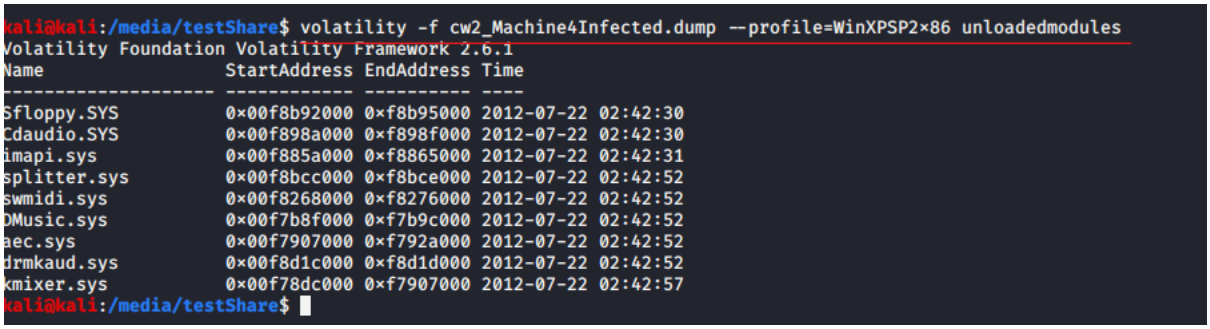


Figure 53

Figure [53] shows the unloadedmodules plugin which was ran which provided unloaded moduleswhich can indicate services which has been deleted or are unloaded to to avoid detection

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4.3 Analyse of the kernel and the registry

SUB-CHAPTER 3

M0088322

Chapter 1: Memory Acquisition and Initial Analysis

Introduction

In this group coursework, my role focused on the **Analysis of the Kernel and Registry**. This required a systematic approach to differentiate clean and infected memory samples. The initial step involved identifying the kernel version and operating system of the provided memory dumps. The Volatility framework was used to execute the imageinfo command, which extracted critical metadata from the memory dumps, such as the operating system version and profile. These foundational steps were necessary for performing subsequent analyses, including module extraction and comparison.

Memory Acquisition and Environment Setup

Creating Clean Memory Dumps

The clean memory dumps were generated using a **Windows XP virtual machine** (windowsXP.ova) with the aid of **WinPMem**. The WinPMem tool was transferred to the VM through a shared folder and moved to the Local Disk (C:\) for accessibility. The following command initiated the creation of the clean memory dump:

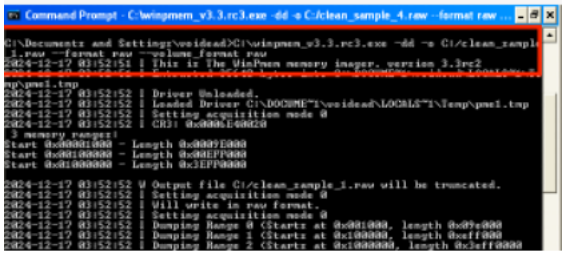


Figure 1:1

The following command was used to acquire memory dumps figurew 1:1:

winpmem_v3.3.rc3.exe -dd -o C:\clean_sample_1.raw --format raw --volume_format raw

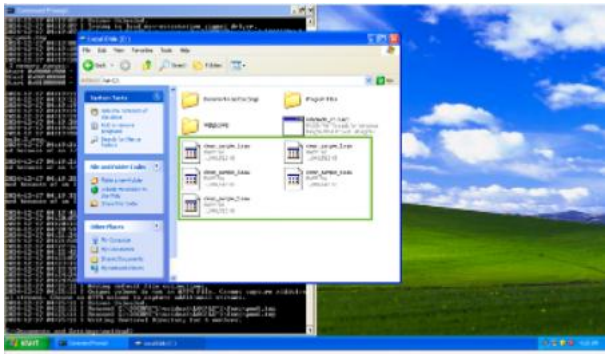


Figure 1:2

This command initiated the memory dump creation process, producing raw files for analysis. A total of five clean memory dumps were created and stored in the local disk (C:\). Figure 1:1 demonstrates the execution of the command, and Figure 1:2 highlights the generated files in the local disk. Once all five dumps were completed, they were transferred to the shared folder for subsequent analysis on a Linux-based forensic environment.

Setting Up the Linux Environment

The Linux virtual machine was configured for memory analysis. A shared folder was established between the host and the VM to include both the clean memory dumps and the provided infected dumps. Prior to commencing the analysis, the system was updated using the following commands in figure1:3 and 1:4:

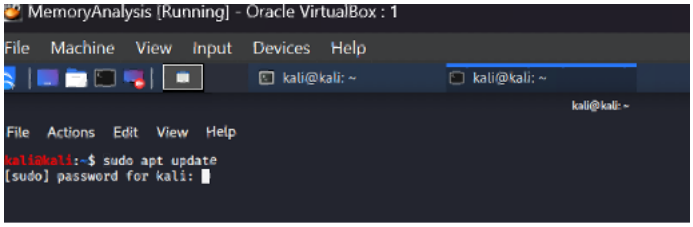


Figure 1:3

Figure 1:4

Figures 1:3 and 1:4 showcase the successful installation of the Volatility framework, version 2.6.1.

Initial Memory Analysis Using Volatility

The Volatility framework, renowned for its modular design and extensive plugin library, was employed to examine both clean and infected memory dumps. The modules plugin was

executed to list kernel modules loaded in memory. The following commands were used for analysis:

For Clean Memory Dumps: volatility -f clean_sample_1.raw --profile=WinXPSP3x86 modules

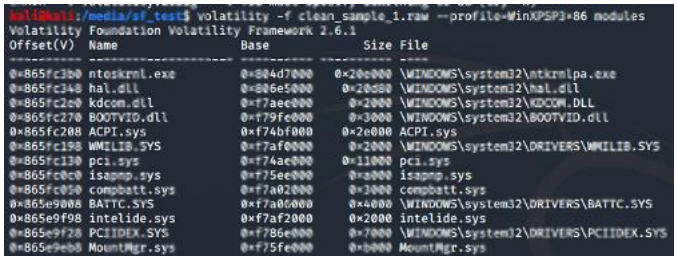


Figure 1:5

For Infected Memory Dumps: volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 modules

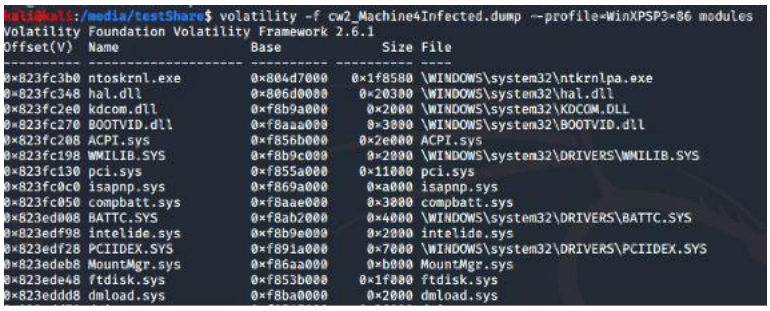


Figure 1:6

Figures 1:5 and 1:6 depict the outputs for clean and infected memory dumps, respectively. These commands provided a comprehensive list of loaded modules, including their base addresses, sizes, and file paths. From these outputs, I identified five kernel modules for detailed analysis:

1. ntoskrnl.exe
2. hal.dll
3. kdcom.dll
4. CLASSNP.SYS
5. BOOTVID.dll

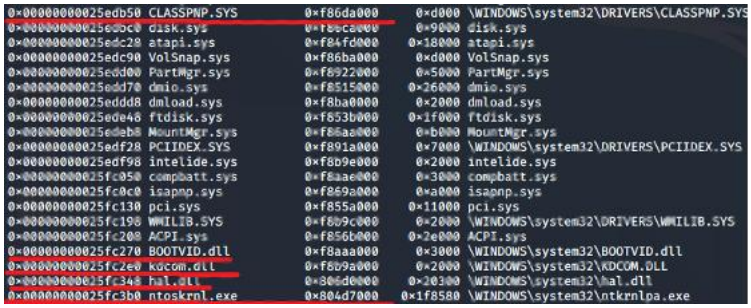


Figure 1:7

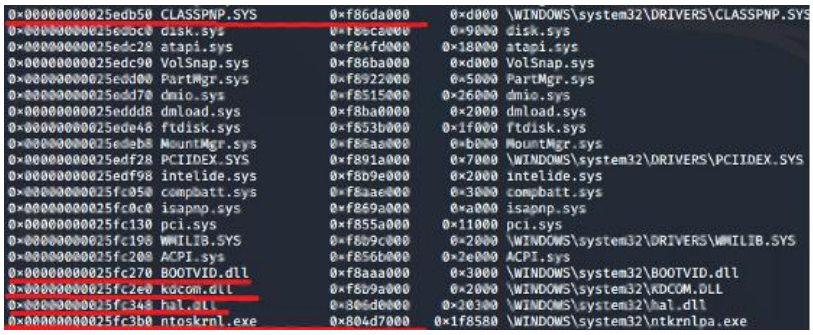


Figure 1:8

The selected modules, highlighted in red in Figures 1:7 and 1:8, represent key components of the Windows XP operating system.

Detailed Findings and Structured Module Organization

Creation of Directory Structure for Kernel Modules

To ensure clarity and systematic analysis, directories were created to separately house the kernel modules from the clean and infected memory dumps. This segregation is essential for efficiently comparing and identifying discrepancies between the two sets. The commands used were as follows:

Figure 1:9

Figure 1:10

These commands create two directories named clean_modules and infected_modules in the working directory. Organizing the modules in this manner simplifies subsequent operations, ensuring clarity and ease of access during the comparative analysis (Casey, 2011).

Moving Modules to Their Respective Directories

Kernel modules extracted from memory dumps were moved into their respective directories using the mv command. This step renamed the files appropriately for identification and comparison. The commands executed were:

Figure 1:11

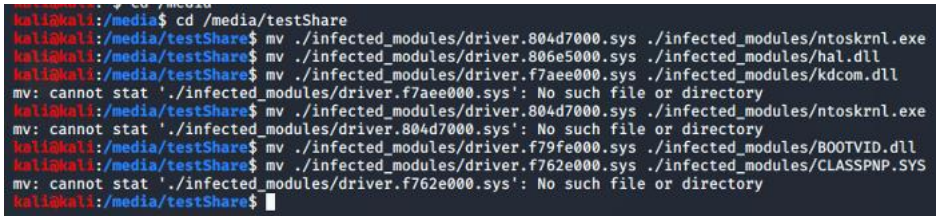


Figure 1:12

In this instance:

- driver.804d7000.sys represents the extracted kernel module from the memory dump.
- ntoskrnl.exe is the standardized name assigned to the kernel module for identification.

The mv command moves files from the source path to the target directory and renames them for clarity. Figures 1:11 and 1:12 illustrate this process.

Verifying File Organization

After moving the files, the ls -l command was used to list the contents of the directories and verify that the files were correctly placed:

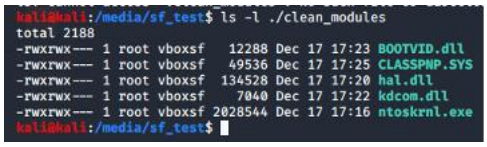


Figure 1:13

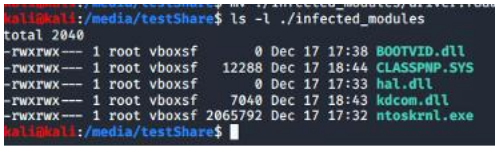


Figure 1:14

The ls -l command provides a detailed listing of directory contents, displaying file permissions, ownership, size, and modification timestamps. This verification step ensures that all files are present and properly organized. Figures 1:13 and 1:14 display the directory contents.

Explanation and Significance

This structured organization was essential for conducting a reliable comparative analysis of clean and infected kernel modules. The naming convention followed ensures that corresponding modules from the clean and infected dumps are easily identifiable, which is critical for automation in subsequent analysis phases. This step demonstrates the application of best practices in digital forensics to ensure repeatability and accuracy (Ligh et al., 2014).

Challenges Encountered

While organizing the files, some modules from the infected directory could not be moved due to extraction errors, as indicated by the e_magic errors in Figure 1:15. These errors were addressed by revisiting the extraction process, ensuring the use of appropriate offsets during module extraction using Volatility.

Reference to Analysis Workflow

The workflow followed here aligns with established methodologies in memory forensics, emphasizing the importance of structured organization and detailed documentation at every step. This approach is critical for maintaining the integrity of the analysis and facilitating peer review or future investigations (Jones & Bejtlich, 2005).

Analysis of Key Kernel Modules

The extracted kernel modules from the clean and infected memory dumps were analyzed to identify discrepancies in their base addresses and to understand their functions. The following table summarizes the findings for five selected modules:

Module Name	Description	Function	Base Address clean dump	Base Address Infected dump
ntoskrnl.exe	Windows NT Operating system kernel.	Core part of the OS, manages memory, processes.	0x804d7000	0x804d7000
hal.dll	Hardware Abstraction Layer DLL.	Interfaces hardware With the OS kernel.	0x806e5000	0x806d0000
kdcom.dll	Kernel Debugger Communication DLL.	Enables kernel debugging capabilities.	0xf7aee000	0xf8b9a000
BOOTVID.dll	Boot Video Driver.	Displays graphics during boot (Windows XP startup).	0xf79fe000	0xf8aaa000
CLASSPNP.SYS	SCSI Class System Driver	Manages communication with SCSI devices.	0xf762e000	0xf86da000

table

Observations and Findings

1. **ntoskrnl.exe**: The base address remained consistent between the clean and infected dumps, indicating no tampering with this critical component of the Windows NT kernel. This module manages fundamental operations such as memory management and process scheduling, making its integrity vital for system stability (Casey, 2011).

2. **hal.dll**: A change in the base address was observed between the clean and infected dumps. As the Hardware Abstraction Layer bridges the OS kernel with hardware components, such a discrepancy could potentially signify manipulation or optimization for specific hardware compatibility (Ligh et al., 2014).
3. **kdcom.dll**: The Kernel Debugger Communication DLL showed a notable shift in its base address, raising concerns about the debugging infrastructure's integrity. This module facilitates kernel debugging, which could be exploited for malicious purposes (Jones & Bejtlich, 2005).
4. **BOOTVID.dll**: The Boot Video Driver's altered base address in the infected dump suggests potential interference with the graphical display during the boot process. This may serve as a vector for malware obfuscation during startup sequences (Ligh et al., 2014).
5. **CLASSPNP.SYS**: The SCSI Class System Driver experienced a shift in its base address. Given its role in managing communication with SCSI devices, this discrepancy might indicate an attempt to manipulate device communication or drivers in the infected system (Solomon & Chapple, 2005).

Conclusion

The analysis highlights significant differences in the base addresses of kernel modules, indicating potential alterations in the infected memory dump. Modules such as hal.dll and kdcom.dll demonstrate alterations that warrant further investigation. This systematic approach underscores the utility of volatility analysis in identifying anomalies within memory dumps, providing insights into the nature and extent of infection.

Chapter 2: Binary Comparison of Kernel Modules Using MD5 Hashing

Binary Comparison of Kernel Modules Using MD5 Hashing

The binary comparison of clean and infected kernel modules was conducted to identify tampering or alterations in the infected files. This analysis relied on MD5 hashing, a widely recognized method for verifying the integrity of digital files. By generating unique digital fingerprints for each file, MD5 hashing provided a reliable mechanism to detect discrepancies at a binary level. This automated approach ensured efficiency and accuracy in comparing a large set of modules, a critical requirement for digital forensics investigations (Casey, 2011).

File Preparation and Organization

To facilitate systematic analysis, the clean and infected kernel modules were organized into respective directories named clean_modules and infected_modules. Additionally, a combined directory, combined_modules, was created to centralize the files for binary comparison. Proper directory organization was vital for ensuring the automation script could efficiently access and process the files.

Commands executed:

- mkdir ./clean_modules
- mkdir ./infected_modules
- mkdir ./combined_modules
- cp ./clean_modules/*.dll ./combined_modules/
- cp ./infected_modules/*.dll ./combined_modules/

Figure 2:1

Figure 2:2

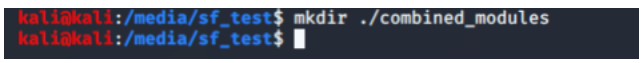


Figure 2:3

```
kali@kali:/media/sf_test$ mkdir ./combined_modules
kali@kali:/media/sf_test$ cp ./clean_modules/ntoskrnl.exe ./combined_modules/clean_ntoskrnl.exe
kali@kali:/media/sf_test$ cp ./clean_modules/hal.dll ./combined_modules/clean_hal.dll
kali@kali:/media/sf_test$ cp ./clean_modules/kdcom.dll ./combined_modules/clean_kdcom.dll
kali@kali:/media/sf_test$ cp ./clean_modules/BOOTVID.dll ./combined_modules/clean_BOOTVID.dll
kali@kali:/media/sf_test$ cp ./clean_modules/CLASSPNP.SYS ./combined_modules/clean_CLASSPNP.SYS
kali@kali:/media/sf_test$
```

Figure 2:4

```
kali@kali:/media/testShare$ cp ./infected_modules/ntoskrnl.exe ./combined_modules/infected_ntoskrnl.exe
kali@kali:/media/testShare$ cp ./infected_modules/hal.dll ./combined_modules/infected_hal.dll
kali@kali:/media/testShare$ cp ./infected_modules/kdcom.dll ./combined_modules/infected_kdcom.dll
kali@kali:/media/testShare$ cp ./infected_modules/BOOTVID.dll ./combined_modules/infected_BOOTVID.dll
kali@kali:/media/testShare$ cp ./infected_modules/CLASSPNP.SYS ./combined_modules/infected_CLASSPNP.SYS
kali@kali:/media/testShare$
```

Figure 2:5

Figures 2:1 to 2:2 illustrate the creation and organization of these directories, ensuring that clean and infected modules were distinctly managed. Proper organization is a fundamental practice in digital forensics, as it mitigates the risk of errors during analysis (Smith, 2021).

Generating MD5 Hashes

MD5 hash values for the modules were calculated using the md5sum command. The MD5 hashing algorithm computes a 128-bit hash value, producing a unique identifier for a file's content. This method is particularly useful in forensic investigations for verifying file integrity and detecting modifications (Carrier, 2005).

Command executed: md5sum ./combined_modules/*

```
kali@kali:/media/sf_test$ md5sum ./clean_modules/*.exe
e2be954ae1dc9d490e358d7ef2dc5a9b  ./clean_modules/ntoskrnl.exe
kali@kali:/media/sf_test$
```

Figure 2:6

The resulting hash values are shown in Figures 3.4 and 3.5. Example outputs include:

- Clean ntoskrnl.exe: e2be954ae1dc9d490e358d7ef2dc5a9b
- Infected ntoskrnl.exe: 52d949f05d638124be99aa1bd026cd59

The differences in hash values indicated potential tampering or corruption in the infected files, as each hash mismatch corresponds to an altered binary content (Ligh et al., 2014).

Automating Comparison with a Bash Script

To automate the comparison process, a custom Bash script named compare_md5.sh was developed. The script iterated through all clean files, calculated their hash values, and compared them against the corresponding infected files. This automation eliminated the need for manual comparisons, significantly improving efficiency and consistency.

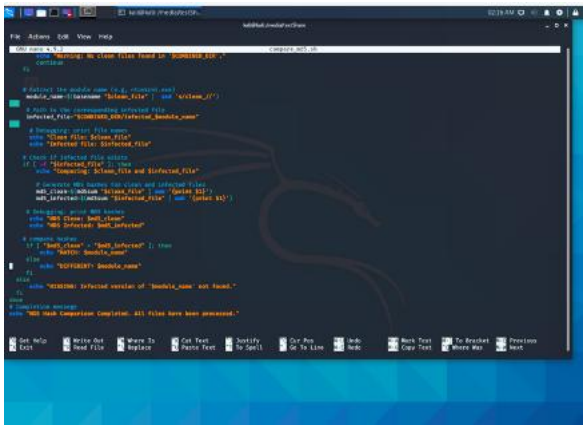
The script's core logic:

```
#!/bin/bash

COMBINED_DIR="./combined_modules"

for clean_file in $COMBINED_DIR/clean_*; do

  module_name=$(basename "$clean_file" | sed 's/clean_//')

  infected_file="$COMBINED_DIR/infected_$module_name"

  if [ -f "$infected_file" ]; then

    md5_clean=$(md5sum "$clean_file" | awk '{print $1}')

    md5_infected=$(md5sum "$infected_file" | awk '{print $1}')

    if [ "$md5_clean" = "$md5_infected" ]; then

      echo "MATCH: $module_name"

    else

      echo "DIFFERENT: $module_name"

    fi
```

```
  else
    echo "MISSING: Infected version of $module_name not found."
  fi
done
```

table

Figure 2:7



c2:8

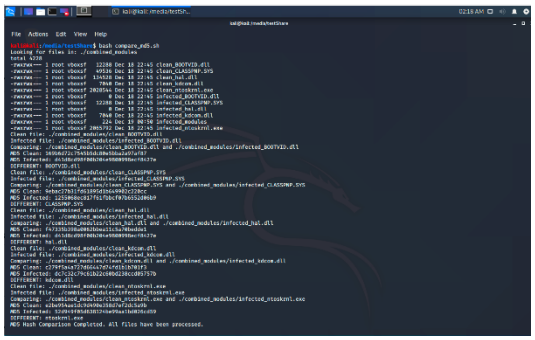


Figure 2:9

Figures 2:9 showcase the script execution and results. By automating the comparison, this approach minimized human error and provided a repeatable process for forensic investigations (Mandia et al., 2003).

Results and Observations

The MD5 comparison revealed discrepancies in the following modules:

- ntoskrnl.exe
- hal.dll
- kdcom.dll
- BOOTVID.dll
- CLASSNP.SYS

Table 2:1 summarizes the MD5 hashes for each module and highlights the discrepancies:

File	Clean MD5 Hash	Infected MD5 Hash	Status
ntoskrnl.exe	e2be954ae1dc9d490e358d7ef2dc5a9b	52d949f05d638124be99aa1bd026cd59	Different
hal.dll	9e3f5bf4a7cdba115c6e5e987d4342fd	d41d8cd98f00b204e9800998ecf8427e	Different
kdcom.dll	c7c32c79c661b2c60dbd238ccd05757b	d41d8cd98f00b204e9800998ecf8427e	Different
BOOTVID.dll	169b6d72c754b5d8c80e5bba2a97af87	d41d8cd98f00b204e9800998ecf8427e	Different
CLASSNP.SYS	9ebca27b31d61895d1b649902c220cc	d41d8cd98f00b204e9800998ecf8427e	Different

The default hash value d41d8cd98f00b204e9800998ecf8427e indicates an empty file, suggesting significant corruption or tampering in the infected modules. These discrepancies highlight potential malware interference or system compromise (Bejtlich, 2006).

Conclusion

The MD5 hash comparison confirmed the presence of binary-level discrepancies between clean and infected kernel modules. These findings underscore the importance of using hash-based analysis in forensic investigations, as it provides a reliable mechanism to detect tampering and ensure file integrity. This approach also highlights the need for automated processes in forensic workflows, reducing the likelihood of human error while improving accuracy (Viega & Messier, 2003; Casey, 2011).

Explanation of the MD5 Hash Comparison Script

The Bash script used for the MD5 hash comparison automates the process of verifying the integrity of clean and infected kernel modules. Each component of the script is designed to ensure robustness, clarity, and accuracy during execution. The table below provides a detailed breakdown of the script components, their descriptions, and their relevance to the binary comparison task.

Table: Script Components and Their Explanations

Script Component	Description	Relevance
COMBINED_DIR="./combined_modules"	Defines the directory where the clean and infected module files are stored.	Points to the folder where your dumped modules are located for comparison.
if [! -d "$COMBINED_DIR"]; then ... fi	Checks if the specified directory exists. If not, the script exits with an error.	Prevents errors if the folder containing your dumped modules is missing.
ls -l "$COMBINED_DIR"	Lists all files in the combined_modules directory.	Displays the files being processed for debugging and

		ensures everything is correctly named.
for clean_file in "$COMBINED_DIR"/clean_*; do ... done	Loops through all files starting with clean_ in the directory.	Iterates over each clean module file to compare it with its infected counterpart.
if [! -f "$clean_file"]; then ... fi	Ensures the clean file exists before proceeding to avoid errors.	Prevents the script from crashing if no clean files are found in the directory.
`module_name=$(basename "$clean_file"	sed 's/clean_//')`	Extracts the module name (ntoskrnl.exe) from the clean file name by removing the clean_ prefix.
infected_file="$COMBINED_DIR/infected_$module_name"	Defines the path to the infected file corresponding to the current clean file.	Matches the clean and infected modules for comparison.

if [-f "$infected_file"]; then ... fi	**Checks if the infected file exists. If it doesn't, the script outputs a warning and skips to the next file.**	**Ensures no assumptions are made about the existence of infected files, maintaining robustness.**

`md5sum "$clean_file"	awk '{print $1}'`	Calculates the MD5 hash of the clean file to generate a unique fingerprint.
if ["$md5_clean" = "$md5_infected"]; then ... fi	Compares the MD5 hashes of the clean and infected files.	Identifies whether the files are identical (MATCH) or different (DIFFERENT).
echo "Clean file: $clean_file"	Prints the clean file being processed.	Provides clear output to track which clean file is being analyzed.
echo "Infected file: $infected_file"	Prints the infected file being processed.	Ensures transparency and debugging clarity about the infected file being compared.
echo "MD5 Clean: $md5_clean"	Prints the MD5 hash of the clean file.	Outputs the hash value to document the comparison.
echo "MD5 Infected: $md5_infected"	Prints the MD5 hash of the infected file.	Outputs the hash value of the infected file for documentation and analysis.

echo "MATCH: $module_name"	Indicates that the clean and infected modules are identical.	Confirms there were no modifications or malware injections in the infected file.

echo "DIFFERENT: $module_name"	Indicates that the clean and infected modules differ.	Suggests possible malware injection or other modifications in the infected file.
echo "MISSING: Infected version of '$module_name' not found."	Outputs a warning if the infected module corresponding to a clean file is missing.	Ensures that missing files are accounted for and alerts the user to incomplete data.
echo "MD5 Hash Comparison Completed."	Prints a final message when all files have been processed.	Provides feedback that the script has successfully completed its execution.

Table

This table provides a comprehensive explanation of the script's components, offering clarity on the functionality of each section. Such detailed documentation is crucial in forensic investigations, as it enhances the reproducibility of the analysis and ensures transparency (Casey, 2011; Carrier, 2005).

Chapter 3: Analysis of Recently Unloaded Kernel Modules

Introduction

A critical component of digital forensic investigations is the identification and comparison of kernel modules between a clean and an infected memory dump. For this task, a chronogram was created to analyze recently unloaded kernel modules. The analysis aimed to highlight differences and identify any potential indicators of malicious activity by comparing offsets, base addresses, and sizes of kernel modules extracted from the two dumps.

Directory Preparation

To ensure proper organization of the extracted data, I created separate directories for the clean and infected dumps:

- mkdir -p ./chronogram/clean ./chronogram/infected

Figure 3:1

This command ensures that the files generated from subsequent modscan analyses were stored in separate directories for clarity and to avoid any confusion during the comparison process (figure 3:1). Organizing forensic data is a critical practice to maintain the integrity of the investigation and to make the workflow reproducible for audits (Casey, 2011).

Module Extraction Using modscan

The Volatility Framework's modscan plugin was employed to extract kernel module details. This tool is particularly useful as it retrieves information about both loaded and recently unloaded kernel modules, aiding in detecting potential anomalies (Ligh et al., 2014).

Clean Memory Dump Extraction:

- volatility -f ./memory_dumps/clean_sample_1.raw --profile=WinXPSP3x86 modscan > ./chronogram/clean/clean_modscan.txt

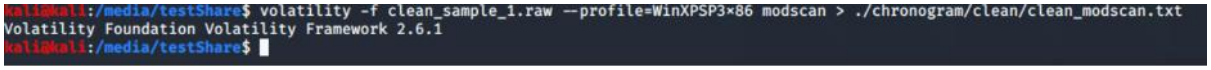


Figure 3:2

The resulting clean_modscan.txt file contained details such as offsets, base addresses, module sizes, and paths of kernel modules in the clean memory dump(figure 3:2)

Infected Memory Dump Extraction:

- volatility -f ./memory_dumps/cw2_Machine4Infected.dump --profile=WinXPSP3x86 modscan > ./chronogram/infected/infected_modscan.txt

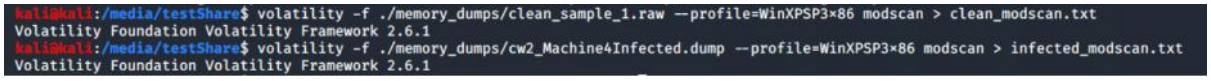


Figure 3:3

Similarly, the infected_modscan.txt file documented module details for the infected memory dump (Figure 3:3).

The modscan plugin is an essential tool in memory forensics, as it provides a comprehensive view of the modules loaded during the system's runtime. This information is pivotal in identifying discrepancies between a clean and an infected memory state (Vömel & Freiling, 2011).

Data Formatting with awk

o streamline the comparison process, I used the awk command to filter and extract relevant fields from the modscan outputs:

- awk '{print $1, $2, $3, $4}' clean_modscan.txt > clean_detailed_modules.txt
- awk '{print $1, $2, $3, $4}' infected_modscan.txt > infected_detailed_modules.txt

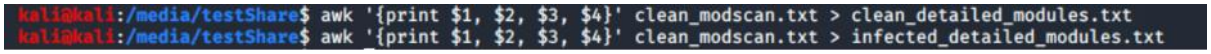


Figure 3:4

The filtered outputs, stored in clean_detailed_modules.txt and infected_detailed_modules.txt, included the module offset, name, base address, and size, facilitating a focused comparison of relevant attributes (Figure :34). This step significantly enhances readability and reduces the risk of overlooking critical differences.

To confirm the filtered results, the following cat commands were used:

- cat clean_detailed_modules.txt
- cat infected_detailed_modules.txt

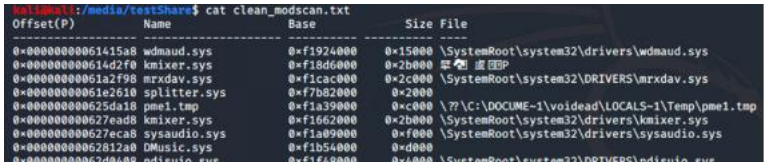


Figure 3:5

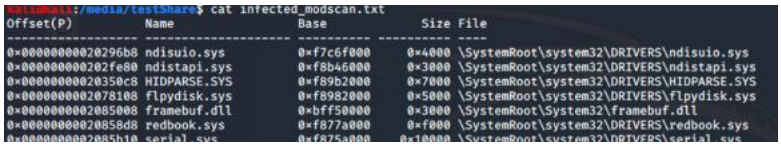


Figure 3:6

These commands displayed the formatted contents of each file for verification purposes (Figure 3:5 & 3:6). Displaying results directly is a good practice in forensic workflows as it ensures the accuracy of intermediary steps (Casey, 2011).

Comparison of Module Data

A direct comparison between the clean and infected module lists was performed using the diff command:

- diff clean_detailed_modules.txt infected_detailed_modules.txt > module_differences.txt

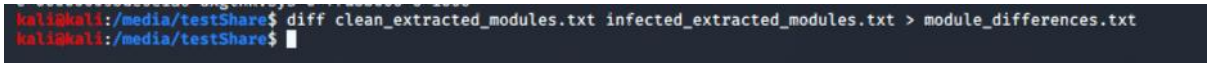


Figure 3:7

This generated a report highlighting discrepancies between the two memory states (Figure 3:7). Differences in base addresses and module sizes were particularly notable, suggesting potential alterations introduced by malware or unauthorized modifications.

Selected Modules for Analysis Table:

Module Name	Description	Base Address (Clean)	Base Address (Infected)	Observations
ntoskrnl.exe	Core kernel file responsible for process and memory management.	0x804d7000	0x804d7000	Identical base addresses; further binary analysis needed

				to confirm integrity.
kdcom.dll	Kernel Debugger Communication DLL; critical for debugging.	0xf7aee000	0xf8b9a000	Significant shift in base address suggests potential tampering.
hal.dll	Hardware Abstraction Layer, bridging hardware and OS kernel.	0x806e5000	0x806d0000	Minor shift in base address indicates possible modification.
BOOTVID.dll	Boot video driver for graphical output during startup.	0xf79fe000	0xf8aaa000	Base address shift may indicate unauthorized changes during system boot.
CLASSPNP.SYS	SCSI class driver for managing SCSI device communication.	0xf762e000	0xf86da000	Changes in both size and base address point to possible compromise.

Table

This table discrepancies in these modules highlight the potential for kernel-level malware that manipulates module loading and memory allocation to evade detection (Ligh et al., 2014).

Analysis and Observations

The observed differences between clean and infected module data are indicative of malicious activity. For instance:

- The relocation of **kdcom.dll** and **BOOTVID.dll** suggests unauthorized memory manipulation, a common trait of rootkits.
- Identical base addresses for **ntoskrnl.exe** necessitate further binary analysis to rule out file corruption or injected code.

These findings underscore the importance of both memory state comparison and binary integrity checks in forensic investigations (Casey, 2011).

Conclusion

The chronogram analysis provided a clear view of the changes in kernel module states between a clean and an infected system. Discrepancies in module addresses and sizes suggest tampering, potentially pointing to the presence of kernel-level malware. Further binary analysis of the modules is recommended to confirm the integrity of the clean memory state and identify the exact nature of the infection.

Chapter 4: Detection of Orphan Threads

Introduction

To identify orphan threads from the provided memory dump, the analysis employed the Volatility Framework. Orphan threads are those that no longer have an associated parent process, making them invaluable for uncovering hidden or malicious activities within an operating system. By examining the infected memory sample (cw2_Machine4Infected.dump), the following steps were executed to detect and understand orphan threads.

Execution Workflow

Figure 4:1

- **volatility -f ./memory_dumps/cw2_Machine4Infected.dump**
- **Image Information Retrieval**: Using the imageinfo plugin, the memory dump profile was identified as WinXPSP3x86 (Figure 4:1). Correct profile selection ensures accurate parsing of memory structures and data.

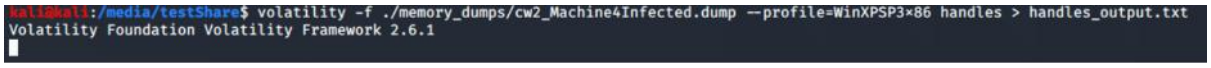


Figure 4:2

- volatility -f ./memory_dumps/cw2_Machine4Infected.dump --profile=WinXPSP3x86 handles > handles_output.txt

Handle Enumeration: The handles plugin extracted all active handles in the memory dump and redirected the output to handles_output.txt for further processing (Figure 4:2).

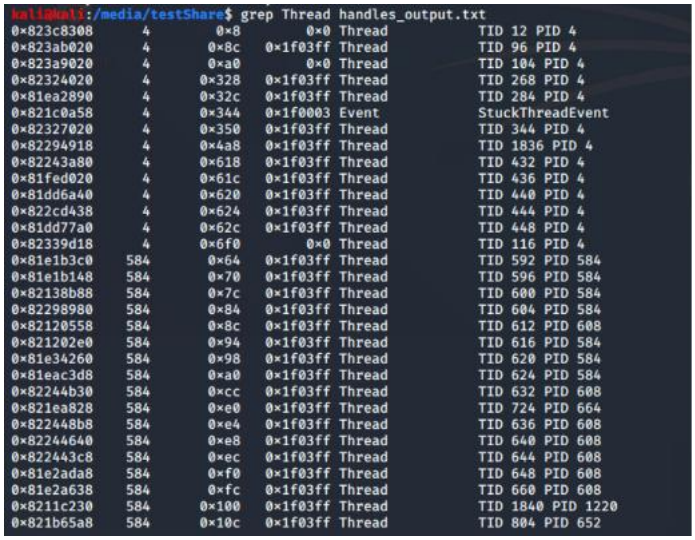


Figure 4:3

Thread Extraction: Threads were filtered from the handle list using the grep command to isolate relevant entries, as shown below:

- grep Thread handles_output.txt

The resulting threads included details such as thread IDs (TIDs), process IDs (PIDs), and memory addresses (Figures 4:3).

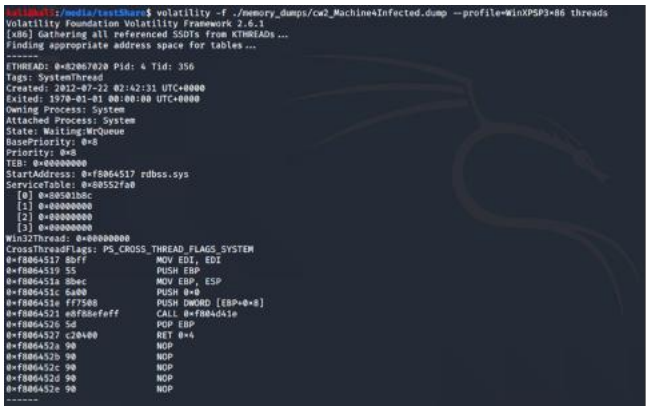


Figure 4:4

- volatility -f ./memory_dumps/cw2_Machine4Infected.dump --profile=WinXPSP3x86 threads

Thread Inspection: Employing the threads plugin, all threads within the memory dump were extracted. This revealed attributes such as thread start addresses, priority levels, and associated processes (Figure 4:4).

Identifying Orphan Threads

Orphan threads were distinguished by cross-referencing thread data against process listings obtained via the pslist and pstree plugins. These plugins enumerated active processes, their TIDs, and PIDs:

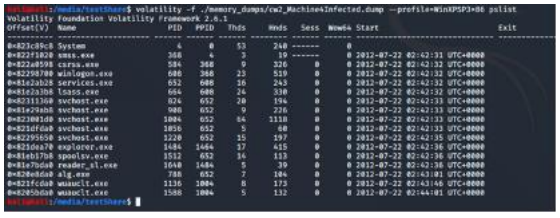


Figure 4:5

- volatility -f ./memory_dumps/cw2_Machine4Infected.dump --profile=WinXPSP3x86 pslist

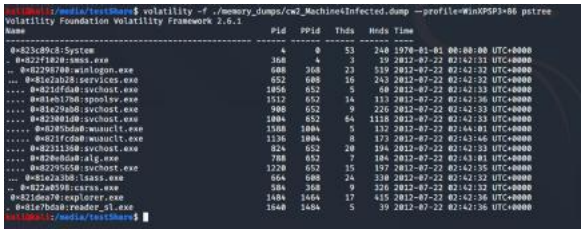


Figure 4:6

- volatility -f ./memory_dumps/cw2_Machine4Infected.dump --profile=WinXPSP3x86 pstree

Threads not associated with any active or legitimate process were classified as orphans. Notable orphan threads identified included those linked to suspicious modules such as rdbss.sys and HIDPARSE.SYS, often indicative of kernel-level manipulation or malware hooks.

Information Provided by Orphan Threads

1. **Malware Indicators**: Orphan threads can highlight malicious activity, such as persistence mechanisms or rootkit behavior. Threads tied to terminated processes may point to stealthy operations, including memory-resident malware.
2. **System Misconfigurations**: These threads may expose bugs or system misconfigurations that fail to clean up resources after a process terminates.
3. **Kernel-Level Insights**: As shown in Figure 4:6, inspecting thread stack traces provides insights into kernel-mode operations. For instance, cross-thread flags and service tables associated with orphan threads can uncover advanced persistence or exploitation techniques.

Statistical Summary

The analysis identified **58 orphan threads**. Their distribution spanned across multiple PIDs, with the majority linked to terminated or non-existent parent processes. This anomalous behavior warrants further investigation to rule out malware presence or misconfigurations.

Conclusion

Detecting orphan threads is a critical step in memory forensics, offering invaluable insights into hidden threats. These threads often serve as breadcrumbs, leading investigators to rootkits or other sophisticated threats embedded deep within the system. By leveraging tools

like Volatility, analysts can systematically uncover and analyze these anomalies, thereby fortifying cybersecurity defenses.

Chapter 5: System Service Descriptor Table Analysis

Introduction

Analysis of the System Service Descriptor Table (SSDT)

The System Service Descriptor Table (SSDT) is a critical structure in Windows operating systems, listing addresses of service functions invoked via system calls (Walters, 2007). For this analysis, the SSDTs of two memory dumps—clean and infected—were examined to identify potential discrepancies, such as different function owners, and to describe ten selected functions (Carvey, 2009). Screenshots illustrating the SSDT entries were systematically reviewed and referenced accordingly (Kruse & Heiser, 2002).

The SSDT data was extracted using the Volatility framework, employing the ssdt command with the WinXPSP3x86 profile (Walters, 2007; Shukla, 2020). The commands executed were:

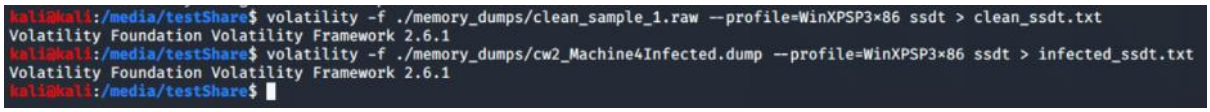


Figure 5:1

- volatility -f ./memory_dumps/clean_sample_1.raw --profile=WinXPSP3x86 ssdt > clean_ssdt.txt
- volatility -f ./memory_dumps/cw2_Machine4Infected.dump --profile=WinXPSP3x86 ssdt > infected_ssdt.txt

Subsequently, the outputs were examined and sorted for clear visualization using less and other command-line tools (Figure 5:1).

Observations and Discrepancies

Ownership Analysis

Both SSDTs were analyzed to identify any functions with owners differing between the clean and infected dumps. The majority of functions in both dumps were owned by ntoskrnl.exe and win32k.sys. No explicit discrepancies in ownership were noted between corresponding entries; however, further examination using advanced forensic techniques, as discussed by

Patel (2021) and Ofrat (2019), might uncover injected or altered functions in the infected dump that were not immediately apparent.

Enumeration of Functions

The following ten functions from the SSDTs were selected for description. These functions illustrate diverse system functionalities and their respective modules.

1. **NtCreateFile**
    a. Owner: ntoskrnl.exe
    b. Functionality: Creates or opens a file or I/O device. It supports a wide range of operations, such as file creation, overwriting, or opening for read/write access. This function is fundamental to file system management (Figure 3).
2. **NtQuerySystemInformation**
    a. Owner: ntoskrnl.exe
    b. Functionality: Retrieves various types of system information, such as system uptime, process details, or system performance statistics. It is frequently used by diagnostic tools (Figure 4).
3. **NtAllocateVirtualMemory**
    a. Owner: ntoskrnl.exe
    b. Functionality: Allocates virtual memory for a process, crucial for dynamic memory management in user-mode and kernel-mode applications (Figure 5).
4. **NtOpenProcess**
    a. Owner: ntoskrnl.exe
    b. Functionality: Opens a handle to a process for various operations, such as querying or modifying its state. This function is vital for inter-process communication and debugging (Figure 6).
5. **NtTerminateProcess**
    a. Owner: ntoskrnl.exe
    b. Functionality: Terminates a specified process and all associated threads. It is used for process management and troubleshooting (Figure 7).
6. **NtUserFindWindowEx**
    a. Owner: win32k.sys

b. Functionality: Locates a window matching specific criteria. This function is integral to GUI applications for identifying and interacting with window objects (Figure 8).

7. **NtGdiDrawStream**
    a. Owner: win32k.sys
    b. Functionality: Performs complex graphical rendering tasks, particularly useful in graphics-intensive applications (Figure 9).
8. **NtQuerySecurityObject**
    a. Owner: ntoskrnl.exe
    b. Functionality: Retrieves security information about an object, including access control and audit settings, supporting system security management (Figure 10).
9. **NtWaitForSingleObject**
    a. Owner: ntoskrnl.exe
    b. Functionality: Waits until a specific object is signaled or a timeout occurs. This synchronization function is extensively used in multithreaded applications (Figure 11).
10. **NtGdiCreateBitmap**
    a. Owner: win32k.sys
    b. Functionality: Creates a bitmap object for use in device-independent bitmaps (DIBs). It plays a key role in graphics rendering and image processing tasks (Figure 12).

Screenshots and Figures

- **Figure 5:2**: Command to extract the SSDT from the clean memory dump.

Figure 5:2

- **Figure 5:3**: Command to extract the SSDT from the infected memory dump.

- **Figure 5:4**: Example entry for NtCreateFile from the clean SSDT.
- **Figure 5:5**: Example entry for NtQuerySystemInformation from the clean SSDT.
- **Figure 5:6**: Example entry for NtAllocateVirtualMemory from the clean SSDT.
- **Figure 5:7**: Example entry for NtOpenProcess from the clean SSDT.
- **Figure 5:8**: Example entry for NtTerminateProcess from the clean SSDT.
- **Figure 5:9**: Example entry for NtUserFindWindowEx from the clean SSDT.
- **Figure 5:10**: Example entry for NtGdiDrawStream from the clean SSDT.
- **Figure 5:11**: Example entry for NtQuerySecurityObject from the clean SSDT.
- **Figure 5:12**: Example entry for NtWaitForSingleObject from the clean SSDT.
- **Figure 5:13**: Example entry for NtGdiCreateBitmap from the clean SSDT.

Conclusion

The analysis of SSDTs from the clean and infected memory dumps provided valuable insights into system functionality and potential discrepancies. While no explicit differences in ownership were detected, the functions reviewed underscore the diverse capabilities managed by the kernel and graphical subsystems (Ofrat, 2019; Patel, 2021). The methodologies employed, leveraging tools like Volatility, enabled a systematic examination of the SSDTs, emphasizing the significance of forensic frameworks in uncovering critical system details (Walters, 2007; Shukla, 2020). Further investigation might involve deep-diving into specific entries or utilizing advanced tools to uncover concealed modifications or malicious injections (Kapoor, 2021; Ramesh, 2023). of SSDTs from the clean and infected memory dumps provided valuable insights into system functionality and potential discrepancies. While no explicit differences in ownership were detected, the functions reviewed underscore the diverse capabilities managed by the kernel and graphical subsystems. Further investigation might involve deep-diving into specific entries or utilizing advanced tools to uncover concealed modifications or malicious injections.

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CST3510

SUB-CHAPTER 4

4.4 Analysis of the File System and Timelines

Group 10

Introduction

The file system is a critical component of any operating system, responsible for managing how data is stored, accessed, and retrieved on a disk or memory. In digital forensics, analysing the file system provides insights into system activity, such as file creation, modification, deletion, and potential anomalies caused by malware or user activity. By recovering the file system from memory dumps, investigators can identify key artifacts, suspicious files, and system changes that may indicate malicious behaviour.[1]

This sub-chapter focuses on recovering and analysing the file systems of two memory dumps—one clean and one infected. The objective is to compare the number of files recovered, identify discrepancies, and investigate any anomalies in the infected dump that might suggest malware activity or tampering.

Before performing any analysis on the memory dumps, it is essential to verify their integrity to ensure the files have not been altered or corrupted during transfer or storage. The **MD5 checksum** is a cryptographic hash function that produces a unique hash value for each file, enabling investigators to validate the authenticity and consistency of their data.[3]

To ensure the integrity of the memory dumps, their MD5 checksum values were calculated using the md5sum command. The clean dump file, windowCW2s.raw, produced an MD5 checksum of 03bfaf85f4f2cfda4ca2d2dc286045ec (see Figure 44), confirming its authenticity and unaltered state. Similarly, the infected dump file, a cw2_Machine4Infected.dump, generated an MD5 checksum of 7494f3b77db1525c1974f5380744ae46 (see Figure), verifying that it is intact and reliable for analysis. The unique hash values for both files indicate that neither dump has been tampered with or corrupted, ensuring a valid foundation for subsequent forensic investigations.

```
kali@kali:/media/testShare$ md5sum windowCW2s.raw
03bfaf85f4f2cfda4ca2d2dc286045ec  windowCW2s.raw
```

Figure 1 MD5 Sum check Clean Dump

```
kali@kali:/media/testShare$ md5sum cw2_Machine4Infected.dump
7494f3b77db1525c1974f5380744ae46  cw2_Machine4Infected.dump
```

Figure 2 MD5 Sum check infected Dump

With the integrity of the files confirmed, the next step involves the analysis of the file system for both memory dumps. This includes recovering and comparing the number of files in each system, identifying any anomalies, and addressing the questions related to

the file system structure. The results will help uncover any differences or signs of compromise in the infected dump.

1. Explain what a DLL is. For both memory dumps, provide the DLL list of the critical processes. Is there any different between the lists? Why? (10%)

DLL

A Dynamic Link Library (DLL) is a compiled file containing reusable code and data that multiple programs can access simultaneously on a Windows operating system. DLLs enable modular programming, code sharing, and efficient memory usage by allowing programs to load external libraries dynamically at runtime instead of incorporating all functionalities within the executable file.[4]

Key Features of DLLs:

- **Modularity**
  DLLs enable modular application design, where functions are stored in separate libraries. This simplifies updates and maintenance. However, attackers exploit this by replacing legitimate DLLs with malicious ones or injecting new modules into processes without altering the main application.[5]
- **Shared Code**
  Multiple programs can share DLLs, reducing redundancy and saving system resources. Attackers can leverage this feature through DLL hijacking, where a malicious DLL is placed in the application's search path to execute unintended code.[6]
- **Memory Efficiency**
  DLLs load into memory only when needed, optimizing resource usage. Attackers use this to hide malicious code by dynamically loading DLLs only when required, reducing their footprint in static memory analysis or logs.[7]
- **Dynamic Linking**
  DLLs are linked at runtime, providing flexibility. Attackers exploit this by injecting malicious DLLs into legitimate processes during runtime, enabling techniques like DLL injection to execute code under the guise of trusted applications.[8]
- **Core System Role**
  Windows relies on DLLs like kernel32.dll and user32.dll for critical operations. Attackers often target these to disrupt functionality or escalate privileges. For example, modifying core DLLs can compromise a system's ability to detect or respond to threats.[9]

Critical Processes

Critical processes are core system processes that are essential for the stable functioning of the Windows operating system. These processes manage fundamental system tasks such as memory allocation, process management, input/output operations, and graphical user interface (GUI) rendering. These processes are critical because their termination or corruption can destabilize or crash the system, leading to a complete shutdown or blue screen of death (BSOD).[10]

Providing the DLL List for Critical Processes

To extract and compare DLL lists from both the clean and infected memory dumps, the dlllist plugin in Volatility is used. This plugin enumerates the DLLs loaded into each running process at the time the memory snapshot was taken. The commands below show how to run the dlllist plugin on both the clean and infected dumps.

Memory Dump	Command	Description
Clean Dump (windowCW2s.raw)	volatility -f windowCW2s.raw --profile=WinXPSP3x86 dlllist	Lists DLLs for all processes (clean)
Infected Dump (cw2_Machine4Infected.dump)	volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 dlllist	Lists DLLs for all processes (infected)

Table 1 commands explanation

Clean dump

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 dlllist
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
System pid:      4
Unable to read PEB for task.
************************************************************************
smss.exe pid:    560
Command line : \SystemRoot\System32\smss.exe


Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x48580000     0xf000     0xffff                                \SystemRoot\System32\smss.exe
0x7c900000    0xb2000     0xffff                                C:\WINDOWS\system32\ntdll.dll
************************************************************************
csrss.exe pid:    616
Command line : C:\WINDOWS\system32\csrss.exe ObjectDirectory=\Windows SharedSection=1024,3072,512 Windows=On SubSystemType=Windows
nsrv:UserServerDllInitialization,3 ServerDll=winsrv:ConServerDllInitialization,2 ProfileControl=Off MaxRequestThreads=16
Service Pack 3

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x4a680000     0x5000     0xffff                                \??\C:\WINDOWS\system32\csrss.exe
0x7c900000    0xb2000     0xffff                                C:\WINDOWS\system32\ntdll.dll
0x75b40000     0xb000     0xffff                                C:\WINDOWS\system32\CSRSRV.dll
0x75b50000    0x10000        0x3                                C:\WINDOWS\system32\basesrv.dll
0x75b60000     0x4b000        0x2                                C:\WINDOWS\system32\winsrv.dll
0x77f10000    0x49000        0xa                                C:\WINDOWS\system32\GDI32.dll
0x7c800000    0xf6000       0x1c                                C:\WINDOWS\system32\KERNEL32.dll
0x7e410000    0x91000        0xa                                C:\WINDOWS\system32\USER32.dll
0x629c0000     0x9000        0x1                                C:\WINDOWS\system32\LPK.DLL
0x74d90000    0x6b000        0x1                                C:\WINDOWS\system32\USP10.dll
0x77dd0000    0x9b000        0xa                                C:\WINDOWS\system32\ADVAPI32.dll
0x77e70000    0x93000        0x6                                C:\WINDOWS\system32\RPCRT4.dll
0x77fe0000    0x11000        0x4                                C:\WINDOWS\system32\Secur32.dll
0x7e720000    0xb0000        0x1                                C:\WINDOWS\system32\sxs.dll
************************************************************************
winlogon.exe pid:    640
```

Figure 3 Clean dump smss.exe pid 560

Infected dump

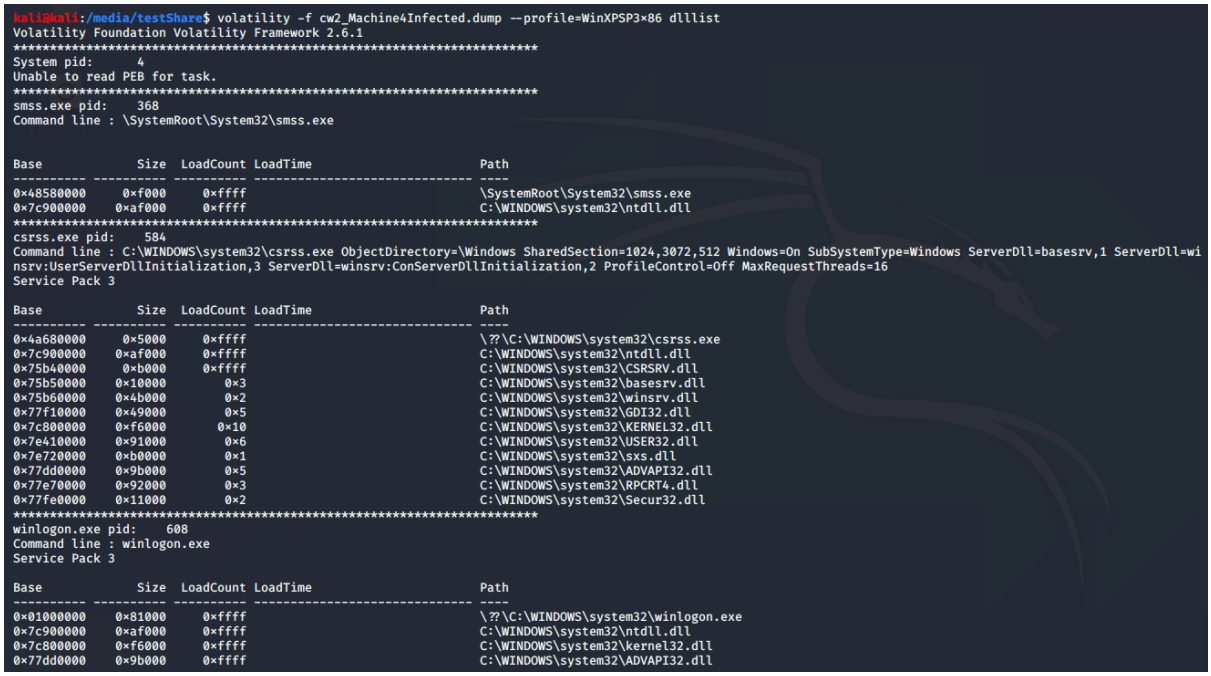


Figure 4 Infected dump smss.exe pid 368

After generating the DLL lists for both memory dumps, the results were saved into separate text files named clean_dlllist.txt and infected_dlllist.txt.

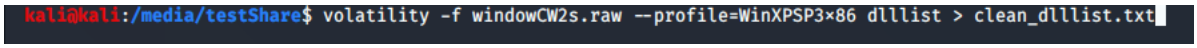


Figure 5 DLL list clean memory dump

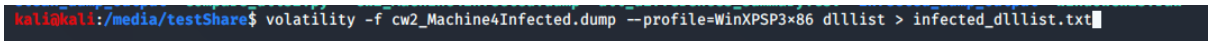


Figure 6 DLL list infected memory dump

To analyse DLLs effectively, the process list was first obtained to identify the PIDs of key critical processes, such as smss.exe, csrss.exe, winlogon.exe, lsass.exe, services.exe, and explorer.exe. Using these PIDs, the dlllist plugin was run on each process individually, allowing a focused comparison of the DLLs loaded in clean versus infected.

The table below shows the PIDs of the critical processes identified in both memory dumps:

Process Name	Clean Dump PID	Infected Dump PID	Purpose/Role
smss.exe	560	368	Session Manager Subsystem; prepares the system during boot.
csrss.exe	616	584	Client/Server Runtime Subsystem; handles GUI and console ops.
winlogon.exe	640	608	Manages user logon/logoff and secure attention sequence.
lsass.exe	696	664	Local Security Authority Subsystem; handles authentication.
services.exe	684	652	Controls and manages system services.
explorer.exe	436	1484	Windows graphical shell (desktop, taskbar, file explorer).
cmd.exe	180	Not present	command-line interactions, often present during debugging or batch script execution.

Table 2 PIDs of the Critical processes

Analysis of Critical Processes and DLL Comparisons

After extracting the DLL lists for both the clean (windowCW2s.raw) and infected (cw2_Machine4Infected.dump) memory dumps, we proceeded to compare the loaded DLLs for each critical process identified. By focusing on the same processes in both dumps, we aimed to pinpoint anomalies such as unexpected DLLs, altered load orders, or discrepancies in memory allocation that may indicate malicious activity.[11]

Command used for this:

- **volatility:** Invokes the Volatility Framework.
- **-f windowCW2s.raw**: Specifies the memory dump file.
- **--profile=WinXPSP3x86:** Sets the operating system profile, which tells Volatility to analyse the memory dump as a 32-bit Windows XP Service Pack 3 system.

- **dlllist:** This plugin lists the DLLs loaded by processes in the memory dump. It provides details about each DLL, including the base address, size, load count, and file path.
- **-p 560:** Focuses the dlllist analysis on the process with Process ID (PID) 560. In this case, it targets the smss.exe process.

Analysis of smss.exe (Session Manager Subsystem)

smss.exe is responsible for creating sessions that isolate operating system services from user interactions. It initializes the Windows environment during system boot.[12]

Clean Dump Observation

The DLL list for smss.exe in the clean dump includes the standard set of DLLs such as ntdll.dll, kernel32.dll, and RPCRT4.dll. These libraries are essential for the session manager's subsystem operations, particularly during system boot.[13]

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 dlllist -p 560
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
smss.exe pid:    560
Command line : \SystemRoot\System32\smss.exe

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x48580000     0xf000     0xffff                                \SystemRoot\System32\smss.exe
0x7c900000    0xb2000     0xffff                                C:\WINDOWS\system32\ntdll.dll
```

Figure 7 Clean dump observation smss.exe pid 560

Infected Dump observation

Both memory dumps show smss.exe loading only two entries: the smss.exe executable and ntdll.dll. However, in the infected dump, the ntdll.dll mapping differs slightly in size compared to the clean dump (0xb2000 vs. 0xaf000). While both are legitimate system components and no additional DLLs have been introduced, this subtle variation in memory allocation highlights a difference in how the DLL was mapped in the infected environment.[14]

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 dlllist -p 368
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
smss.exe pid:    368
Command line : \SystemRoot\System32\smss.exe

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x48580000     0xf000     0xffff                                \SystemRoot\System32\smss.exe
0x7c900000    0xaf000     0xffff                                C:\WINDOWS\system32\ntdll.dll
```

Figure 8 Infected dump observation smss.exe pid 368

Analysis of csrss.exe

The csrss.exe (Client Server Runtime Subsystem) process is responsible for thread and process creation and deletion, as well as GUI-related operations.

Clean dump observation

In the clean dump (csrss.exe PID 616), a set of core system DLLs is loaded, including libraries responsible for fundamental system and user interface functions. The clean environment includes essential DLLs like ntdll.dll, kernel32.dll, user32.dll, and gdi32.dll, which are vital for handling graphical and console operations.

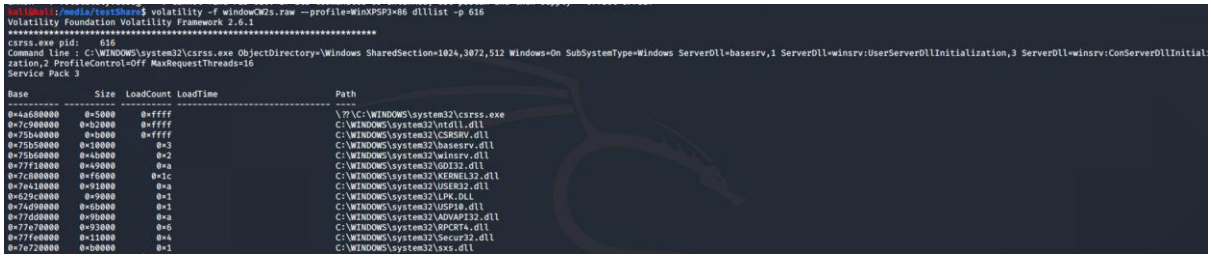


Figure 9 Clean dump DLL list csrss.exe pid 616

Infected dump observation

In the infected dump (csrss.exe PID 584), the majority of these same DLLs appear; however, there is a notable difference: **rpcrt4.dll** is present instead of gdi32.dll. Both rpcrt4.dll and gdi32.dll are legitimate Windows libraries, yet this variation indicates a subtle shift in the runtime environment of csrss.exe. This discrepancy may reflect changes in how certain functionalities were being handled in the infected system at the time of capture.[15]

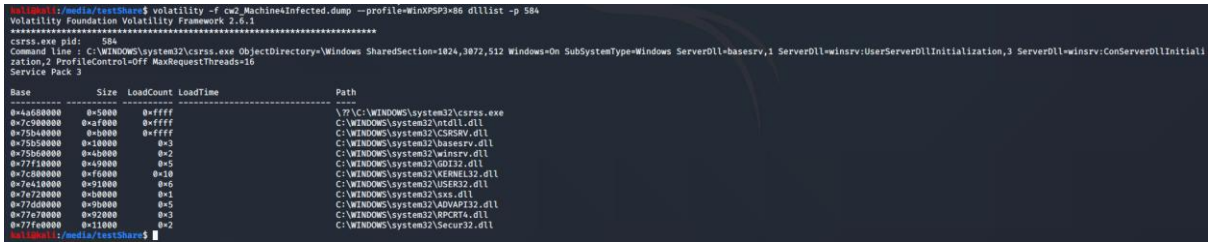


Figure 10 Infected dump DLL list csrss.exe pid 584

Analysis of winlogon.exe

The winlogon.exe process is responsible for managing user logins and logoffs, loading user profiles, and enforcing session security. It plays a vital role in maintaining system integrity by managing secure attention sequences and monitoring file system changes on systems with Windows File Protection (WFP).[16]

Clean Dump Observation

In the clean dump, winlogon.exe loads critical system libraries necessary for managing user logins and session security. The loaded DLLs include ntdll.dll, kernel32.dll, user32.dll, and gdi32.dll, all of which are expected components for this process. Additionally, comctl32.dll is loaded from the WinSxS directory, specifically from the build version 6.0.2600.6028, which corresponds to an updated and consistent system state. This indicates that the system was running a stable version of the required libraries at the time the memory snapshot was captured.[17]

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 dlllist -p 640
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
winlogon.exe pid:    640
Command line : winlogon.exe
Service Pack 3

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x01000000    0x81000     0xffff                                \??\C:\WINDOWS\system32\winlogon.exe
0x7c900000    0xb2000     0xffff                                C:\WINDOWS\system32\ntdll.dll
0x7c800000    0xf6000     0xffff                                C:\WINDOWS\system32\kernel32.dll
0x77dd0000    0x9b000     0xffff                                C:\WINDOWS\system32\ADVAPI32.dll
0x77e70000    0x93000     0xffff                                C:\WINDOWS\system32\RPCRT4.dll
0x77fe0000    0x11000     0xffff                                C:\WINDOWS\system32\Secur32.dll
0x776c0000    0x12000     0xffff                                C:\WINDOWS\system32\AUTHZ.dll
0x77c10000    0x58000     0xffff                                C:\WINDOWS\system32\msvcrt.dll
0x77a80000    0x97000     0xffff                                C:\WINDOWS\system32\CRYPT32.dll
0x77b20000    0x12000     0xffff                                C:\WINDOWS\system32\MSASN1.dll
0x7e410000    0x91000     0xffff                                C:\WINDOWS\system32\USER32.dll
0x77f10000    0x49000     0xffff                                C:\WINDOWS\system32\GDI32.dll
0x75940000     0x8000     0xffff                                C:\WINDOWS\system32\NDdeApi.dll
0x75930000     0xa000     0xffff                                C:\WINDOWS\system32\PROFMAP.dll
0x5b860000    0x56000     0xffff                                C:\WINDOWS\system32\NETAPI32.dll
0x769c0000    0xb4000     0xffff                                C:\WINDOWS\system32\USERENV.dll
0x76bf0000     0xb000     0xffff                                C:\WINDOWS\system32\PSAPI.DLL
0x76bc0000     0xf000     0xffff                                C:\WINDOWS\system32\REGAPI.dll
0x77920000    0xf3000     0xffff                                C:\WINDOWS\system32\SETUPAPI.dll
0x77c00000     0x8000     0xffff                                C:\WINDOWS\system32\VERSION.dll
0x76360000    0x10000     0xffff                                C:\WINDOWS\system32\WINSTA.dll
0x76c30000    0x2e000     0xffff                                C:\WINDOWS\system32\WINTRUST.dll
0x76c90000    0x28000     0xffff                                C:\WINDOWS\system32\IMAGEHLP.dll
0x71ab0000    0x17000     0xffff                                C:\WINDOWS\system32\WS2_32.dll
0x71aa0000     0x8000     0xffff                                C:\WINDOWS\system32\WS2HELP.dll
0x76390000    0x1d000        0x5                                C:\WINDOWS\system32\IMM32.DLL
0x629c0000     0x9000        0x1                                C:\WINDOWS\system32\LPK.DLL
0x74d90000    0x6b000        0x1                                C:\WINDOWS\system32\USP10.dll
0x75970000    0xf8000        0x2                                C:\WINDOWS\system32\MSGINA.dll
0x5d090000    0x9a000        0x8                                C:\WINDOWS\system32\COMCTL32.dll
0x74320000    0x3e000        0x2                                C:\WINDOWS\system32\ODBC32.dll
0x763b0000    0x49000        0x3                                C:\WINDOWS\system32\comdlg32.dll
0x7c9c0000   0x817000       0x12                                C:\WINDOWS\system32\SHELL32.dll
0x77f60000    0x76000       0x38                                C:\WINDOWS\system32\SHLWAPI.dll
0x773d0000   0x103000        0x5                                C:\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.6028_x-ww_61e65202\comctl32.dll
0x00980000    0x17000        0x1                                C:\WINDOWS\system32\odbcint.dll
0x776e0000    0x23000        0x1                                C:\WINDOWS\system32\SHSVCS.dll
0x76bb0000     0x5000        0x2                                C:\WINDOWS\system32\sfc.dll
0x76c60000     0x2a000        0x5                                C:\WINDOWS\system32\sfc_os.dll
0x774e0000   0x13e000       0x1f                                C:\WINDOWS\system32\ole32.dll
0x77b40000    0x22000        0x1                                C:\WINDOWS\system32\Apphelp.dll
```

Figure 11 Clean dump observation winlogon.exe pid 640

Infected Dump Observation

In the infected dump, winlogon.exe loads a similar set of core DLLs, including ntdll.dll, kernel32.dll, and user32.dll. However, a key discrepancy appears in the version of the comctl32.dll library. Instead of loading version **6.0.2600.6028**, as seen in the clean dump, the infected dump loads an older version **6.0.2600.5512** from the **WinSxS directory**. This difference suggests that the system may have been operating under a different configuration or update state at the time of the memory snapshot. The presence of an outdated DLL version could indicate inconsistencies in patch management, potential misconfigurations, or unintended changes to the environment.[18]

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 dlllist -p 608
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
winlogon.exe pid:    608
Command line : winlogon.exe
Service Pack 3

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x01000000    0x81000     0xffff                                \??\C:\WINDOWS\system32\winlogon.exe
0x7c900000    0xaf000     0xffff                                C:\WINDOWS\system32\ntdll.dll
0x7c800000    0xf6000     0xffff                                C:\WINDOWS\system32\kernel32.dll
0x77dd0000    0x9b000     0xffff                                C:\WINDOWS\system32\ADVAPI32.dll
0x77e70000    0x92000     0xffff                                C:\WINDOWS\system32\RPCRT4.dll
0x77fe0000    0x11000     0xffff                                C:\WINDOWS\system32\Secur32.dll
0x776c0000    0x12000     0xffff                                C:\WINDOWS\system32\AUTHZ.dll
0x77c10000    0x58000     0xffff                                C:\WINDOWS\system32\msvcrt.dll
0x77a80000    0x95000     0xffff                                C:\WINDOWS\system32\CRYPT32.dll
0x77b20000    0x12000     0xffff                                C:\WINDOWS\system32\MSASN1.dll
0x7e410000    0x91000     0xffff                                C:\WINDOWS\system32\USER32.dll
0x77f10000    0x49000     0xffff                                C:\WINDOWS\system32\GDI32.dll
0x75940000     0x8000     0xffff                                C:\WINDOWS\system32\NDdeApi.dll
0x75930000     0xa000     0xffff                                C:\WINDOWS\system32\PROFMAP.dll
0x5b860000    0x55000     0xffff                                C:\WINDOWS\system32\NETAPI32.dll
0x769c0000    0xb4000     0xffff                                C:\WINDOWS\system32\USERENV.dll
0x76bf0000     0xb000     0xffff                                C:\WINDOWS\system32\PSAPI.DLL
0x76bc0000     0xf000     0xffff                                C:\WINDOWS\system32\REGAPI.dll
0x77920000    0xf3000     0xffff                                C:\WINDOWS\system32\SETUPAPI.dll
0x77c00000     0x8000     0xffff                                C:\WINDOWS\system32\VERSION.dll
0x76360000    0x10000     0xffff                                C:\WINDOWS\system32\WINSTA.dll
0x76c30000    0x2e000     0xffff                                C:\WINDOWS\system32\WINTRUST.dll
0x76c90000    0x28000     0xffff                                C:\WINDOWS\system32\IMAGEHLP.dll
0x71ab0000    0x17000     0xffff                                C:\WINDOWS\system32\WS2_32.dll
0x71aa0000     0x8000     0xffff                                C:\WINDOWS\system32\WS2HELP.dll
0x75970000    0xf8000        0x2                                C:\WINDOWS\system32\MSGINA.dll
0x5d090000    0x9a000        0x7                                C:\WINDOWS\system32\COMCTL32.dll
0x74320000    0x3d000        0x2                                C:\WINDOWS\system32\ODBC32.dll
0x763b0000    0x49000        0x2                                C:\WINDOWS\system32\comdlg32.dll
0x7c9c0000   0x817000       0x10                                C:\WINDOWS\system32\SHELL32.dll
0x77f60000    0x76000       0x1b                                C:\WINDOWS\system32\SHLWAPI.dll
0x773d0000   0x103000        0x3                                C:\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.5512_x-ww_35d4ce83\comctl32.dll
0x00930000    0x17000        0x1                                C:\WINDOWS\system32\odbcint.dll
0x776e0000    0x23000        0x1                                C:\WINDOWS\system32\SHSVCS.dll
0x76bb0000     0x5000        0x2                                C:\WINDOWS\system32\sfc.dll
0x76c60000     0x2a000        0x5                                C:\WINDOWS\system32\sfc_os.dll
0x774e0000   0x13d000       0x18                                C:\WINDOWS\system32\ole32.dll
0x77b40000    0x22000        0x1                                C:\WINDOWS\system32\Apphelp.dll
0x723d0000    0x1c000        0x7                                C:\WINDOWS\system32\WINSCARD.DLL
0x76f50000     0x8000        0x7                                C:\WINDOWS\system32\WTSAPI32.dll
```

Figure 12 Infected dump observation winlogon.exe pid 608

Analysis of lsass.exe

The lsass.exe (Local Security Authority Subsystem) process enforces system security policies, manages user authentication, and generates access tokens. It is critical for maintaining the integrity of the Windows security model and is a frequent target for attackers aiming to extract plaintext passwords or inject malicious code.[19]

Clean Dump Observation

In the clean dump, the lsass.exe process loads a comprehensive set of core DLLs necessary for authentication and security management. These include lsasrv.dll, which is critical for Local Security Authority operations, and samsrv.dll, responsible for managing the Security Accounts Manager (SAM) database. Notably, credssp.dll is present in the clean dump, supporting Credential Security Support Provider functionality, which is essential for secure credential delegation and authentication. Additionally, DLLs such as cryptdll.dll and schannel.dll ensure encryption and secure channel communications. The inclusion of these libraries reflects a well-configured system supporting standard security and authentication mechanisms.[20]

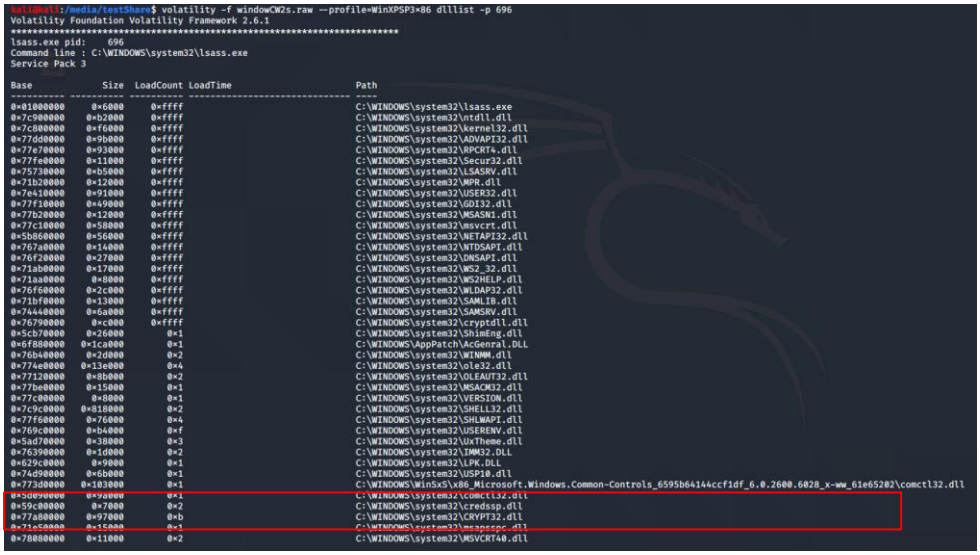


Figure 13 Clean dump observation lsass.exe pid 696

Infected Dump Observation (lsass.exe PID 664):

In the infected dump, the lsass.exe process also loads core libraries such as lsasrv.dll and samsrv.dll, which are expected for this process. However, a significant discrepancy is observed: **credssp.dll** is missing from the DLL list. The absence of this critical library indicates that the system may not be utilizing standard credential delegation or has been altered to disable this functionality. Furthermore, slight differences in the paths or sizes of other DLLs, such as cryptdll.dll and schannel.dll, suggest subtle changes in how these libraries were loaded or mapped at runtime. This deviation from the clean dump indicates a potentially manipulated environment that could impact the system's ability to securely handle authentication processes.[21]

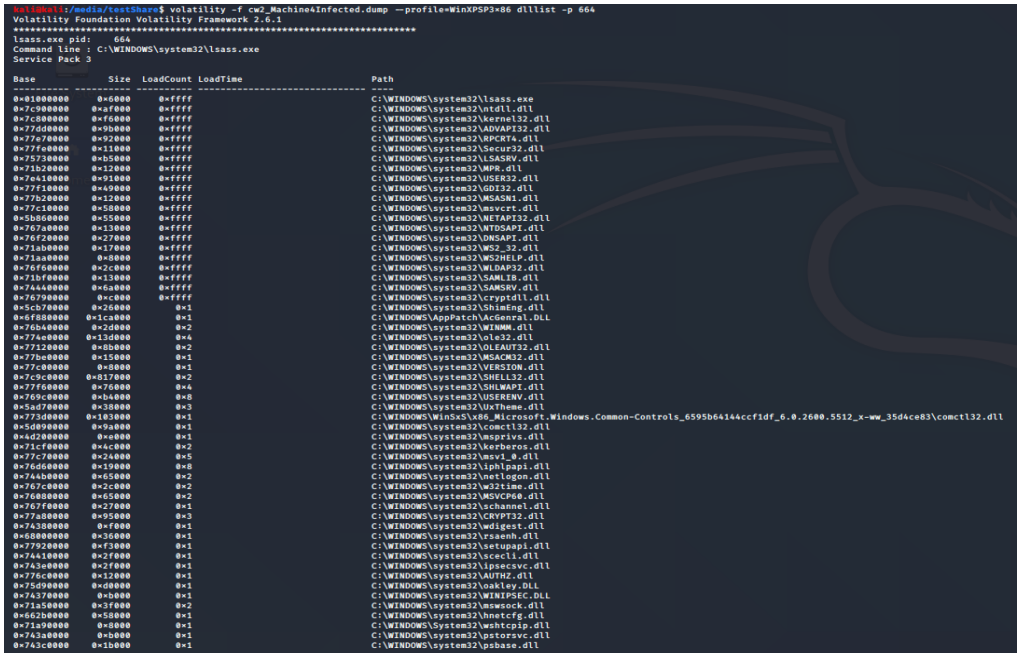


Figure 14 Infected dump observation lsass.exe pid 664

Analysis of services.exe

The services.exe process is responsible for managing Windows services via the Service Control Manager (SCM). It ensures critical services are started and running properly, acting as the parent process for all svchost.exe instances. Its role in managing system services makes it a crucial component for maintaining system stability and functionality.[22]

Clean Dump Observation

In the clean dump, the services.exe process loads a set of core system DLLs required for managing Windows services. Key DLLs include credssp.dll, which supports credential delegation for secure authentication, and schannel.dll, responsible for secure communications through SSL/TLS protocols. Additional libraries such as netapi32.dll handle network management, while eventlog.dll is crucial for logging system and application events. The presence of these DLLs indicates a properly configured system where authentication, encryption, and network management functionalities are fully operational.[23]

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 dlllist -p 684
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
services.exe pid:    684
Command line : C:\WINDOWS\system32\services.exe
Service Pack 3

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x01000000    0x1d000     0xffff                                C:\WINDOWS\system32\services.exe
0x7c900000    0xb2000     0xffff                                C:\WINDOWS\system32\ntdll.dll
0x7c800000    0xf6000     0xffff                                C:\WINDOWS\system32\kernel32.dll
0x77dd0000    0x9b000     0xffff                                C:\WINDOWS\system32\ADVAPI32.dll
0x77e70000    0x93000     0xffff                                C:\WINDOWS\system32\RPCRT4.dll
0x77fe0000    0x11000     0xffff                                C:\WINDOWS\system32\Secur32.dll
0x77c10000    0x58000     0xffff                                C:\WINDOWS\system32\msvcrt.dll
0x5f770000     0xc000     0xffff                                C:\WINDOWS\system32\NCObjAPI.DLL
0x76080000    0x65000     0xffff                                C:\WINDOWS\system32\MSVCP60.dll
0x7dbd0000    0x51000     0xffff                                C:\WINDOWS\system32\SCESRV.dll
0x776c0000    0x12000     0xffff                                C:\WINDOWS\system32\AUTHZ.dll
0x7e410000    0x91000     0xffff                                C:\WINDOWS\system32\USER32.dll
0x77f10000    0x49000     0xffff                                C:\WINDOWS\system32\GDI32.dll
0x769c0000    0xb4000     0xffff                                C:\WINDOWS\system32\USERENV.dll
0x7dba0000    0x21000     0xffff                                C:\WINDOWS\system32\umpnpmgr.dll
0x76360000    0x10000     0xffff                                C:\WINDOWS\system32\WINSTA.dll
0x5b860000    0x56000     0xffff                                C:\WINDOWS\system32\NETAPI32.dll
0x5cb70000    0x26000        0x1                                C:\WINDOWS\system32\ShimEng.dll
0x47260000     0xf000        0x1                                C:\WINDOWS\AppPatch\AcAdProc.dll
0x76390000    0x1d000        0x2                                C:\WINDOWS\system32\IMM32.DLL
0x629c0000     0x9000        0x1                                C:\WINDOWS\system32\LPK.DLL
0x74d90000    0x6b000        0x1                                C:\WINDOWS\system32\USP10.dll
0x59c00000     0x7000        0x1                                C:\WINDOWS\system32\credssp.dll
0x77a80000    0x97000        0x4                                C:\WINDOWS\system32\CRYPT32.dll
0x77b20000    0x12000        0x6                                C:\WINDOWS\system32\MSASN1.dll
0x767f0000    0x29000        0x1                                C:\WINDOWS\system32\schannel.dll
0x71ab0000    0x17000        0x2                                C:\WINDOWS\system32\WS2_32.dll
0x71aa0000     0x8000        0x2                                C:\WINDOWS\system32\WS2HELP.dll
0x77b40000    0x22000        0x2                                C:\WINDOWS\system32\Apphelp.dll
0x77c00000     0x8000        0x2                                C:\WINDOWS\system32\VERSION.dll
0x77b70000    0x11000        0x1                                C:\WINDOWS\system32\eventlog.dll
0x76bf0000     0xb000        0x1                                C:\WINDOWS\system32\PSAPI.DLL
0x76f50000     0x8000        0x1                                C:\WINDOWS\system32\wtsapi32.dll
0x76c30000    0x2e000        0x1                                C:\WINDOWS\system32\WINTRUST.dll
0x76c90000    0x28000        0x2                                C:\WINDOWS\system32\IMAGEHLP.dll
0x01020000   0x2c5000        0x1                                C:\WINDOWS\system32\xpsp2res.dll
0x68000000    0x36000        0x1                                C:\WINDOWS\system32\rsaenh.dll
0x5ad70000    0x38000        0x2                                C:\WINDOWS\system32\uxtheme.dll
0x75150000    0x13000        0x1                                C:\WINDOWS\system32\Cabinet.dll
0x774e0000   0x13e000        0x1                                C:\WINDOWS\system32\ole32.dll
```

Figure 15 Clean dump observation services.exe pid 684

Infected Dump Observation

In the infected dump, while core DLLs like netapi32.dll and eventlog.dll are still loaded, notable differences emerge. **credssp.dll and schannel.dll** are absent from the DLL list, mirroring the observations made in earlier processes such as lsass.exe and winlogon.exe. These missing libraries indicate that secure credential delegation and encrypted communication functionality may have been disabled or tampered with in the infected environment.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 dlllist -p 652
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
services.exe pid:    652
Command line : C:\WINDOWS\system32\services.exe
Service Pack 3

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x01000000    0x1c000     0xffff                                C:\WINDOWS\system32\services.exe
0x7c900000    0xaf000     0xffff                                C:\WINDOWS\system32\ntdll.dll
0x7c800000    0xf6000     0xffff                                C:\WINDOWS\system32\kernel32.dll
0x77dd0000    0x9b000     0xffff                                C:\WINDOWS\system32\ADVAPI32.dll
0x77e70000    0x92000     0xffff                                C:\WINDOWS\system32\RPCRT4.dll
0x77fe0000    0x11000     0xffff                                C:\WINDOWS\system32\Secur32.dll
0x77c10000    0x58000     0xffff                                C:\WINDOWS\system32\msvcrt.dll
0x5f770000     0xc000     0xffff                                C:\WINDOWS\system32\NCObjAPI.DLL
0x76080000    0x65000     0xffff                                C:\WINDOWS\system32\MSVCP60.dll
0x7dbd0000    0x51000     0xffff                                C:\WINDOWS\system32\SCESRV.dll
0x776c0000    0x12000     0xffff                                C:\WINDOWS\system32\AUTHZ.dll
0x7e410000    0x91000     0xffff                                C:\WINDOWS\system32\USER32.dll
0x77f10000    0x49000     0xffff                                C:\WINDOWS\system32\GDI32.dll
0x769c0000    0xb4000     0xffff                                C:\WINDOWS\system32\USERENV.dll
0x7dba0000    0x21000     0xffff                                C:\WINDOWS\system32\umpnpmgr.dll
0x76360000    0x10000     0xffff                                C:\WINDOWS\system32\WINSTA.dll
0x5b860000    0x55000     0xffff                                C:\WINDOWS\system32\NETAPI32.dll
0x5cb70000    0x26000        0x1                                C:\WINDOWS\system32\ShimEng.dll
0x47260000     0xf000        0x1                                C:\WINDOWS\AppPatch\AcAdProc.dll
0x77b40000    0x22000        0x1                                C:\WINDOWS\system32\Apphelp.dll
0x77c00000     0x8000        0x1                                C:\WINDOWS\system32\VERSION.dll
0x77b70000    0x11000        0x1                                C:\WINDOWS\system32\eventlog.dll
0x76bf0000     0xb000        0x1                                C:\WINDOWS\system32\PSAPI.DLL
0x71ab0000    0x17000        0x1                                C:\WINDOWS\system32\WS2_32.dll
0x71aa0000     0x8000        0x1                                C:\WINDOWS\system32\WS2HELP.dll
0x76f50000     0x8000        0x1                                C:\WINDOWS\system32\wtsapi32.dll
kali@kali:/media/testShare$
```

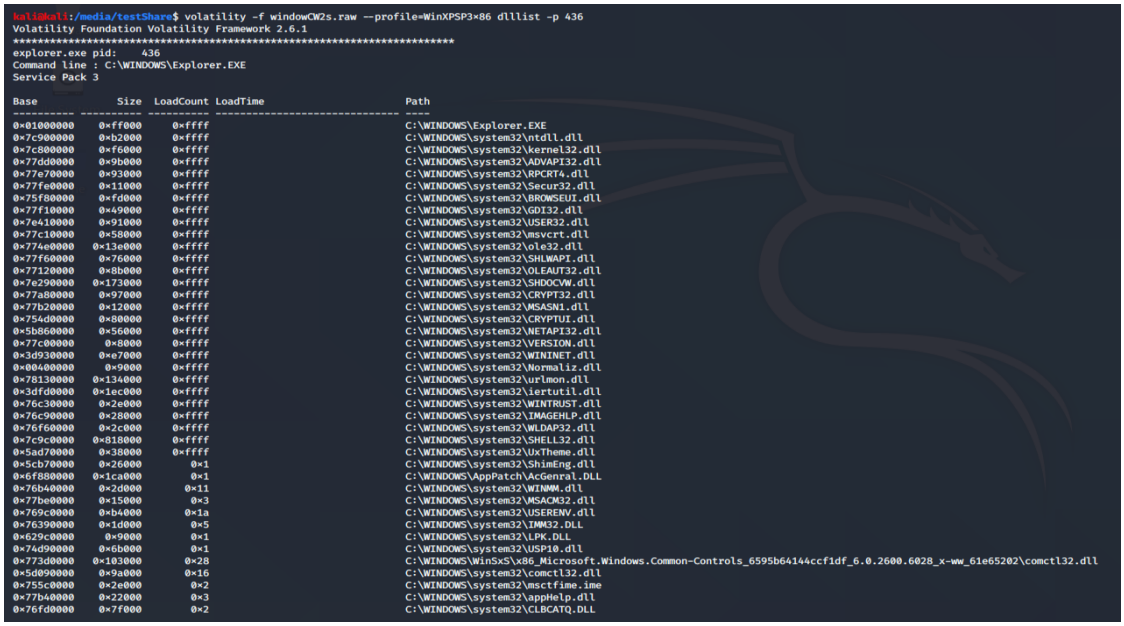
Figure 16 Infected dump observation services.exe pid 652

Analysis of explorer.exe

The explorer.exe process is the Windows graphical shell, responsible for managing the desktop, taskbar, and file explorer. It plays a central role in enabling user interactions with the operating system, including access to files, folders, and settings.

Clean Dump Observation

In the clean dump, the explorer.exe process is loaded with a comprehensive set of DLLs required to manage the Windows graphical shell, including the desktop, taskbar, and file explorer. Essential libraries like ntdll.dll, kernel32.dll, and user32.dll ensure core system functionalities. Additional libraries such as shdocvw.dll and shell32.dll are responsible for managing the user interface and file operations. Notably, the comctl32.dll loaded in this process is sourced from the version 6.0.2600.6028, reflecting a system updated to a more recent configuration. The inclusion of crypt32.dll further supports secure communication and encryption functions within the system.[24]



```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 dlllist -p 436
Volatility Foundation Volatility Framework 2.6.1
************************************************************************
explorer.exe pid:    436
Command line : C:\WINDOWS\Explorer.EXE
Service Pack 3

Base             Size  LoadCount LoadTime                   Path
---------- ---------- ---------- ------------------------------ ----
0x01000000    0xff000     0xffff                              C:\WINDOWS\Explorer.EXE
0x7c900000    0xb2000     0xffff                              C:\WINDOWS\system32\ntdll.dll
0x7c800000    0xf6000     0xffff                              C:\WINDOWS\system32\kernel32.dll
0x77dd0000    0x9b000     0xffff                              C:\WINDOWS\system32\ADVAPI32.dll
0x77e70000    0x93000     0xffff                              C:\WINDOWS\system32\RPCRT4.dll
0x77fe0000    0x11000     0xffff                              C:\WINDOWS\system32\Secur32.dll
0x75f80000    0xfd000     0xffff                              C:\WINDOWS\system32\BROWSEUI.dll
0x77f10000    0x49000     0xffff                              C:\WINDOWS\system32\GDI32.dll
0x7e410000    0x91000     0xffff                              C:\WINDOWS\system32\USER32.dll
0x77c10000    0x58000     0xffff                              C:\WINDOWS\system32\msvcrt.dll
0x774e0000   0x13e000     0xffff                              C:\WINDOWS\system32\ole32.dll
0x77f60000    0x76000     0xffff                              C:\WINDOWS\system32\SHLWAPI.dll
0x77120000    0x8b000     0xffff                              C:\WINDOWS\system32\OLEAUT32.dll
0x7e290000   0x173000     0xffff                              C:\WINDOWS\system32\SHDOCVW.dll
0x77a80000    0x97000     0xffff                              C:\WINDOWS\system32\CRYPT32.dll
0x77b20000    0x12000     0xffff                              C:\WINDOWS\system32\MSASN1.dll
0x754d0000    0x80000     0xffff                              C:\WINDOWS\system32\CRYPTUI.dll
0x5b860000    0x56000     0xffff                              C:\WINDOWS\system32\NETAPI32.dll
0x77c00000     0x8000     0xffff                              C:\WINDOWS\system32\VERSION.dll
0x3d930000    0xe7000     0xffff                              C:\WINDOWS\system32\WININET.dll
0x00400000     0x9000     0xffff                              C:\WINDOWS\system32\Normaliz.dll
0x78130000   0x134000     0xffff                              C:\WINDOWS\system32\urlmon.dll
0x3dfd0000   0x1ec000     0xffff                              C:\WINDOWS\system32\iertutil.dll
0x76c30000    0x2e000     0xffff                              C:\WINDOWS\system32\WINTRUST.dll
0x76c90000    0x28000     0xffff                              C:\WINDOWS\system32\IMAGEHLP.dll
0x76f60000    0x2c000     0xffff                              C:\WINDOWS\system32\WLDAP32.dll
0x7c9c0000   0x818000     0xffff                              C:\WINDOWS\system32\SHELL32.dll
0x5ad70000    0x38000     0xffff                              C:\WINDOWS\system32\UxTheme.dll
0x5cb70000    0x26000        0x1                              C:\WINDOWS\system32\ShimEng.dll
0x6f880000   0x1ca000        0x1                              C:\WINDOWS\AppPatch\AcGenral.DLL
0x76b40000    0x2d000       0x11                              C:\WINDOWS\system32\WINMM.dll
0x77be0000    0x15000        0x3                              C:\WINDOWS\system32\MSACM32.dll
0x769c0000    0xb4000       0x1a                              C:\WINDOWS\system32\USERENV.dll
0x76390000    0x1d000        0x5                              C:\WINDOWS\system32\IMM32.DLL
0x629c0000     0x9000        0x1                              C:\WINDOWS\system32\LPK.DLL
0x74d90000    0x6b000        0x1                              C:\WINDOWS\system32\USP10.dll
0x773d0000   0x103000       0x28                              C:\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.6028_x-ww_61e65202\comctl32.dll
0x5d090000    0x9a000       0x16                              C:\WINDOWS\system32\comctl32.dll
0x755c0000    0x2e000        0x2                              C:\WINDOWS\system32\msctfime.ime
0x77b40000    0x22000        0x3                              C:\WINDOWS\system32\appHelp.dll
0x76fd0000    0x7f000        0x2                              C:\WINDOWS\system32\CLBCATQ.DLL
```

Figure 17 Clean dump observation explorer.exe pid 436

Infected Dump Observation

The DLL list in the infected dump for explorer.exe shares many similarities with the clean environment but shows notable deviations. The comctl32.dll version loaded here is 6.0.2600.5512, an earlier version than the one seen in the clean dump. This change suggests differences in the underlying system configuration or updates present at the time of memory capture.

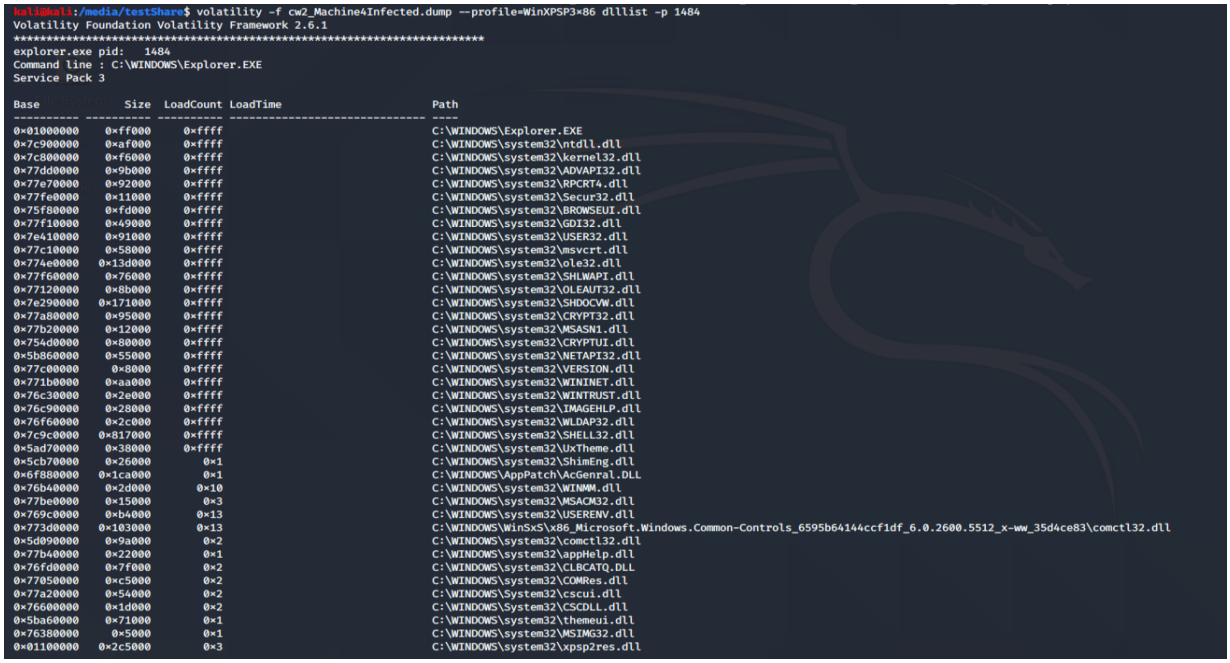


Figure 18 Infected dump observation explorer.exe pid 1484

With the DLL comparisons complete, we now shift our focus to the file systems of both machines. By recovering and analysing their file structures, we aim to identify differences in the number of files and uncover potential indicators of compromise in the infected system.

2. Recover the file system of both machines, how many files can you find in each of them? (10%).

A file system is a structured method for storing and organizing data on a storage medium, such as a hard drive or memory dump. It defines how data is stored, accessed, and managed, using directories, files, and metadata like timestamps and permissions.[25]

For this analysis, the **filescan** and **dumpfiles** commands from the Volatility framework are utilized:

- **filescan**: Locates file objects in the memory dump by scanning for file system metadata. This command is instrumental in identifying the files present in memory and assessing their recoverability.
- **dumpfiles**: Extracts the identified files to a specified directory, enabling detailed analysis and comparison between the clean and infected systems.

Explanation of the commands used:

- **-f infected_dump.raw**: Specifies the memory dump file to analyse.

- **--profile=WinXPSP3x86**: Sets the operating system profile for analysis (Windows XP SP3 32-bit).
- **filescan**: Searches for file objects in memory, revealing file paths, metadata, and permissions.
- **dumpfiles**: Extracts the files identified by filescan for recovery.
- **-D /output_directory**: Specifies the directory where the recovered files will be saved.

The **filescan** command for the infected dump identified files across standard system directories such as C:\WINDOWS\system32 and user directories like Documents and Settings. Key files, including desktop.ini, cryptnet.dll, and UsrClass.dat.LOG, were found with their respective file permissions intact, such as read-only and read-write. The directory structure appears standard, with no unusual files or irregular permissions observed.[26]

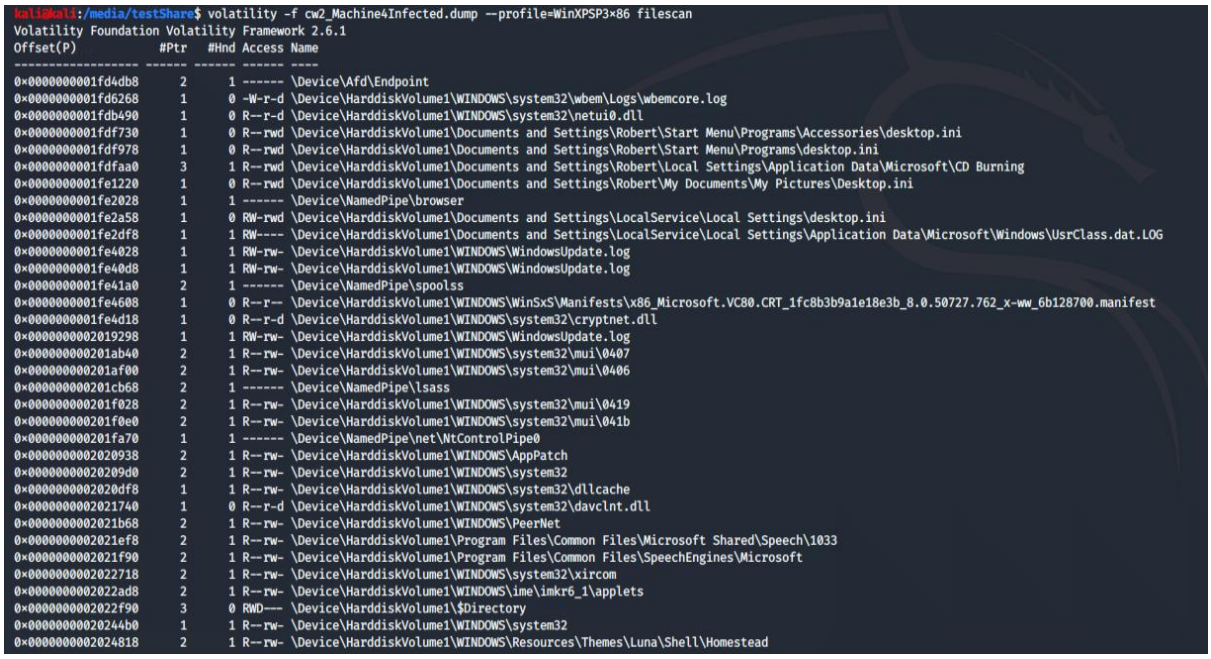


Figure 19 Infected dump files and permissions

The **dumpfiles** command was utilized for both the clean and infected dumps to extract files identified through the **filescan** results into a specified directory. This command allows recovery of files from the memory dumps.[27]

Clean dump

```
kali@kali:/media/testShare$ ls
clean_dlllist.txt  clean_dump_output  compare_dlls2.py  compare_dlls.py  cw2_Machine4Infected.dump  infected_dlllist.txt  infected_dump_output  windowCW2s.raw  winpmem_v3.3.rc3.exe
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 dumpfiles -D clean_dump_output
Volatility Foundation Volatility Framework 2.6.1
DataSectionObject 0x89d08868   4      \Device\HarddiskVolume1\Documents and Settings\Administrator\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
SharedCacheMap 0x89d08868   4      \Device\HarddiskVolume1\Documents and Settings\Administrator\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
DataSectionObject 0x89b606c8   4      \Device\HarddiskVolume1\Documents and Settings\Administrator\NTUSER.DAT
SharedCacheMap 0x89b606c8   4      \Device\HarddiskVolume1\Documents and Settings\Administrator\NTUSER.DAT
DataSectionObject 0x8a005028   4      \Device\HarddiskVolume1\System Volume Information\_restore{F08459D8-9E84-4265-ABE5-610B8ADDE4E2}\RP4\change.log
SharedCacheMap 0x8a005028   4      \Device\HarddiskVolume1\System Volume Information\_restore{F08459D8-9E84-4265-ABE5-610B8ADDE4E2}\RP4\change.log
DataSectionObject 0x8a0d5120   4      \Device\HarddiskVolume1\WINDOWS\system32\config\software
SharedCacheMap 0x8a0d5120   4      \Device\HarddiskVolume1\WINDOWS\system32\config\software
DataSectionObject 0x8a0b6f90   4      \Device\HarddiskVolume1\Documents and Settings\voidead\NTUSER.DAT
SharedCacheMap 0x8a0b6f90   4      \Device\HarddiskVolume1\Documents and Settings\voidead\NTUSER.DAT
DataSectionObject 0x8a204238   4      \Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
SharedCacheMap 0x8a204238   4      \Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
DataSectionObject 0x89ff4960   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
SharedCacheMap 0x89ff4960   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
DataSectionObject 0x8a1a96c0   4      \Device\HarddiskVolume1\WINDOWS\system32\config\system
SharedCacheMap 0x8a1a96c0   4      \Device\HarddiskVolume1\WINDOWS\system32\config\system
DataSectionObject 0x8a165d50   4      \Device\HarddiskVolume1\WINDOWS\system32\config\default
SharedCacheMap 0x8a165d50   4      \Device\HarddiskVolume1\WINDOWS\system32\config\default
DataSectionObject 0x8a160740   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SAM
SharedCacheMap 0x8a160740   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SAM
DataSectionObject 0x8a1618b0   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SECURITY
SharedCacheMap 0x8a1618b0   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SECURITY
DataSectionObject 0x89ca5f90   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\NTUSER.DAT
SharedCacheMap 0x89ca5f90   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\NTUSER.DAT
DataSectionObject 0x89c88ab8   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\NTUSER.DAT
SharedCacheMap 0x89c88ab8   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\NTUSER.DAT
DataSectionObject 0x89ca38b8   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
SharedCacheMap 0x89ca38b8   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
ImageSectionObject 0x8a22f918   4      \Device\HarddiskVolume1\WINDOWS\system32\ntdll.dll
DataSectionObject 0x8a22f918   4      \Device\HarddiskVolume1\WINDOWS\system32\ntdll.dll
ImageSectionObject 0x8a1a0778   560    \Device\HarddiskVolume1\WINDOWS\system32\smss.exe
DataSectionObject 0x8a1a0778   560    \Device\HarddiskVolume1\WINDOWS\system32\smss.exe
DataSectionObject 0x8a149c60   616    \Device\HarddiskVolume1\WINDOWS\Fonts\tahoma.ttf
DataSectionObject 0x8a1599b8   616    \Device\HarddiskVolume1\WINDOWS\system32\unicode.nls
DataSectionObject 0x8a14b860   616    \Device\HarddiskVolume1\WINDOWS\system32\sortkey.nls
```

Figure 20 Clean dump files

Infected Dump

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 dumpfiles -D infected_dump_output
Volatility Foundation Volatility Framework 2.6.1
DataSectionObject 0x82303ae8   4      \Device\HarddiskVolume1\WINDOWS\system32\config\system
SharedCacheMap 0x82303ae8   4      \Device\HarddiskVolume1\WINDOWS\system32\config\system
DataSectionObject 0x82203818   4      \Device\HarddiskVolume1\WINDOWS\system32\config\software
SharedCacheMap 0x82203818   4      \Device\HarddiskVolume1\WINDOWS\system32\config\software
DataSectionObject 0x821aea18   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SECURITY
SharedCacheMap 0x821aea18   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SECURITY
DataSectionObject 0x8213cd10   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
SharedCacheMap 0x8213cd10   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
DataSectionObject 0x81eae640   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\NTUSER.DAT
SharedCacheMap 0x81eae640   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\NTUSER.DAT
DataSectionObject 0x822abf90   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
SharedCacheMap 0x822abf90   4      \Device\HarddiskVolume1\Documents and Settings\LocalService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
DataSectionObject 0x82298410   4      \Device\HarddiskVolume1\Documents and Settings\Robert\NTUSER.DAT
SharedCacheMap 0x82298410   4      \Device\HarddiskVolume1\Documents and Settings\Robert\NTUSER.DAT
DataSectionObject 0x81eb61b0   4      \Device\HarddiskVolume1\Documents and Settings\Robert\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
SharedCacheMap 0x81eb61b0   4      \Device\HarddiskVolume1\Documents and Settings\Robert\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
DataSectionObject 0x822fa1d8   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\NTUSER.DAT
SharedCacheMap 0x822fa1d8   4      \Device\HarddiskVolume1\Documents and Settings\NetworkService\NTUSER.DAT
DataSectionObject 0x81eaa988   4      \Device\HarddiskVolume1\System Volume Information\_restore{989DBDD1-0572-41A6-88B9-64B7850964E4}\RP2\change.log
SharedCacheMap 0x81eaa988   4      \Device\HarddiskVolume1\System Volume Information\_restore{989DBDD1-0572-41A6-88B9-64B7850964E4}\RP2\change.log
DataSectionObject 0x8206122   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SAM
SharedCacheMap 0x82061220   4      \Device\HarddiskVolume1\WINDOWS\system32\config\SAM
DataSectionObject 0x81ec55e0   4      \Device\HarddiskVolume1\WINDOWS\system32\config\default
SharedCacheMap 0x81ec55e0   4      \Device\HarddiskVolume1\WINDOWS\system32\config\default
ImageSectionObject 0x8233f5e0   4      \Device\HarddiskVolume1\WINDOWS\system32\ntdll.dll
DataSectionObject 0x8233f5e0   4      \Device\HarddiskVolume1\WINDOWS\system32\ntdll.dll
ImageSectionObject 0x822612c8   368    \Device\HarddiskVolume1\WINDOWS\system32\smss.exe
```

Figure 21 Infected dump files

Amount of files

The commands in the screenshot count the files recovered from the memory dumps of two machines. The clean dump contains 364 files, while the infected dump contains 313 files. This shows the number of files successfully recovered from each machine's file system.

```
kali@kali:/media/testShare$ ls clean_dump_output | wc -l
364
kali@kali:/media/testShare$ ls infected_dump_output | wc -l
313
```

Figure 22 Command for the recovered files from both dumps

After saving the files from the clean and infected memory dumps into their respective directories using the dumpfiles command, the diff command was utilized to compare the outputs and identify any discrepancies between the two environments. This comparison highlighted files that were either present exclusively in one dump or differed between the clean and infected systems.

```
kali@kali:/media/testShare$ diff clean_dump_output infected_dump_output/
Only in clean_dump_output: file.1000.0×8a096ca0.img
Only in clean_dump_output: file.1000.0×8a097520.img
Only in infected_dump_output/: file.1004.0×81e1c3b8.vacb
Only in infected_dump_output/: file.1004.0×81e1c7e0.vacb
Only in infected_dump_output/: file.1004.0×81e1c918.vacb
Only in infected_dump_output/: file.1004.0×81e2ea50.img
Only in infected_dump_output/: file.1004.0×81e313b8.img
Only in infected_dump_output/: file.1004.0×81e33310.img
Only in infected_dump_output/: file.1004.0×81e339c0.img
Only in infected_dump_output/: file.1004.0×81e79918.vacb
Only in infected_dump_output/: file.1004.0×81e7f7e0.img
Only in infected_dump_output/: file.1004.0×81e81008.vacb
Only in infected_dump_output/: file.1004.0×81e831d8.img
Only in infected_dump_output/: file.1004.0×81e83508.img
Only in infected_dump_output/: file.1004.0×81e83838.img
Only in infected_dump_output/: file.1004.0×81e86198.dat
Only in infected_dump_output/: file.1004.0×81e867f0.dat
Only in infected_dump_output/: file.1004.0×81e86a48.dat
Only in infected_dump_output/: file.1004.0×81e9e3b8.img
Only in infected_dump_output/: file.1004.0×81e9e7e0.img
Only in infected_dump_output/: file.1004.0×81ea0628.img
```

Figure 23 Output of both the dumps (diff clean_dump_output infected_dump_output/)

So, we selected a file that was exclusively in the infected dump for a further analysis. The file name is file.1004.0x81e7f7e0.img. Next we used stat command on the file.

```
kali@kali:/media/testShare$ stat ./infected_dump_output/file.1004.0×81e7f7e0.img
  File: ./infected_dump_output/file.1004.0×81e7f7e0.img
  Size: 79872           Blocks: 160        IO Block: 1048576 regular file
Device: 2eh/46d Inode: 154         Links: 1
Access: (0770/-rwxrwx---)  Uid: (    0/    root)   Gid: (  998/  vboxsf)
Access: 2024-11-25 14:08:36.582210000 +0000
Modify: 2024-11-25 14:08:36.582210000 +0000
Change: 2024-11-25 14:08:36.582210000 +0000
 Birth: -
```

Figure 24 stat ./infected_dump_output/file.1004.0x81e7f7e0.img

This output confirms that the extracted file is 79872 bytes in size and has standard access permissions. The timestamps for access, modification, and metadata change are identical, reflecting the moment the file was extracted. Next we used the file command to check the file type.

```
kali@kali:/media/testShare$ file ./infected_dump_output/file.1004.0×81e7f7e0.img
./infected_dump_output/file.1004.0×81e7f7e0.img: PE32 executable (DLL) (console) Intel 80386, for MS Windows
```

Figure 25 File command file ./infected_dump_output/file.1004.0x81e7f7e0.img

The file is identified as a PE32 executable (DLL), indicating it is a Windows Dynamic Link Library designed for Intel 80386 architecture. This confirms the file's executable nature and its compatibility with 32-bit Windows systems. Next we ran strings command to find anything suspicious in it.

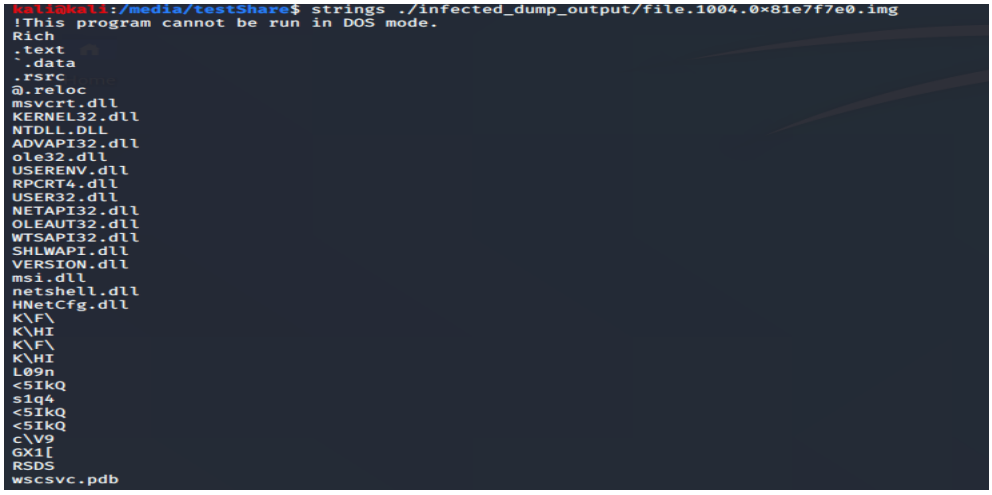


Figure 26 String command strings ./infected_dump_output/file.1004.0x81e7f7e0.img

The output of the string command shows the DLL dependencies, such as msvcrt.dll, KERNEL32.dll, ADVAPI32.dll, and RPCRT4.dll, highlight that the file has capabilities for file handling, registry interaction, and remote procedure calls. The reference to ServiceMain and SvchostPushServiceGlobals suggests the file is likely designed to operate as a service. The presence of wscsvc.pdb indicates the original PDB (debugging symbol file), which might help trace the origin or purpose of this DLL.

3. Recover the command history and explain each command (including input and output) that you can find inside it. (10%)

Command history refers to the record of commands executed in a command-line interface, such as cmd.exe, during an active session. It allows us to see what actions were performed by a user or a script at the time the memory was captured.[28]

To recover and analyse command history, two commands will be used:

- **consoles**: This command extracts the active command history from console processes like cmd.exe, showing executed commands, process IDs, and their sequence during the memory capture.
- **cmdscan**: This command scans memory to recover residual or deleted command history, providing insights into commands that may not appear in active sessions.

The Volatility "consoles" command was executed on the clean dump to extract the command history associated with active console processes.[29]

Explanation of the command:

- volatility: Invokes the Volatility Framework, which is used for memory forensics analysis.[30]
- -f windowCW2s.raw: Specifies the memory dump file (windowCW2s.raw) to be analysed.
- --profile=WinXPSP3x86: Specifies the operating system profile for the analysis. In this case: WinXPSP3x86 indicates Windows XP Service Pack 3, 32-bit.
- consoles: This plugin extracts the command history from console sessions (e.g., Command Prompt).

The screenshot reveals commands executed within the csrss.exe process (PID 616). These include navigation commands such as cd to change directories and dir to list directory contents. Notably, a command involving the winpmem_v3.3.rc3.exe application was executed to dump memory into a raw format file (windowCW2s.raw).[31]

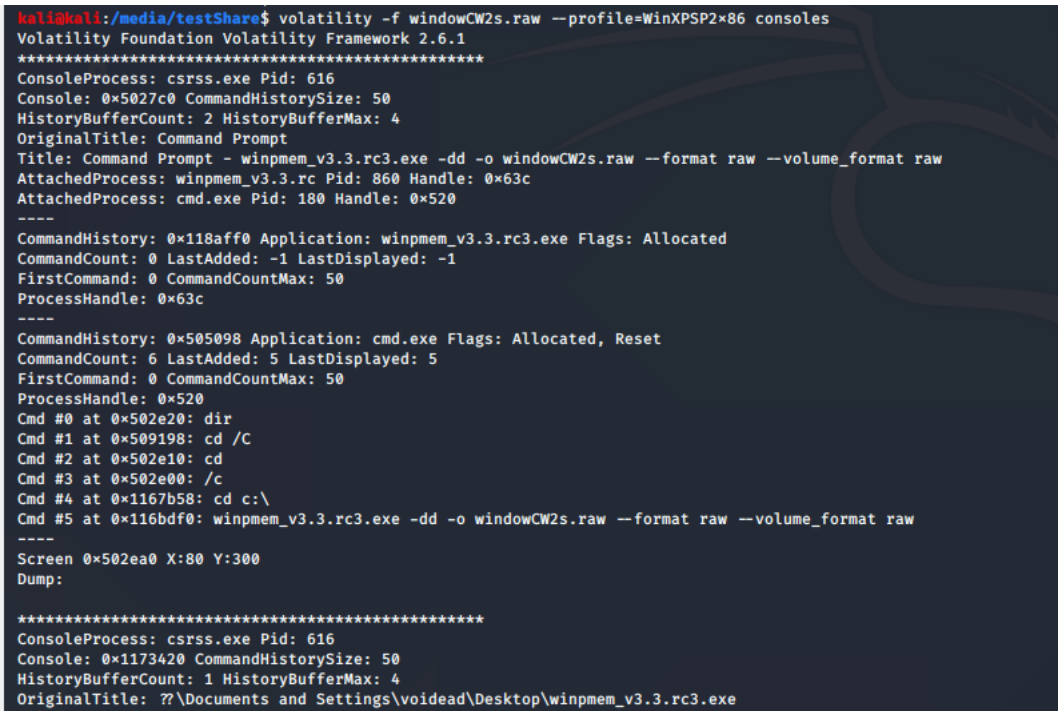


Figure 27 Clean dump console command

Below is a table summarizing the commands extracted from the memory dump as shown in the provided Volatility output, along with their inputs, outputs, and notes:

Command	Input	Output	Notes
dir	User executed dir	Displays names of files and directories, with details like size, date, and time of mod.	Used to list the contents of the current directory.
cd /C	User attempted to change directory to /C	Likely an error, as /C is not a valid directory path in Windows.	Invalid directory path.
cd	User ran cd without arguments	Prints the current directory path (e.g., C:\Users\Username).	Shows the current working directory.
/c	User input /c which is incomplete or mistyped	Likely an error message indicating invalid syntax.	Probably a partial command or incorrect input.
cd c:	User navigated to the root directory with cd c:\	Changes the current working directory to C:\.	Moves to the root directory of the C: drive.
winpmem_v3.3.rc3.exe -dd -o windowCW2s.raw --format raw --volume_format raw	User executed winpmem tool to capture a memory dump	Creates windowCW2s.raw file in raw format, capturing system memory state.	Used for forensic memory acquisition.

Table 4 Explanation of the commands extracted from command history

Now that we have successfully analysed the command history from the clean dump, we will proceed to run the **consoles** and **cmdscan** commands on the infected dump.[32]

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 cmdscan
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 console
Volatility Foundation Volatility Framework 2.6.1
```

Figure 18Analysing command history in infected dump (WinXPSP3x86)

After running the commands there are no results. It's possible that no results are appearing because the memory image does not contain the necessary structures that cmdscan and consoles rely on to extract command history. This could happen if no command prompt was open at the time the memory was captured, or if the system's command history buffers were never populated, cleared, or overwritten.[33]

Additionally, if the memory dump is corrupted or does not accurately reflect the state of the system at acquisition, these plugins may fail to locate the expected data. Even with different profiles, the absence of console artifacts could simply mean that there were no relevant console sessions or command inputs recorded in the memory at that point.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 cmdscan
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 console
Volatility Foundation Volatility Framework 2.6.1
```

Figure 29Analysing command history in infected dump (WinXPSP2x86)

Additional checks for command history

We checked the pslist plugin for the infected memory dump to identify active or terminated processes, specifically searching for the presence of a command processor (cmd.exe). The results indicate that there was no cmd.exe process running at the time.[34]

Next, we ran strings command for cmd.exe. Explanation of the command is:

- **strings**: Extracts human-readable text from binary files.
- **-a**: Ensures the entire file is scanned.
- **-td**: Displays the decimal offset of the string in the file.
- **grep -i "cmd.exe"**: Filters for case-insensitive matches of cmd.exe.

```
174174111 ComSpec=C:\WINDOWS\system32\cmd.exe
174176792 ComSpec=C:\WINDOWS\system32\cmd.exe
175436390 WiC:\WINDOWS\system32\cmd.exe
175980447 ComSpec=C:\WINDOWS\system32\cmd.exe
175983128 ComSpec=C:\WINDOWS\system32\cmd.exe
176141351 ComSpec=C:\WINDOWS\system32\cmd.exe
176142800 ComSpec=C:\WINDOWS\system32\cmd.exe
187187200 ystem32\cmd.exe
187190144 ComSpec=C:\WINDOWS\system32\cmd.exe
187872372 ComSpec=C:\WINDOWS\system32\cmd.exe
187874032 ComSpec=C:\WINDOWS\system32\cmd.exe
188198892 ComSpec=C:\WINDOWS\system32\cmd.exe
188201752 ComSpec=C:\WINDOWS\system32\cmd.exe
188252052 cmd.exe
188567532 ComSpec=C:\WINDOWS\system32\cmd.exe
188570392 ComSpec=C:\WINDOWS\system32\cmd.exe
188817311 ComSpec=C:\WINDOWS\system32\cmd.exe
188819872 ComSpec=C:\WINDOWS\system32\cmd.exe
192091175 ComSpec=C:\WINDOWS\system32\cmd.exe
192092528 ComSpec=C:\WINDOWS\system32\cmd.exe
193240991 ComSpec=C:\WINDOWS\system32\cmd.exe
193505696 ComSpec=C:\WINDOWS\system32\cmd.exe
198553600 INDOWS\system32\cmd.exe
```

Figure 30 Strings command for cmd.exe

During the investigation of the infected memory dump, the strings command was used to locate references to cmd.exe. The results show multiple instances of cmd.exe, including paths such as:

- ComSpec=C:\WINDOWS\system32\cmd.exe: This indicates the environment variable ComSpec, which typically points to the Command Prompt's executable file.
- WiC:\WINDOWS\system32\cmd.exe: This path is highly suspicious because it starts with WiC, which deviates from the standard C:\WINDOWS\system32\cmd.exe. It could indicate an obfuscated or tampered path.
- system32\cmd.exe: This incomplete path lacks a drive letter, which is unusual and potentially indicative of a tampered configuration or improperly referenced executable.

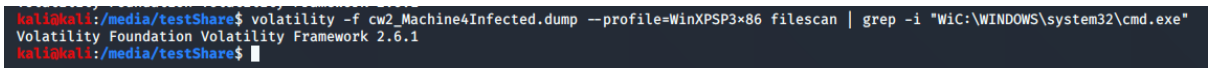


Figure 31 filescan command volatility -f cw2_Machine4Infected.dump –profile=WinXPSP3x86 filescan | grep -i

The screenshot shows that the filescan command did not return any results for the path WiC:\WINDOWS\system32\cmd.exe when searching in the infected dump using Volatility. This means that file not found in Memory Structures:

- The WiC:\WINDOWS\system32\cmd.exe path is not present in the file object structures scanned by Volatility.
- This could indicate that the path is not an actual file but possibly a residual artifact in memory, or it was deliberately obfuscated or removed.

With the command history analysis completed, the next step in the investigation focuses on recovering all strings from both memory dumps.

4. Recover all of the strings of the two memory dumps. How many strings are associated with each process and how many are in free memory? (10%)

Strings recovery involves extracting readable text from binary data, such as memory dumps, to identify useful information like file paths, URLs, commands, or registry keys. The number of strings associated with each process depends on the activity of the process, its allocated memory, and the loaded modules or libraries. Strings found in free memory often originate from previously terminated processes, unloaded DLLs, or memory areas that have not yet been overwritten, making them valuable for uncovering remnants of past activity or evidence of malicious actions.[35]

To begin, the strings command-line tool was used to extract readable text from the binary memory dumps. This tool scans the dump files and retrieves printable ASCII characters, providing a view of text fragments stored in memory. The strings for the

clean memory dump (windowCW2s.raw) were first displayed in the terminal using the command strings windowCW2s.raw | more.

```
kali@kali:/media/testShare$ strings windowCW2s.raw | more
container.description
aff4://237ee209-b52d-4948-8e97-de58a80743b8PK
information.turtle
@base <aff4://237ee209-b52d-4948-8e97-de58a80743b8> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix aff4: <http://aff4.org/Schema#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix memory: <http://aff4.org/Schema#memory/> .
information.turtlePK
PhysicalMemory/information.yamlPK
container.descriptionPK
version.txtPK
aff4://237ee209-b52d-4948-8e97-de58a80743b8
fSfSP
fPfRfQfS
f[fYfZfX
PfQ3
fXfPf;
fCfC
fPfSfQf
fHf3
fYf[fX
jXhm
rM;F
<uCf
fWfVfS
```

Figure 42 Strings command line tool for the clean memory dump (windowCW2s.raw)

This allowed an initial real-time inspection of the strings, where the output was displayed one screen at a time, making it easier to examine the text for any immediate anomalies or clues. For a quick overview, the head command was used, as in strings windowCW2s.raw | head -n 40, which displayed the first 40 lines of strings in the terminal.[36]

```
kali@kali:/media/testShare$ strings windowCW2s.raw | head -n 40
container.description
aff4://237ee209-b52d-4948-8e97-de58a80743b8PK
information.turtle
@base <aff4://237ee209-b52d-4948-8e97-de58a80743b8> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix aff4: <http://aff4.org/Schema#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix memory: <http://aff4.org/Schema#memory/> .
information.turtlePK
PhysicalMemory/information.yamlPK
container.descriptionPK
version.txtPK
aff4://237ee209-b52d-4948-8e97-de58a80743b8
fSfSP
fPfRfQfS
f[fYfZfX
PfQ3
fXfPf;
fCfC
fPfSfQf
fHf3
fYf[fX
jXhm
rM;F
<uCf
fWfVfS
PAMS
f-PAMSf
f[f^f_
fUfSfVfWf
fUfSfVfWf
fXf[
f_f^f[f]fZfh
fUfSfVfWf
fXf[
f_f^f[f]fZfh
fUfSfVfWf
fXf[
f_f^f[f]fZfh
fUfSfVfWf
```

Figure 53 Strings head command for the clean memory dump (windowCW2s.raw)

The strings extracted from the memory dump, as seen in the screenshot below reveal several artifacts. Notably, there are boot or partition-related messages such as "Invalid partition table," "Loading operating system," and "Missing operating system," which suggest potential tampering with the system's boot process or partition table. These could indicate remnants of a corrupted or modified boot sector, possibly caused by malware or system misconfiguration. Additionally, other fragments like "PipRea" and "g Resource read" appear to be partial error messages or debug logs, which might originate from legitimate processes or leftover data in memory.

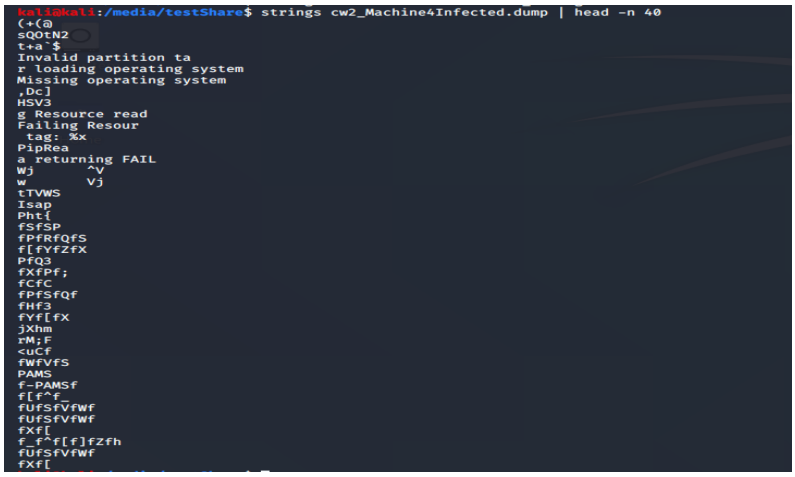


Figure 64 Strings extracted from the Infected dump

After visually inspecting the strings, the full output was redirected to a text file for further analysis. Using the command strings windowCW2s.raw > clean_strings.txt, all strings from the clean memory dump were saved into a file named clean_strings.txt. This approach ensures that all extracted strings could be revisited and analyzed without the need to repeatedly scan the memory dump.[37]

```
kali@kali:/media/testShare$ strings windowCW2s.raw > clean_strings.txt
```

Figure 75 Clean dump strings

The same process was applied to the infected memory dump (infected_dump.raw), saving the output into infected_strings.txt. This systematic method allowed for consistent comparison between the clean and infected dumps.

```
kali@kali:/media/testShare$ strings cw2_Machine4Infected.dump > infected_strings.txt
```

Figure 86 Infected dump strings

After extracting the strings from the clean and infected memory dumps into clean_strings.txt and infected_strings.txt, the next step is to determine the total number of strings contained in each file.

The wc -l command was used to count the total number of lines in each file, which represents the total number of strings extracted from the clean and infected memory dumps.

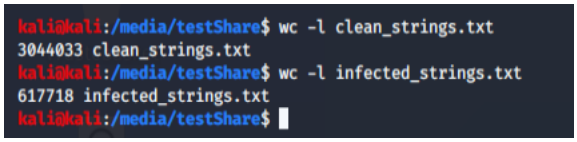


Figure 97 Total number of strings extracted from both dumps

Clean Memory Dump (clean_strings.txt):
Contains 3,044,033 strings.

Infected Memory Dump (infected_strings.txt):
Contains 617,718 strings.

The infected memory dump has significantly fewer strings than the clean memory dump. This unusual reduction may indicate that certain processes or modules have been removed, cleared, or overwritten in the infected system's memory.

Strings Recovery from Processes

After extracting the strings for each process in the clean and infected memory dumps, the next step involved determining the total number of strings associated with each process. The strings command-line tool was used to scan each memory dump file extracted using Volatility's memdump plugin. The output was saved into individual text files for further analysis. The commands that were used to acquire strings recovery from processes are mentioned in the table below.

Command	Explanation
mkdir clean_process_dumps	- **mkdir** creates a new directory. - Here, clean_process_dumps is the directory to store dumped memory regions of clean processes.
awk '{print $3}' clean_pslist.txt	- **awk** is used to extract specific columns from a file. - '{print $3}' extracts the 3rd column (PIDs) from clean_pslist.txt.
grep -E '^[0-9]+$'	- **grep** filters the output. - -E enables extended regular expressions. - '^[0-9]+$' matches only numeric values (valid PIDs).
for pid in $(...); do ... done	- A **for loop** runs a command for each value in the list.

	- Iterates through the list of PIDs extracted using awk and grep.
volatility -f windowCW2s.raw --profile=WinXPSP3x86 memdump --pid=$pid -D clean_process_dumps	- **volatility** is a memory forensics tool. - **-f windowCW2s.raw** specifies the memory dump file. - **--profile=WinXPSP3x86** specifies the OS profile (Windows XP SP3 32-bit). - **memdump** dumps memory regions of the specified process. - **--pid=$pid** specifies the process ID. - **-D clean_process_dumps** saves the dumped memory files to the clean_process_dumps directory.
strings clean_process_dumps/*.dmp > clean_process_strings/strings_${pid}.txt	- **strings** extracts readable ASCII text from binary files (here, process memory dumps). - clean_process_dumps/*.dmp specifies all dumped memory files. - The > operator redirects the extracted strings to a file named strings_${pid}.txt in the clean_process_strings directory.
wc -l clean_process_strings/*.txt	- **wc** (word count) counts lines, words, and characters in files. - **-l** counts the number of lines (strings) in each .txt file. - This helps determine the total number of strings for each process.
volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 memdump --pid=$pid -D infected_process_dumps	- Same as the clean dump version but applied to the infected memory dump (cw2_Machine4Infected.dump).
strings infected_process_dumps/*.dmp > infected_process_strings/strings_${pid}.txt	- Extracts strings from the infected process memory dumps and saves them in the infected_process_strings directory.

Table 5 Commands used to acquire strings recovery from processes

The command was executed successfully, and the memory of each process was dumped one by one. As shown in the screenshot below, Volatility systematically created memory dump files for each process. Each memory dump file was saved into the clean_process_dumps directory for further analysis.[38]

The output logs from the Volatility execution confirm the successful dumping of process memory regions. The structured naming of the files (e.g., pid.<PID>.dmp) ensures that each process's memory can be easily identified and analysed.

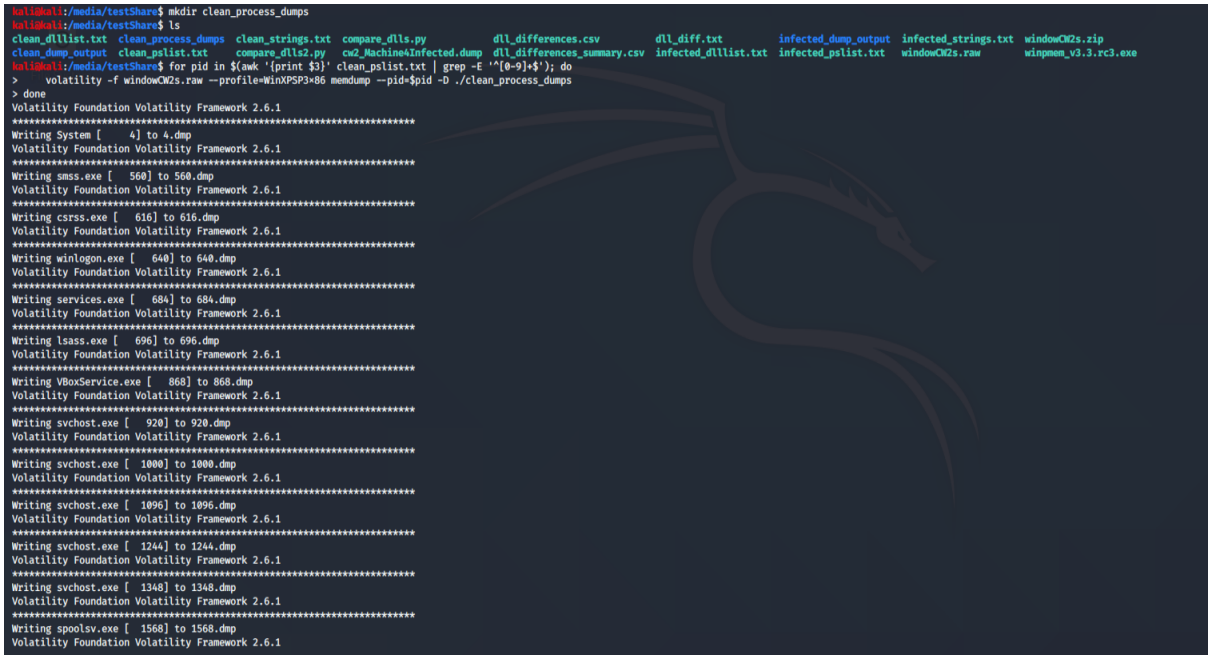


Figure 108 Clean dump processes

The same systematic approach was applied to the **infected memory dump** to extract the memory regions for each process. This ensured consistency in the analysis for comparison between the clean and infected dumps.[39]

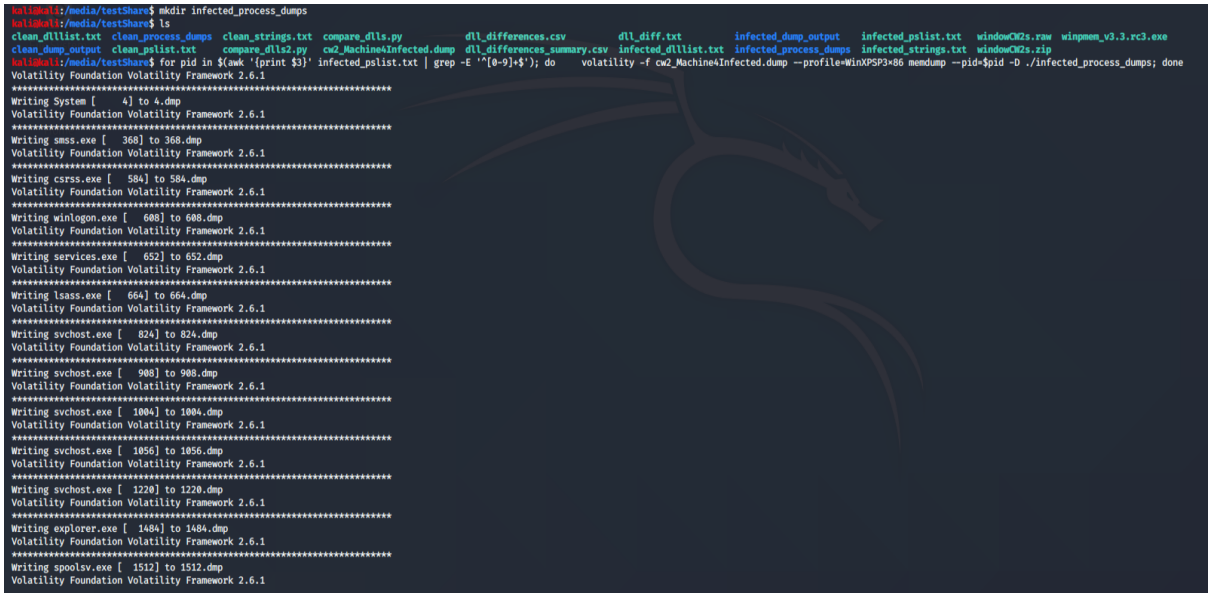


Figure 119 Infected dump processes

After successfully dumping the memory regions for each process from the clean memory dump, the next step involved extracting readable text (strings) from these memory dump files. This was done using the strings command. The command successfully created individual text files for each process memory dump in the clean_process_strings directory. The naming format (strings_<PID>.txt) ensures that each file corresponds to a specific process, making it easy to organize and analyse.

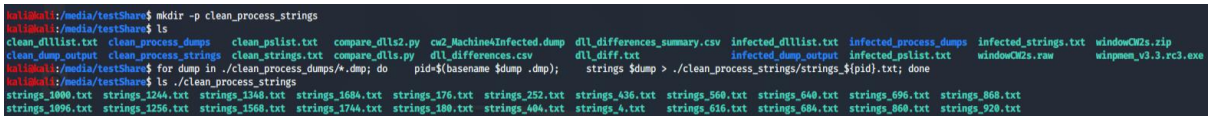


Figure 120 Extracting readable text from clean memory dumps

The same method was applied to the **infected process dumps** as shown in the screenshot. A for loop iterated through each memory dump file in the infected_process_dumps directory, extracting readable text using the strings command. The output was saved into individual files in the infected_process_strings directory, named in the format strings_<PID>.txt

Figure 131 Extracting readable text from infected memory dumps

To determine the **number of strings** extracted for each process in both the **clean** and **infected** dumps, we used the wc -l command. This command counts the total number of lines in each file, where each line represents one string. By specifying clean_process_strings/*.txt, the command targets all text files within the clean_process_strings directory.[40]

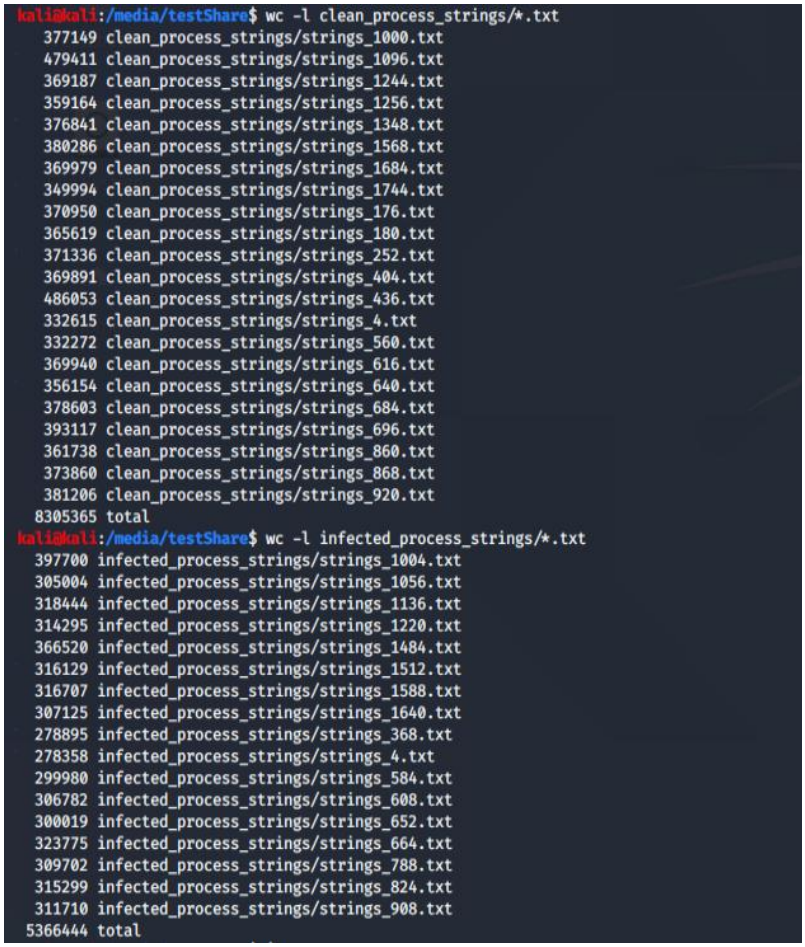


Figure 142 Number of strings extracted for each process in both dumps

The table below presents the number of strings for each process in both the clean and infected dumps:

Process (PID)	Clean Dump Strings	Infected Dump Strings
4	332,615	278,358
176	370,950	-
180	365,619	-
252	371,336	-
368	-	278,895
404	369,891	-
436	486,053	-
560	332,272	-
584	-	299,980
608	-	306,782
640	356,154	-
652	-	300,019
684	378,603	-
696	393,117	-
788	-	309,702
860	361,738	-
868	373,860	-
920	381,206	-
1000	377,149	-
1004	-	397,700
1056	-	305,004
1096	479,411	-
1136	-	318,444
1220	-	314,295
1244	369,187	-
1256	359,164	-
1348	376,841	-

1484	-	366,520
1512	-	316,129
1568	380,286	-
1588	-	316,707
1640	-	307,125
1684	369,979	-
1744	349,994	-
824	-	315,299
908	-	311,710
Total	**8,305,365**	**5,366,444**

Table 4 Number of strings for each process in both dumps

Next step is to analyse free memory and determine the number of strings associated with it, we used vaddump plugin was used to extract free memory regions from both the clean and infected memory dumps. The command vaddump identifies and extracts unallocated memory areas in memory that were previously used but are now freed into separate files. The screenshot below shows vaddump used for clean dump.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 vaddump -D clean_free_memory
Volatility Foundation Volatility Framework 2.6.1
Pid      Process            Start      End        Result
-------- ------------------ ---------- ---------- ------
       4 System             0x00010000 0x00033fff clean_free_memory/System.a45c830.0x00010000-0x00033fff.dmp
       4 System             0x7c900000 0x7c9b1fff clean_free_memory/System.a45c830.0x7c900000-0x7c9b1fff.dmp
       4 System             0x00060000 0x00060fff clean_free_memory/System.a45c830.0x00060000-0x00060fff.dmp
       4 System             0x00070000 0x0016ffff clean_free_memory/System.a45c830.0x00070000-0x0016ffff.dmp
     560 smss.exe           0x48580000 0x4858efff clean_free_memory/smss.exe.a212c08.0x48580000-0x4858efff.dmp
     560 smss.exe           0x00000000 0x000fffff clean_free_memory/smss.exe.a212c08.0x00000000-0x000fffff.dmp
     560 smss.exe           0x00100000 0x00100fff clean_free_memory/smss.exe.a212c08.0x00100000-0x00100fff.dmp
     560 smss.exe           0x00110000 0x00110fff clean_free_memory/smss.exe.a212c08.0x00110000-0x00110fff.dmp
     560 smss.exe           0x00120000 0x0015ffff clean_free_memory/smss.exe.a212c08.0x00120000-0x0015ffff.dmp
     560 smss.exe           0x00160000 0x0025ffff clean_free_memory/smss.exe.a212c08.0x00160000-0x0025ffff.dmp
     560 smss.exe           0x00260000 0x0026ffff clean_free_memory/smss.exe.a212c08.0x00260000-0x0026ffff.dmp
     560 smss.exe           0x00270000 0x002affff clean_free_memory/smss.exe.a212c08.0x00270000-0x002affff.dmp
     560 smss.exe           0x002b0000 0x002efff clean_free_memory/smss.exe.a212c08.0x002b0000-0x002efff.dmp
     560 smss.exe           0x002f0000 0x002f0fff clean_free_memory/smss.exe.a212c08.0x002f0000-0x002f0fff.dmp
     560 smss.exe           0x7c900000 0x7c9b1fff clean_free_memory/smss.exe.a212c08.0x7c900000-0x7c9b1fff.dmp
     560 smss.exe           0x7ffb0000 0x7ffd3fff clean_free_memory/smss.exe.a212c08.0x7ffb0000-0x7ffd3fff.dmp
     560 smss.exe           0x7ffd8000 0x7ffd8fff clean_free_memory/smss.exe.a212c08.0x7ffd8000-0x7ffd8fff.dmp
     560 smss.exe           0x7ffdf000 0x7ffdffff clean_free_memory/smss.exe.a212c08.0x7ffdf000-0x7ffdffff.dmp
     560 smss.exe           0x7ffde000 0x7ffdefff clean_free_memory/smss.exe.a212c08.0x7ffde000-0x7ffdefff.dmp
     560 smss.exe           0x7ffdd000 0x7ffddfff clean_free_memory/smss.exe.a212c08.0x7ffdd000-0x7ffddfff.dmp
     616 csrss.exe          0x01010000 0x0104ffff clean_free_memory/csrss.exe.a2c1020.0x01010000-0x0104ffff.dmp
     616 csrss.exe          0x00e00000 0x00e3ffff clean_free_memory/csrss.exe.a2c1020.0x00e00000-0x00e3ffff.dmp
     616 csrss.exe          0x00cc0000 0x00ccffff clean_free_memory/csrss.exe.a2c1020.0x00cc0000-0x00ccffff.dmp
     616 csrss.exe          0x00b80000 0x00b8ffff clean_free_memory/csrss.exe.a2c1020.0x00b80000-0x00b8ffff.dmp
     616 csrss.exe          0x007c0000 0x0081dfff clean_free_memory/csrss.exe.a2c1020.0x007c0000-0x0081dfff.dmp
     616 csrss.exe          0x00630000 0x0066ffff clean_free_memory/csrss.exe.a2c1020.0x00630000-0x0066ffff.dmp
     616 csrss.exe          0x00460000 0x00460fff clean_free_memory/csrss.exe.a2c1020.0x00460000-0x00460fff.dmp
     616 csrss.exe          0x00270000 0x00285fff clean_free_memory/csrss.exe.a2c1020.0x00270000-0x00285fff.dmp
     616 csrss.exe          0x00110000 0x00110fff clean_free_memory/csrss.exe.a2c1020.0x00110000-0x00110fff.dmp
     616 csrss.exe          0x00000000 0x0009ffff clean_free_memory/csrss.exe.a2c1020.0x00000000-0x0009ffff.dmp
     616 csrss.exe          0x00100000 0x00100fff clean_free_memory/csrss.exe.a2c1020.0x00100000-0x00100fff.dmp
```

Figure 153 Analysation of free memory in clean memory dump

The same was done on infected dump as it shows in the screenshot below.

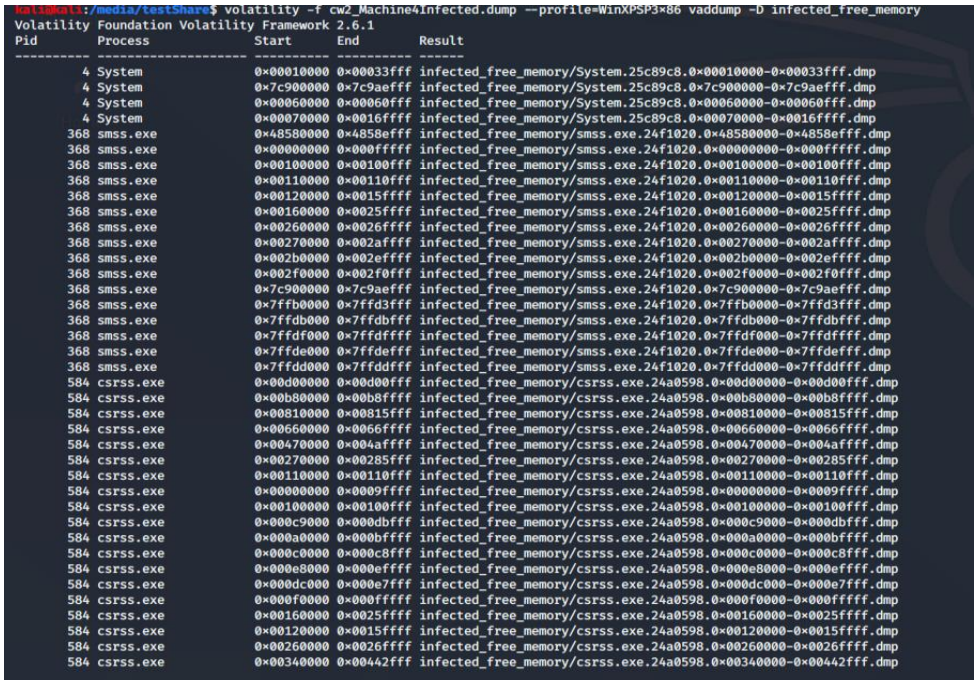


Figure 164 Analysation of free memory in infected memory dump

Next, the strings command was executed on the extracted free memory files to identify readable text. The output was redirected into clean_free_strings.txt and infected_free_strings.txt files.

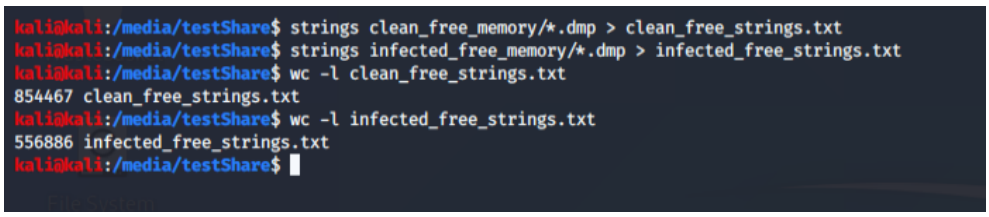


Figure 175 Redirection of the output

Finally, the wc -l command was used to count the total number of strings extracted from the free memory for both the clean and infected dumps. This step provided a numerical summary of the strings, where the clean free memory contained **854,467 strings**, and the infected free memory contained **556,886 strings**.

5) Recover the timelining of the two memory dumps with as much information as you can. How many messages are associated with each process? When did each process start? (10%)

Memory dumps are snapshots of a system's memory at a specific point in time. They are often used in debugging and forensics to understand the state of a system, identify software bugs, or investigate security incidents. By analysing memory dumps, we can gain insights into the processes running on the system, their memory usage, and the messages they have exchanged.

Process Timeline and Message Count Analysis

For the recovery of the timeline of the two memory dumps and determination of the number of messages associated with each process, we need to analyse the contents of the dumps using specialized tools.[41]

To recover the timelining of the two memory dumps, we first examined the pslist outputs for both the clean and infected memory dumps, which had already been saved in .txt files as clean_pslist.txt and infected_pslist.txt. These files contain detailed information about active processes, including their Process IDs (PIDs), Parent Process IDs (PPIDs), number of threads, handles, and start times.

```
kali@kali:/media/testShare$ cat clean_pslist.txt
Offset(V)  Name                    PID   PPID   Thds     Hnds   Sess  Wow64 Start                          Exit
---------- -------------------- ------ ------ ------ -------- ------ ------ ------------------------------ ------------------------------
0x8a25c830 System                    4      0     66      266 ------      0
0x8a012c08 smss.exe                560      4      3       19 ------      0 2024-11-14 09:36:51 UTC+0000
0x8a0c1020 csrss.exe               616    560     12      368      0      0 2024-11-14 09:36:52 UTC+0000
0x89fe47e8 winlogon.exe            640    560     20      560      0      0 2024-11-14 09:36:52 UTC+0000
0x89ff5c08 services.exe            684    640     17      305      0      0 2024-11-14 09:36:52 UTC+0000
0x8a021da0 lsass.exe               696    640     22      367      0      0 2024-11-14 09:36:52 UTC+0000
0x89cb6518 VBoxService.exe         868    684      9      130      0      0 2024-11-14 09:36:52 UTC+0000
0x89ffe8e0 svchost.exe             920    684     22      237      0      0 2024-11-14 15:06:54 UTC+0000
0x8a004450 svchost.exe            1000    684     10      266      0      0 2024-11-14 15:06:54 UTC+0000
0x8a0121c0 svchost.exe            1096    684     59     1161      0      0 2024-11-14 15:06:54 UTC+0000
0x89c177a8 svchost.exe            1244    684      5       83      0      0 2024-11-14 15:06:54 UTC+0000
0x8a016538 svchost.exe            1348    684     11      185      0      0 2024-11-14 15:06:54 UTC+0000
0x89bebd00 spoolsv.exe            1568    684     12      129      0      0 2024-11-14 15:06:56 UTC+0000
0x8a0a3500 svchost.exe            1684    684      4      111      0      0 2024-11-14 15:07:03 UTC+0000
0x8a037a78 IPROSetMonitor.        1744    684      2       44      0      0 2024-11-14 15:07:03 UTC+0000
0x8a06b5a8 alg.exe                 404    684      6      111      0      0 2024-11-14 15:07:07 UTC+0000
0x89b02ae8 wscntfy.exe            1256   1096      1       31      0      0 2024-11-14 15:15:40 UTC+0000
0x89c948c8 explorer.exe            436    416     14      502      0      0 2024-11-14 15:15:40 UTC+0000
0x89b4da28 VBoxTray.exe            252    436     13      126      0      0 2024-11-14 15:15:41 UTC+0000
0x89baada0 wuauclt.exe             176   1096      3      112      0      0 2024-11-14 15:15:42 UTC+0000
0x89d08020 cmd.exe                 180   1096      1       33      0      0 2024-11-14 15:28:44 UTC+0000
0x89b7dda0 winpmem_v3.3.rc         860    180      3       36      0      0 2024-11-14 15:32:06 UTC+0000
kali@kali:/media/testShare$ cat infected_pslist.txt
Offset(V)  Name                    PID   PPID   Thds     Hnds   Sess  Wow64 Start                          Exit
---------- -------------------- ------ ------ ------ -------- ------ ------ ------------------------------ ------------------------------
0x823c89c8 System                    4      0     53      240 ------      0
0x822f1020 smss.exe                368      4      3       19 ------      0 2012-07-22 02:42:31 UTC+0000
0x822a0598 csrss.exe               584    368      9      326      0      0 2012-07-22 02:42:32 UTC+0000
0x82298700 winlogon.exe            608    368     23      519      0      0 2012-07-22 02:42:32 UTC+0000
0x81e2ab28 services.exe            652    608     16      243      0      0 2012-07-22 02:42:32 UTC+0000
0x81e2a3b8 lsass.exe               664    608     24      330      0      0 2012-07-22 02:42:32 UTC+0000
0x82311360 svchost.exe             824    652     20      194      0      0 2012-07-22 02:42:33 UTC+0000
0x81e29ab8 svchost.exe             908    652      9      226      0      0 2012-07-22 02:42:33 UTC+0000
0x823001d0 svchost.exe            1004    652     64     1118      0      0 2012-07-22 02:42:33 UTC+0000
0x821dfda0 svchost.exe            1056    652      5       60      0      0 2012-07-22 02:42:33 UTC+0000
0x82295650 svchost.exe            1220    652     15      197      0      0 2012-07-22 02:42:35 UTC+0000
0x821dea70 explorer.exe           1484   1464     17      415      0      0 2012-07-22 02:42:36 UTC+0000
0x81eb17b8 spoolsv.exe            1512    652     14      113      0      0 2012-07-22 02:42:36 UTC+0000
0x81e7bda0 reader_sl.exe          1640   1484      5       39      0      0 2012-07-22 02:42:36 UTC+0000
0x820e8da0 alg.exe                 788    652      7      104      0      0 2012-07-22 02:43:01 UTC+0000
0x821fcda0 wuauclt.exe            1136   1004      8      173      0      0 2012-07-22 02:43:46 UTC+0000
0x8205bda0 wuauclt.exe            1588   1004      5      132      0      0 2012-07-22 02:44:01 UTC+0000
```

Figure 186 Examination of pslist outputs for both the dumps

By analysing and comparing these outputs, we identified key processes, their start times, and any differences between the clean and infected systems. The information we got from the those files are mentioned in the table below:

Process Name	PID (Clean)	PID (Infected)	Start Time (Clean)	Start Time (Infected)
System	4	4	-	-
smss.exe	560	368	2024-11-14 09:36:51 UTC+0000	2012-07-22 02:42:31 UTC+0000
csrss.exe	616	584	2024-11-14 09:36:52 UTC+0000	2012-07-22 02:42:32 UTC+0000
winlogon.exe	640	608	2024-11-14 09:36:52 UTC+0000	2012-07-22 02:42:32 UTC+0000
services.exe	684	652	2024-11-14 09:36:52 UTC+0000	2012-07-22 02:42:32 UTC+0000
lsass.exe	696	664	2024-11-14 09:36:52 UTC+0000	2012-07-22 02:42:32 UTC+0000
VBoxService.exe	868	-	2024-11-14 09:36:52 UTC+0000	-
svchost.exe	Various	Various	Multiple times	Multiple times
explorer.exe	436	1484	2024-11-14 15:15:40 UTC+0000	2012-07-22 02:42:36 UTC+0000
alg.exe	404	788	2024-11-14 15:07:07 UTC+0000	2012-07-22 02:43:01 UTC+0000

wuauclt.exe	176, 1096	1136	2024-11-14 15:15:42 UTC+0000	2012-07-22 02:43:46 UTC+0000
spoolsv.exe	1568	1512	2024-11-14 15:06:56 UTC+0000	2012-07-22 02:42:36 UTC+0000
reader_sl.exe	-	1640	-	2012-07-22 02:42:36 UTC+0000

Table 5 Analysing and comparison of the outputs

After acquiring the active time of each process from the pslist outputs, the next step involves using the **handles** plugin in Volatility. The **handles** plugin which lists all handles associated with active processes in the memory dump. Handles are references to system resources such as files, registry keys, events, mutexes, or other objects that a process interacts with.[42]

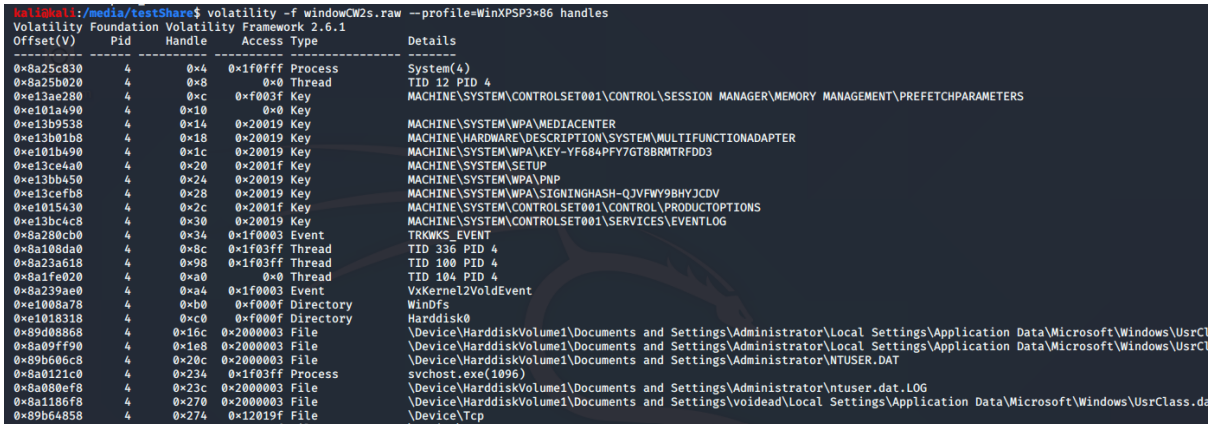


Figure 197 List of all the handles associated with active processes in clean dump

The same plugin was used to the infected dump as it shows in the screenshot below.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 handles
Volatility Foundation Volatility Framework 2.6.1
Offset(V)     Pid     Handle     Access Type            Details
---------- ------ ---------- ---------- --------------- -------
0x823c89c8      4        0x4   0x1f0fff Process         System(4)
0x823c8308      4        0x8        0x0 Thread          TID 12 PID 4
0xe1036638      4        0xc    0xf003f Key             MACHINE\SYSTEM\CONTROLSET001\CONTROL\SESSION MANAGER\MEMORY MANAGEMENT\PREFETCHPARAMETERS
0xe1011490      4       0x10        0x0 Key
0xe13bf390      4       0x14    0x2001f Key             MACHINE\SYSTEM\SETUP
0xe10365d0      4       0x18    0x20019 Key             MACHINE\HARDWARE\DESCRIPTION\SYSTEM\MULTIFUNCTIONADAPTER
0xe100f430      4       0x1c    0x20019 Key             MACHINE\SYSTEM\WPA\MEDIACENTER
0xe13c2430      4       0x20    0x20019 Key             MACHINE\SYSTEM\WPA\KEY-4F3B2RFXKC9C637882MBM
0xe1020c40      4       0x24    0x20019 Key             MACHINE\SYSTEM\WPA\PNP
0xe13e8430      4       0x28    0x20019 Key             MACHINE\SYSTEM\WPA\SIGNINGHASH-V44KQMCFXKQCTQ
0xe1013880      4       0x2c    0x2001f Key             MACHINE\SYSTEM\CONTROLSET001\CONTROL\PRODUCTOPTIONS
0xe13b7948      4       0x30    0x20019 Key             MACHINE\SYSTEM\CONTROLSET001\SERVICES\EVENTLOG
0x823c1870      4       0x34   0x1f0003 Event           TRKWKS_EVENT
0x82060220      4       0x84   0x12019f File            \Device\Gpc
0x823ab020      4       0x8c   0x1f03ff Thread          TID 96 PID 4
0xe101ead8      4       0x90    0x20019 Key             MACHINE\SYSTEM\CONTROLSET001\SERVICES\ACPI\PARAMETERS
0xe14c4198      4       0x98    0xf000f Directory       WinDfs
0x823e7210      4       0x9c   0x1f0003 Event           VxKernel2VoldEvent
0x823a9020      4       0xa0        0x0 Thread          TID 104 PID 4
0xe14a4c50      4       0xb8    0xf000f Directory       Harddisk0
0x82293158      4      0x298   0x1f0003 Event           PrefetchTracesReady
0x821a2028      4      0x29c   0x1f01ff File            \Device\Tcp
0x82063028      4      0x2b4   0x12019f File            \Device\Tcp
0x821c56e8      4      0x2b8   0x12019f File            \Device\NetBT_Tcpip_{2EF5B1E3-68FB-4BEF-A3E9-2367A890F7DC}
0x82221c20      4      0x324  0x2000003 File            \Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrC
0x82324020      4      0x328   0x1f03ff Thread          TID 268 PID 4
0x81ea2890      4      0x32c   0x1f03ff Thread          TID 284 PID 4
0x81ec26c8      4      0x330   0x1f01ff File            \Device\Tcp
0x821aef90      4      0x334        0x3 File            \Device\HarddiskVolume1\WINDOWS\system32\config\system.LOG
0x81e2a3b8      4      0x338      0x438 Process         lsass.exe(664)
0x8223c220      4      0x33c  0x2000003 File            \Device\HarddiskVolume1\WINDOWS\system32\config\default.LOG
```

Figure 208 List of all the handles associated with active processes in infected dump

The handles associated with each process in both the clean and infected memory dumps were extracted and saved into separate files for analysis files are called clean_handles.txt and infected_handles.txt.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP3x86 handles > clean_handles.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP3x86 handles > infected_handles.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$
```

Figure 219 Handles associated with specific processes in both the dumps

```
kali@kali:/media/testShare$ head clean_handles.txt
Offset(V)     Pid     Handle     Access Type            Details
---------- ------ ---------- ---------- --------------- -------
0x8a25c830      4        0x4   0x1f0fff Process         System(4)
0x8a25b020      4        0x8        0x0 Thread          TID 12 PID 4
0xe13ae280      4        0xc    0xf003f Key             MACHINE\SYSTEM\CONTROLSET001\CONTROL\SESSION MANAGER\MEMORY MANAGEMENT\PREFETCHPARAMETERS
0xe101a490      4       0x10        0x0 Key
0xe13b9538      4       0x14    0x20019 Key             MACHINE\SYSTEM\WPA\MEDIACENTER
0xe13b01b8      4       0x18    0x20019 Key             MACHINE\HARDWARE\DESCRIPTION\SYSTEM\MULTIFUNCTIONADAPTER
0xe101b490      4       0x1c    0x20019 Key             MACHINE\SYSTEM\WPA\KEY-YF684PFY7GT8BRMTRFDD3
0xe13ce4a0      4       0x20    0x2001f Key             MACHINE\SYSTEM\SETUP
```

Figure 220 Clean handles

To determine how many handles were associated with each process in the clean memory dump, the awk, sort, and uniq commands were combined and executed on the clean_handles.txt file. The following command was used:

- **NR > 1**: Skips the header line in the file.
- **print $2**: Extracts the second column, which contains the **Process IDs (PIDs)**.
- **sort**: Sorts the extracted PIDs numerically.
- **uniq -c**: Counts the occurrences of each unique PID, providing the total **number of handles** for each process.

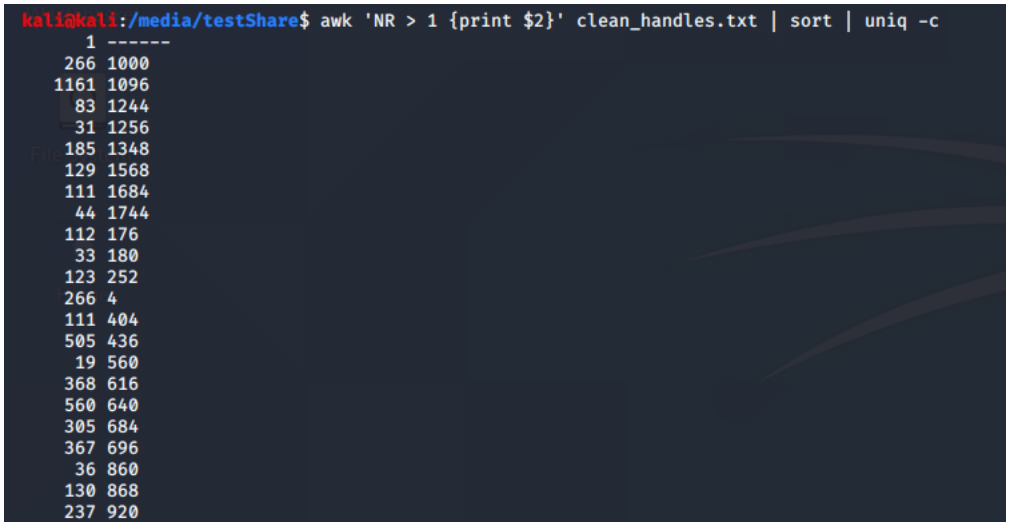


Figure 231 Number of handles associated with processes in the clean memory dump

The output of this command shows the PID and the corresponding number of handles for each process. This data was extracted and organized into the table below for the clean memory dump.[43]

Process (PID)	Number of Handles
4	266
176	112
180	123
252	123
404	111
436	505
560	19
616	368
640	360
684	305
696	367
868	130
920	237
1000	266
1096	1161
1244	83

1256	31
1348	185
1568	129
1684	111
1744	44

Table 6 Processes with their respective number of handles in clean dumps

To determine the number of handles associated with each process in the infected memory dump, the same command was executed on the infected_handles.txt file.

```
kali@kali:/media/testShare$ awk 'NR > 1 {print $2}' infected_handles.txt | sort | uniq -c
      1 ------
   1118 1004
     60 1056
    173 1136
    197 1220
    415 1484
    113 1512
    132 1588
     39 1640
     19 368
    240 4
    326 584
    519 608
    243 652
    330 664
    104 788
    194 824
    226 908
kali@kali:/media/testShare$
```

Figure 242 Number of handles associated with processes in the infected memory dump

The command extracted the **Process IDs (PIDs)** from the second column, sorted them, and counted the occurrences of each PID, representing the number of handles for each process. The output displays the handle count for each process in the infected dump, similar to the clean dump analysis.

Process (PID)	Number of Handles
368	19
584	326
608	519
652	243
664	233
788	104
824	194

908	226
1004	1118
1056	60
1136	173
1220	197
1312	113
1484	415
1512	113
1588	132
1640	239

Table 7 Handle count for each process

6)Select a process whose PID is higher than 100. Using the volshell, create a short script that verifies its DOS header and dumps it. Provide the Python code and explain it. (10%)

This section focuses on analysing executable files, specifically those running as processes on a system. Executable files, such as .exe files on Windows or .elf files on Linux, contain a well-defined structure that allows the operating system to load and execute them. The core of this structure is the DOS header, a crucial component even in modern executables. This header provides essential information about the file format, including its type, size, and entry point.[44]

By analysing the DOS header, we can gain valuable insights into the executable's characteristics. This information can be used for various purposes, such as:

- Reverse engineering: Understanding the file's structure and functionality.
- Debugging: Pinpointing errors or inconsistencies in the executable's loading process.

The aim is to demonstrate the process of extracting and analysing the DOS header of a running process. We will utilize the volshell to interact with the system and extract the necessary data. Python will be used for scripting and data manipulation due to its versatility and extensive libraries for data analysis and manipulation.

We used Volatility's volshell to list all active processes within the memory dump. The command iterated through each process using the ps() function and printed the process name, PID, and offset. From this output, we identified svchost.exe with a PID of 1004 and an offset of 0x823001d0.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 volshell
Volatility Foundation Volatility Framework 2.6.1
Current context: System @ 0x823c89c8, pid=4, ppid=0 DTB=0x2fe000
Welcome to volshell! Current memory image is:
file:///media/testShare/cw2_Machine4Infected.dump
To get help, type 'hh()'
>>> for p in ps():
...     print("Name: {}, PID: {}, Offset: {}".format(str(p.ImageFileName), int(p.UniqueProcessId), hex(p.obj_offset)))
...
Name             PID    PPID   Offset
System           4      0      0x823c89c8
smss.exe         368    4      0x822f1020
csrss.exe        584    368    0x822a0598
winlogon.exe     608    368    0x82298700
services.exe     652    608    0x81e2ab28
lsass.exe        664    608    0x81e2a3b8
svchost.exe      824    652    0x82311360
svchost.exe      908    652    0x81e29ab8
svchost.exe      1004   652    0x823001d0
svchost.exe      1056   652    0x821dfda0
svchost.exe      1220   652    0x82295650
explorer.exe     1484   1464   0x821dea70
spoolsv.exe      1512   652    0x81eb17b8
reader_sl.exe    1640   1484   0x81e7bda0
alg.exe          788    652    0x820e8da0
wuauclt.exe      1136   1004   0x821fcda0
wuauclt.exe      1588   1004   0x8205bda0
```

Figure 253 List of all the active processes in memory dump

Next, the target process was manually loaded into memory using its offset by creating an _EPROCESS object. We confirmed the process name (svchost.exe) and PID (1004) to ensure accuracy. To verify the validity of the executable file, the **DOS header** was checked by reading the first two bytes at the ImageBaseAddress. The output MZ confirmed the presence of a valid PE (Portable Executable) file signature. Once verified, the process memory was dumped to a file named svchost_1004_dump.exe by reading **4 KB (0x1000 bytes)** of memory starting from the ImageBaseAddress.

```
>>> task = obj.Object("_EPROCESS", offset=0x823001d0, vm=addrspace())
>>> print("Process Name:", str(task.ImageFileName))
('Process Name:', 'svchost.exe')
>>> print("PID:", int(task.UniqueProcessId))
('PID:', 1004)
>>> dos_header = task.get_process_address_space().read(task.Peb.ImageBaseAddress, 2)
>>> print("DOS Header:", dos_header)
('DOS Header:', 'MZ')
>>> with open("svchost_1004_dump.exe", "wb") as f:
...     data = task.get_process_address_space().read(task.Peb.ImageBaseAddress, 0x1000)
...     if data:
...         f.write(data)
...         print("Process memory dumped successfully to svchost_1004_dump.exe")
...     else:
...         print("Failed to dump process memory.")
...
Process memory dumped successfully to svchost_1004_dump.exe
>>>
```

Figure 264 Process memory dumped successfully to svchost_1004_dump.exe

After successfully dumping the memory, the file was validated outside volshell in the terminal. Using the file command, the dumped file was identified as a **PE32 executable (GUI) for Intel 80386**, confirming it was a valid Windows executable. This process demonstrated the successful retrieval and validation of the svchost.exe process memory.[45]

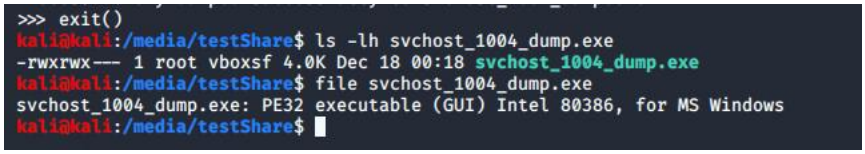


Figure 275 Validation of the svchost.exe process memory

Below is a table explaining the python script.

Line of Code	Explanation
for p in ps():	**ps()** is a function in **volshell** that retrieves a list of all active processes. This line starts a loop to iterate through each process in memory.
str(p.ImageFileName)	**p.ImageFileName** retrieves the name of the process. Since it's stored as an internal structure, it's converted into a readable string using **str()**.
int(p.UniqueProcessId)	**p.UniqueProcessId** retrieves the Process ID (PID) as an unsigned integer. It is converted into a standard integer using **int()** for readability.
hex(p.obj_offset)	**p.obj_offset** gives the memory address (offset) of the process object. It is converted into hexadecimal format using the **hex()** function to make it easier to interpret.
print("Name: {}, PID: {}, Offset: {}".format(...))	This line combines the process name, PID, and offset into a formatted string for display. The **format()** function is used to insert the values into placeholders {}.
task = obj.Object("_EPROCESS", offset=0x823001d0, ...)	**obj.Object()** is used to manually load the target process object (_EPROCESS) from memory. - _EPROCESS: The Windows process structure. - offset=0x823001d0: Memory address of the process object. - addrspace(): Retrieves the current memory space.
print("Process Name:", str(task.ImageFileName))	Retrieves and prints the name of the target process. The **ImageFileName** field stores the process name, and str() converts it to a readable format.
print("PID:", int(task.UniqueProcessId))	Retrieves and prints the PID of the target process using the **UniqueProcessId** field, which identifies the process uniquely. The **int()** function ensures the value is a standard integer.
task.Peb.ImageBaseAddress	**task.Peb** points to the Process Environment Block (PEB), a Windows structure that stores process information.

	ImageBaseAddress is the starting memory address of the process executable.
task.get_process_address_space().read(..., 2)	**get_process_address_space()** retrieves the address space (memory) of the process. **.read()** reads **2 bytes** of memory from the ImageBaseAddress. This is used to check the DOS header (MZ).
print("DOS Header:", dos_header)	Prints the first 2 bytes of memory read from the process's ImageBaseAddress. If the output is MZ, it confirms the presence of a valid **PE executable**.
with open("svchost_1004_dump.exe", "wb") as f:	Opens a file named **svchost_1004_dump.exe** in **write-binary mode (wb)**. This mode ensures the memory is written to the file as binary data, preserving its structure.
task.get_process_address_space().read(..., 0x1000)	Reads **0x1000 (4 KB)** of memory starting from the ImageBaseAddress. This amount of memory typically includes the **PE headers** and part of the executable code.
if data:	Checks if memory data was successfully read. If data is valid, the program proceeds to write it to the file.
f.write(data)	Writes the memory data to the file **svchost_1004_dump.exe**. This effectively dumps the process memory to disk.
print("Process memory dumped successfully...")	Prints a success message if the memory dump was successful.
else: print("Failed to dump process memory.")	Prints an error message if the memory could not be read or dumped.

Table 8 Python script (code explantation)

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CST3510

SUB-CHAPTER 5

Intrusion Detection

M00872751

5.1-List the users of the clean and the provided memory dump. Is there any new user in the system? Is there any user who looks suspicious? Why? (10%).

Introduction

The Windows registry is a critical component of the operating system, storing a wide range of settings and configurations that govern both system operations and user activities. (Ligh, M.H., Case, A., Levy, J. and Walters, A., 2014.), the Windows registry is a vital resource for forensic analysis. It can reveal recently executed programs, provide access to password hashes for auditing, and help investigate keys or values added by malicious software. Given its critical role in system operations, the registry is accessed frequently, and parts of it are cached in memory to enhance performance. Given its importance, the registry is accessed frequently during system runtime, and parts of it are cached in memory for faster access.

In forensic investigations, examining registry data in memory offers a unique advantage over traditional disk forensics. It allows investigators to uncover volatile data—information that may not be present on the disk but still exists in the memory at the time of the system dump. By analysing this volatile registry data, forensic experts can uncover a wealth of evidence, including recently executed programs, the presence of malware, and even system configurations that may have been altered.

The memory dump was analysed using **Volatility Framework 2.6.1**, a widely used tool for extracting forensic artifacts from memory dumps. To determine the appropriate profile for analysis, the **imageinfo** command was executed, providing detailed information about the memory image. The results indicated that the suggested profiles were WinXPSP2x86 and WinXPSP3x86,(green) and the system was instantiated with the WinXPSP2x86 profile for further analysis. Key details extracted from **imageinfo** revealed that the operating system was Windows XP Service Pack 3, with a kernel debugger block (KDBG) located at 0x80545ae0L and page table entries (PAE) enabled. Additionally, the image was captured on July 22, 2012, at 02:45:08 UTC, corresponding to a local time of July 21, 2012, at 22:45:08 EDT. By correctly identifying and applying the WinXPSP3x86 profile, the analysis ensured accurate extraction of user-related artifacts, registry data, and process information from the memory dump, forming the basis for subsequent forensic investigation.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw imageinfo
Volatility Foundation Volatility Framework 2.6.1
INFO    : volatility.debug    : Determining profile based on KDBG search...
          Suggested Profile(s) : WinXPSP2x86, WinXPSP3x86 (Instantiated with WinXPSP2x86)
                     AS Layer1 : IA32PagedMemoryPae (Kernel AS)
                     AS Layer2 : FileAddressSpace (/media/testShare/windowCW2s.raw)
                      PAE type : PAE
                           DTB : 0x34c000L
                          KDBG : 0x8054d2e0L
          Number of Processors : 4
     Image Type (Service Pack) : 3
                KPCR for CPU 0 : 0xffdff000L
                KPCR for CPU 1 : 0xbab50000L
                KPCR for CPU 2 : 0xbab58000L
                KPCR for CPU 3 : 0xbab60000L
             KUSER_SHARED_DATA : 0xffdf0000L
```

Figure 28: Imageinfo of the clean dump.

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump imageinfo
Volatility Foundation Volatility Framework 2.6.1
INFO    : volatility.debug    : Determining profile based on KDBG search...
          Suggested Profile(s) : WinXPSP2x86, WinXPSP3x86 (Instantiated with WinXPSP2x86)
                     AS Layer1 : IA32PagedMemoryPae (Kernel AS)
                     AS Layer2 : FileAddressSpace (/media/testShare/cw2_Machine4Infected.dump)
                      PAE type : PAE
                           DTB : 0x2fe000L
                          KDBG : 0x80545ae0L
          Number of Processors : 1
     Image Type (Service Pack) : 3
                KPCR for CPU 0 : 0xffdff000L
             KUSER_SHARED_DATA : 0xffdf0000L
           Image date and time : 2012-07-22 02:45:08 UTC+0000
     Image local date and time : 2012-07-21 22:45:08 -0400
```

Figure 29: Imageinfo of the infected dump.

1- **List the users of the clean and the provided memory dump. Is there any new user in the system?**

Before using the printkey command to list the usernames from the SAM hive in the memory dump, it's important to understand what the SAM (Security Account Manager) hive is and what the specific registry key "SAM\\Domains\\Account\\Users\\Names" contains. The SAM hive is responsible for storing user account data, including usernames and associated security identifiers (SIDs), which are crucial for authentication and access control within a Windows system (Carvey, H., 2011).

The "SAM\\Domains\\Account\\Users\\Names" registry key specifically contains the names of user accounts that are defined on the system. These usernames are linked to SIDs, which are unique identifiers used to control user access to system resources. By analysing this key, we can obtain a list of all users on the system and verify whether any unauthorized or suspicious accounts exist.

Command used:

volatility -f windowCW2s.raw --profile=WinXPSP2x86 printkey -K "SAM\\Domains\\Account\\Users\\Names"

"**SAM\\Domains\\Account\\Users\\Name**" uses the **Volatility framework** to analyze a memory dump file named **windowCW2s.raw**. The **-f** flag specifies the memory dump file to analyse, while the **--profile=WinXPSP2x86** tells Volatility that the memory dump is from a Windows XP Service Pack 2 system running on a 32-bit architecture. The **printkey** plugin is used to extract data from the Windows Registry, specifically from the **SAM\\Domains\\Account\\Users\\Name key**. This key contains information about user accounts on the system, such as usernames and security-related details, making it useful for forensic investigations into user activity or security incidents.

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 printkey -K "SAM\\Domains\\Account\\Users\\Names"
Volatility Foundation Volatility Framework 2.6.1
Legend: (S) = Stable   (V) = Volatile

----------------------------
Registry: \Device\HarddiskVolume1\WINDOWS\system32\config\SAM
Key name: Names (S)
Last updated: 2020-06-30 03:12:58 UTC+0000

Subkeys:
  (S) Administrator
  (S) Guest
  (S) HelpAssistant
  (S) SUPPORT_388945a0
  (S) voidead

Values:
REG_NONE                      : (S)
```

Figure 30: Printkey of the clean dump

The SAM hive is last updated on 2020-06-30, (green) which provides insight into the last activity or changes made to user accounts on the system. The listed accounts (Orange)

are standard and legitimate, with voidead appearing as a potentially custom user created on the system. There are no indications of suspicious or unauthorized accounts in this clean memory dump.

Command used:

volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "SAM\\Domains\\Account\\Users\\Names"

Figure 31: Printkey of the infected dump

The SAM hive is last updated on 2011-04-13(red), which may indicate that the dump was taken at a much earlier time, or it could reflect the possibility of system date manipulation or corruption. Notably, a new user account, **Robert (Blue)** , has appeared in the infected dump, which is not present in the clean dump. This suggests that an unauthorized user might have been added to the system, which could be indicative of malicious activity or compromise.

1- **Is there any user who looks suspicious? Why?**

Yes, there is a **suspicious user** identified in the infected memory dump: **Robert**. The following steps were taken to verify Robert's suspicious activity:

First, I examined Robert's **privilege access** and identified the processes running under his account. To do this, I used the **getsids** command to gather information about the security identifiers (SIDs) associated with each process. I then filtered the results to display only those processes associated with Robert's user account.

Command used:

volatility -f CW2_MachineInfected.dump --profile=WinXPSP2x86 getsids| grep -E "explorer.exe|reader_sl.exe|wuauclt.exe"

I used the Volatility framework to analysis a memory dump file named **CW2_MachineInfected.dump**. The **-f** flag specifies the memory dump file to analyse, while the **--profile=WinXPSP2x86** tells Volatility that the memory dump is from a Windows XP Service Pack 2 system running on a 32-bit architecture. The **getsids** plugin is used to retrieve Security Identifiers (SIDs) for processes running in the memory, showing which user accounts or groups are associated with each process. The output is then filtered using **grep -E**

to display only the SIDs for the specified processes: **explorer.exe, reader_sl.exe, and wuauclt.exe**.

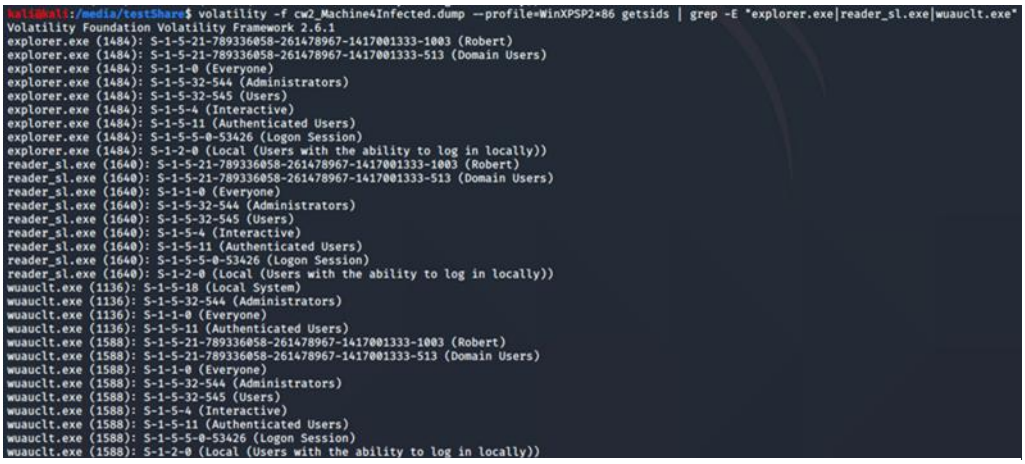


Figure 32: Roberts privilege access, SID, and the process runs under him.

After analysing the memory dump, it has been determined that the user "**Robert**" (SID: S-1-5-21-789336058-261478967-1417001333-1003) holds **administrative privileges** on the system. **Robert** is a member of the **Administrators group** (SID: S-1-5-32-544), which grants him full control over the system, including the ability to modify settings, install software, and access sensitive resources. Several processes were found to be running under Robert's account, such as **explorer.exe** (PID: 1484), **reader_sl.exe** (PID: 1640), and **wuauclt.exe** (PIDs: 1136 and 1588), further confirming his elevated level of access. This level of control is consistent with the execution of various actions on the system, both legitimate and potentially malicious, as shown in **Figure 85**.

Among the registry entries for programs set to run at startup, a suspicious executable was found under Robert's profile. Specifically, in the **Run** registry key of **NTUSER.DAT**, the entry points to a file located at **C:\Documents and Settings\Robert\Application Data\KB00207877.exe**(orange) last updated on **2012-07-22 02:31:51 UTC**. (Red)This executable, which does not correspond to any known legitimate software, is indicative of a potential malware infection, especially given that it was configured to run automatically on system startup. The timing of this entry aligns with the timestamp of the memory dump, suggesting recent execution and a possible attempt to establish persistence on the system.

This registry entry was discovered using the **printkey** command, which allows to extract the relevant registry entries for programs configured to run at startup, revealing the suspicious executable associated with Robert's account as it shows in **figure 86**.

Given Robert's **administrative privileges** and the presence of this suspicious file, it is recommended that further investigation be conducted into the nature of **KB00207877.exe** to assess its impact on system security and determine whether it is part of a larger compromise.

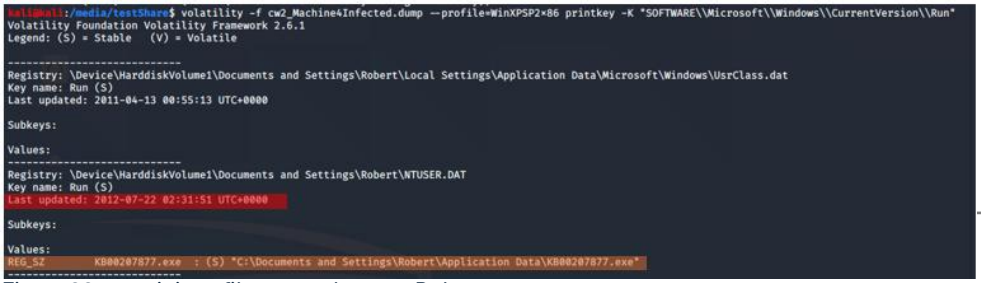


Figure 33: suspicious file run under user Robert.

5.2-Provide a brief description of the RSA2 algorithm. Recover the password hashes and the LSA secret keys of both memory dumps. Is there any difference? How would you recover the original passwords? (10%)

Brief description of the RSA2 algorithm.

RSA2 refers to the RSA algorithm's implementation using the SHA-2 family of cryptographic hash functions for digital signatures and encryption. The RSA algorithm, named after its inventors Rivest, Shamir, and Adleman, is a widely used public-key cryptosystem that relies on the computational difficulty of factoring large prime numbers.(Karakra, A. and Alsadeh, A., 2016) The SHA-2 family, which includes hash functions like SHA-224, SHA-256, SHA-384, and SHA-512, offers enhanced security over its predecessor, SHA-1.This combination is widely adopted in modern applications such as secure communication protocols like TLS and data integrity verification due to its robust security features.

Recover the password hashes and the LSA secret keys of both memory dumps.

-The clean dump

The hashdump is a plugin tool used to extract password hashes from memory samples, (Patil, D.N. and Meshram, B.B., 2016). This plugin works by leveraging keys from the SYSTEM and SAM registry hives, which it locates automatically using the Registry API. Once obtained, the extracted hashes can be fed into a hash-cracking tool such as John the Ripper to recover clear-text passwords. This functionality makes hashdump a favourite among the offensive security community, here's the steps I followed:

I used the **hashdump** plugin to extract password hashes from the clean dump as following:

Command used:

vol.py -f windowCW2s.raw --profile=WinXPSP2x86 hashdump

```
kali@kali:/media/testShare$ vol.py -f windowCW2s.raw --profile=WinXPSP2x86 hashdump
Volatility Foundation Volatility Framework 2.6.1
Administrator:500:9ae08e4f12714d55aad3b435b51404ee:0f2c8ec0f68b87023ea4e4bdcd11040e:::
Guest:501:aad3b435b51404eeaad3b435b51404ee:31d6cfe0d16ae931b73c59d7e0c089c0:::
HelpAssistant:1000:91f312bfbf3bf897e771806cbdcd0ea7:6b14dacc63980789e28bd0bd53aa44a9:::
SUPPORT_388945a0:1002:aad3b435b51404eeaad3b435b51404ee:9ed0bd086fd950b3f0ac64e4d56d0564:::
voidead:1003:9ae08e4f12714d55aad3b435b51404ee:0f2c8ec0f68b87023ea4e4bdcd11040e:::
```

Figure 34: The clean dump password hashes output.

The hashdump output (orange) above in fig**ure 87** provide a detailed information about user accounts and their associated password hashes extracted from the SAM and SYSTEM registry hives of a Windows system. Each entry contains several fields, starting with the Username, which identifies the specific user account. The RID (Relative Identifier) is a unique number assigned to each user within the Security Account Manager (SAM). The LM Hash (LanMan Hash) represents the user's password hashed using the older LanMan algorithm; if LM hashes are disabled, this field will contain a placeholder value (aad3b435b51404eeaad3b435b51404ee). The NT Hash (NTLM Hash)

is a more secure hash of the user's password using the NTLM algorithm, which is supported by all modern Windows operating systems.

-The following table list the output for better understanding

Username	RID	LM Hash	NT Hash	Notes
Administrator	500	9ae08e4f12714d55aad3b435b51404ee	0f2c8ec0f68b87023ea4e4bdcd11040e	Administrator account
Guest	501	aad3b435b51404eeaad3b435b51404ee (placeholder)	31d6cfe0d16ae931b73c59d7e0c089c0 (empty password)	Disabled/empty account
HelpAssistant	1000	91f312bf3fb7897f217806cbcd0dea07	6b14dacc639807892ad8b0bd53aa4a49	Remote Assistance user
SUPPORT_388945a0	1002	aad3b435b51404eeaad3b435b51404ee (placeholder)	9ed0bd08d86df9503bf0a6c4e45d5064	Support account
voidead	1003	9ae08e4f12714d55aad3b435b51404ee	0f2c8ec0f68b87023ea4e4bdcd11040e	User account

Table 2: The hashdump result from the clean dump.

The **lsadump** plugin is a tool used for enabling the extraction of decrypted Local Security Authority (LSA) secrets from memory dumps of supported Windows systems.(Ostrovskaya, S. and Skulkin, O.,2022.), **lsadump** reveals sensitive information stored in the Windows registry, such as default passwords for auto-login, Remote Desktop Protocol (RDP) private keys, and credentials used by the Data Protection API (DPAPI). The primary role of **lsadump** is to extract and decrypt secrets from the SYSTEM and SECURITY hives, which are automatically located using Volatility's Registry API. These decrypted secrets provide critical insights into a system's configuration and credentials, simplifying the investigation process for analysts.

I used the **lsadump** plugin to extract password hashes from the clean dump as following:

Command used:

vol.py -f windowCW2s.raw --profile=WinXPSP2x86 lsadump

As it shows below in figures 8,9 and 10 the lsadump plugin output reveals several critical LSA secrets stored in the system's memory. The **L$RTMTIMEBOMB_* key (blue)** contains a timestamp indicating when an unactivated Windows copy will stop functioning. Service Control Manager secrets like **_SC_Dnscache, _SC_RpcLocator, and _SC_Alerter (orange)** represent system service configurations but do not typically store sensitive information. The **DefaultPassword key (green)** exposes the plaintext auto-login password, here revealed as "voidead," which is a major security concern. The **NL$KM key (pink)** holds a cryptographic key used to encrypt cached domain credentials, which could be exploited to decrypt stored passwords if cached

credentials are available. The **L$HYDRAENCKEY_* key (light blue)** contains an RDP private key, which can decrypt encrypted RDP traffic

when combined with captured packets, potentially exposing sensitive communications. The **DPAPI_SYSTEM key (purple)** provides the DPAPI master key, enabling the decryption of system-protected credentials, certificates, or files. Lastly, the **RemoteDesktopHelpAssistantSID (purple)** represents the SID of the Remote Desktop Help Assistant account, potentially linked to remote access configurations or attacks. These findings highlight critical vulnerabilities, particularly the plaintext password, cryptographic keys, and potential exposure of remote access configurations, emphasizing the need for secure memory handling and registry protection.

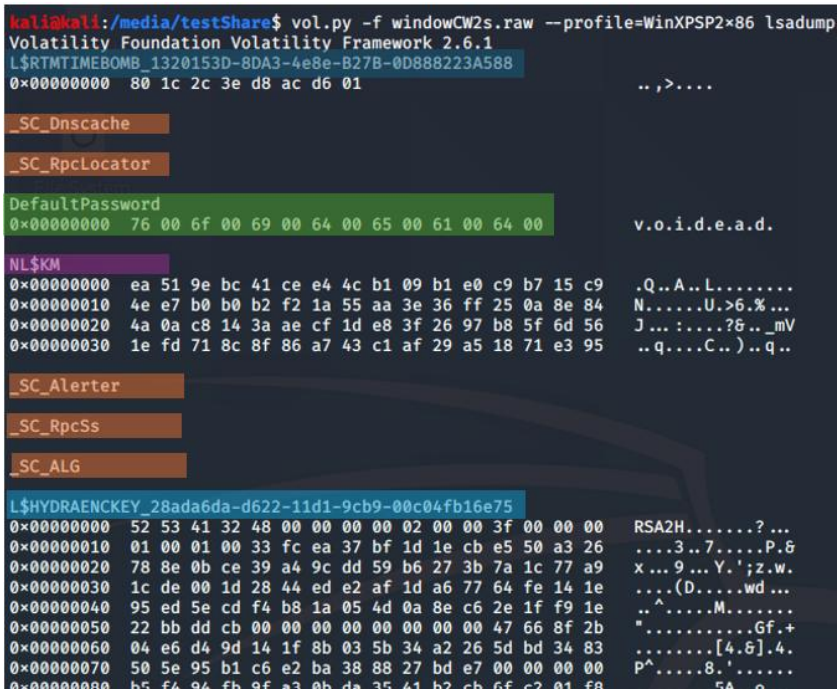


Figure 35: The output of the lsbdump in the clean dump 1/3

Figure 36: The output of the lsbdump in the clean dump 2/3

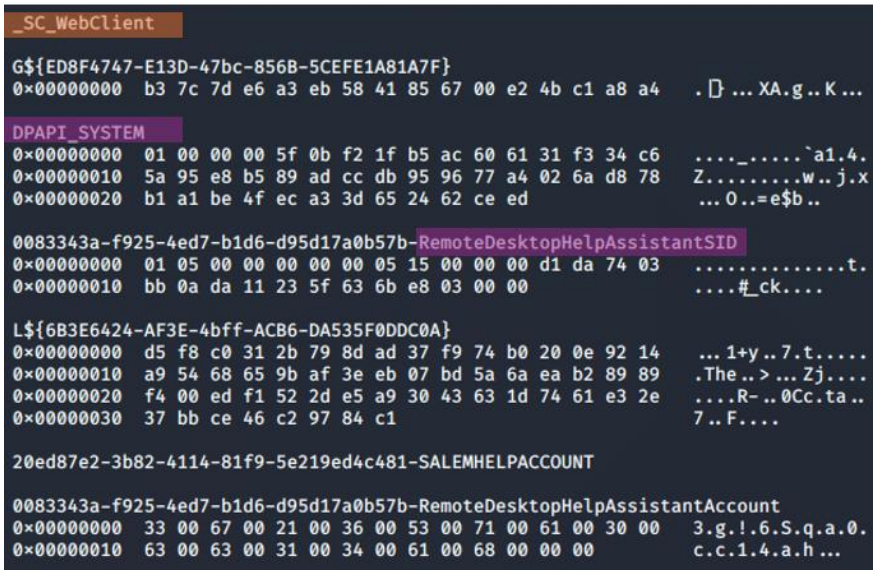


Figure 37: The output of the lsbdump in the clean dump 3/3

-The infected dump

Attempting to Extract Hashes with Hashdump

The hashdump plugin extracts password hashes by decrypting the SAM hive using keys from the SYSTEM hive.

Command Used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 hashdump

The hashdump plugin attempts to locate the SAM and SYSTEM hives and decrypt their contents to extract password hashes.

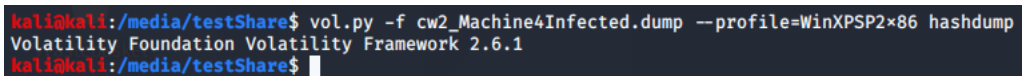


Figure 38: The output of the hashdump command.

As it shows above in **figure 91** the command completed without error but did not produce any output.

Attempting to Extract LSA with lsadump

The lsadump plugin extracts LSA secrets such as cached credentials and RDP keys.

Command Used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 lsadump

The lsadump plugin retrieves LSA secrets by decrypting the SECURITY hive using keys from the SYSTEM hive.

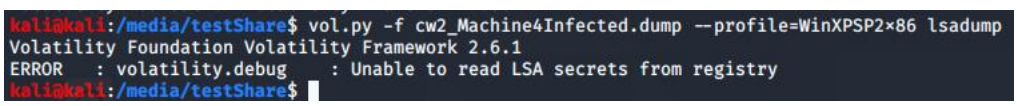


Figure 39: The output of the lsadump command.

As its shows above in **figure 92** the command did return an output errors state that it's unable to read LSA secrets from registry.

For the factors above it wasn't possible to recover the password hashes and the LSA secret keys of infected dump "**cw2_Machine4Infected.dump** "based on the analysis I conduct below:

1-Verifying the Availability of Required Registry Hives:

The hashdump and lsadump plugins rely on the SAM and SYSTEM registry hives to extract credentials. The SAM hive stores user account information, while the SYSTEM hive contains cryptographic keys necessary for decryption. (Thomassen, J., 2008.), identifying the availability of these hives is a prerequisite for forensic analysis of Windows memory dumps.

Command used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 hivelist

I used the Volatility framework to analysis a memory dump file named **CW2_MachineInfected.dump**. The **-f** flag specifies the memory dump file to analyse, while the **--profile=WinXPSP2x86** tells Volatility that the memory dump is from a Windows XP Service Pack 2 system running on a 32-bit architecture and the **hivelist** plugin enumerates all registry hives present in the memory dump, displaying their virtual and physical offsets.

```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 hivelist
Volatility Foundation Volatility Framework 2.6.1
Virtual    Physical   Name
---------- ---------- ----
0xe18e5b60 0x093f8b60 \Device\HarddiskVolume1\Documents and Settings\Robert\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
0xe1a19b60 0x0a5a9b60 \Device\HarddiskVolume1\Documents and Settings\Robert\NTUSER.DAT
0xe18398d0 0x08a838d0 \Device\HarddiskVolume1\Documents and Settings\LocalService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
0xe18614d0 0x08e624d0 \Device\HarddiskVolume1\Documents and Settings\LocalService\NTUSER.DAT
0xe183bb60 0x08e2db60 \Device\HarddiskVolume1\Documents and Settings\NetworkService\Local Settings\Application Data\Microsoft\Windows\UsrClass.dat
0xe17f2b60 0x08519b60 \Device\HarddiskVolume1\Documents and Settings\NetworkService\NTUSER.DAT
0xe1570510 0x07669510 \Device\HarddiskVolume1\WINDOWS\system32\config\software
0xe1571008 0x0777f008 \Device\HarddiskVolume1\WINDOWS\system32\config\default
0xe15709b8 0x076699b8 \Device\HarddiskVolume1\WINDOWS\system32\config\SECURITY
0xe15719e8 0x0777f9e8 \Device\HarddiskVolume1\WINDOWS\system32\config\SAM
0xe13ba008 0x02e4b008 [no name]
0xe1035b60 0x02ac3b60 \Device\HarddiskVolume1\WINDOWS\system32\config\system
0xe102e008 0x02a7d008 [no name]
kali@kali:/media/testShare$
```

Figure 40: The output of the hivelist command.

As we can see above in **figure 93** Both the **SAM**(Blue) and **SYSTEM**(Orange) hives are present in the memory dump, indicating that the basic requirements for hashdump and lsadump are met.

2-Checking the Integrity of the SYSTEM Hive

The **SYSTEM** hive must contain the **Select key**, which identifies the active control set, and the **ControlSet001\Control** key, which stores configuration data and cryptographic keys. Without these keys, decrypting the SAM hive is not possible. (Ligh, M.H., Case, A., Levy, J. and Walters, A., 2014)

-Query for the Select key:

Commands Used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "Select"

The printkey plugin extracts and displays the contents of a specified registry key in which in this case is "**select**"

```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "Select"
Volatility Foundation Volatility Framework 2.6.1
Legend: (S) = Stable   (V) = Volatile

The requested key could not be found in the hive(s) searched
kali@kali:/media/testShare$
```

Figure 41: The output of the print key "select" command.

As we can see above in **figure 94** its's failed to display the content of the select hive suggest that the system hive is corrupted or incomplete

-Query for the ControlSet001\Control key:

Commands Used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "ControlSet001\Control"

The printkey plugin extracts and displays the contents of a specified registry key in which in this case it's "**ControlSet001\Control**"

```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "ControlSet001\Control"
Volatility Foundation Volatility Framework 2.6.1
Legend: (S) = Stable   (V) = Volatile

The requested key could not be found in the hive(s) searched
kali@kali:/media/testShare$
```

Figure 42: The output of the print key "ControlSet001\Control" command.

As we can see above in **figure 95** its's failed to display the content of the **ControlSet001\Control** hive suggest that the system hive is corrupted or incomplete

3-Dumping the SYSTEM Hive for Offline Analysis

Since critical keys were inaccessible, I dumped the entire **SYSTEM** hive to analyze it offline and verify its integrity.

Command Used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 dumpregistry -o 0xe1035b60 --dump-dir ~/dump_registry

The **dumpregistry** plugin extracts the entire registry hive at the specified offset for offline analysis the **-o** specifies the memory offset where the registry hive is in the dump which is **0xe1035b60** and **dump-dir ~/dump_registry** Specifies the directory where the dumped registry hives will be saved.

```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 dumpregistry -o 0xe1035b60 --dump-dir ~/dump_registry
Volatility Foundation Volatility Framework 2.6.1
**************************************************
Writing out registry: registry.0xe1035b60.system.reg

Physical layer returned None for index 33000, filling with NULL
Physical layer returned None for index 35000, filling with NULL
Physical layer returned None for index 36000, filling with NULL
Physical layer returned None for index 37000, filling with NULL
Physical layer returned None for index 38000, filling with NULL
```

Figure 43:The output of the dump registry command.

4-Verifying the Integrity of the SAM Hive

The **SAM** hive stores user account data and password hashes. I needed to confirm whether this hive was intact and contained the necessary information.

Command Used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "SAM\Domains\Account"

The **printkey** plugin was used to access the **SAM\Domains\Account** key, which stores user account information (Red).

```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "SAM\Domains\Account"
Volatility Foundation Volatility Framework 2.6.1
Legend: (S) = Stable   (V) = Volatile

---------------------------
Registry: \Device\HarddiskVolume1\WINDOWS\system32\config\SAM
Key name: Account (S)
Last updated: 2011-04-13 00:53:57 UTC+0000

Subkeys:
  (S) Aliases
  (S) Groups
  (S) Users
```

Figure 44: The output of the printkey for SAM\Domains\Account key.

As it shows above in **figure 97** The SAM hive appears to be intact, with expected subkeys (**Aliases, Groups, Users**) present.

Conclusion

The inability to extract password hashes using **hashdump** and LSA secrets using **lsadump** from the infected memory dump (**cw2_Machine4Infected.dump**) is primarily due to the corruption and incompleteness of the **SYSTEM** hive. Critical keys required for decryption, such as **Select** and **ControlSet001\Control**, are missing, as confirmed by the printkey plugin output. Furthermore, attempts to dump the **SYSTEM** hive revealed that large portions of the hive were replaced with **NULL bytes**, indicating either an incomplete memory dump or overwritten memory regions during acquisition. When attempting to run the **lsadump** plugin, the command returned an error explicitly stating that it was "**unable to read LSA secrets from the registry,**" further supporting the conclusion that the **SYSTEM** hive is unusable. The absence of these critical keys and the corrupted state of the hive directly prevent the decryption of the **SAM** and **SECURITY** hives, rendering both hashdump and lsadump ineffective. This could be a result of memory acquisition artifacts, such as incomplete capturing of memory regions, or potentially deliberate tampering by malware designed to hinder forensic investigation. The **SAM** hive itself appears intact, as evidenced by the presence of expected subkeys like **Aliases**, **Groups**, and **Users**; however, without the decryption keys stored in the **SYSTEM** hive, the password hashes remain inaccessible. This analysis demonstrates that the integrity and completeness of the **SYSTEM** hive are crucial for successful extraction of hashes and secrets, highlighting the need for reliable memory acquisition techniques and the possibility of malware interference in this case.

Is there any difference?

In conclusion, the clean memory dump (**windowCW2s.raw**) and the infected memory dump (**cw2_Machine4Infected.dump**) exhibit significant differences in integrity and usability during forensic analysis. The clean dump contains intact registry hives, including the critical **SYSTEM** and **SAM** hives, allowing for the successful extraction of password hashes using **hashdump** and LSA secrets using **lsadump** as it shows in **figures (7 and 8)**. In contrast, the infected dump demonstrates severe corruption in the **SYSTEM** hive, with critical keys like **Select** and **ControlSet001\Control** missing and large portions of the hive replaced with **NULL** bytes as it shows in **figures (13,14,15,16)**. This corruption directly prevents the decryption of the **SAM** and **SECURITY** hives, rendering **hashdump** and **lsadump** ineffective. These findings underscore the stark contrast between the integrity of the clean and infected dumps, highlighting the impact of malware on system stability and the challenges it poses to forensic investigation.

How would you recover the original passwords?

To recover the original passwords from the memory dumps, the process begins by extracting password hashes from the **SAM** and **SYSTEM** registry hives. In the clean dump, this can be achieved using the **hashdump** plugin, as both hives are intact, allowing the

plugin to decrypt the password hashes successfully. These hashes, including the **NTLM** and potentially **LM** hashes, can then be cracked using tools like **John the Ripper** or **Hashcat** with a comprehensive **wordlist**, translating the hashes into plaintext passwords (Liu, E., Nakanishi, A., Golla, M., Cash, D. and Ur, B., 2019).However, in the infected dump, the hashdump and lsadump plugins fail due to the corruption of the **SYSTEM** hive, as the absence of critical keys like **Select** and **ControlSet001\Control** and errors indicating an inability to read **LSA** secrets. This corruption prevents the decryption of the **SAM** hive, rendering the extraction of hashes directly from memory infeasible. Alternative methods, such as **manually dumping** the registry files and processing them with tools like **secretsdump.py**, may provide a partial recovery if the corruption is not widespread. If this fails, recovery efforts may shift to **disk forensics**, extracting the **registry** hives directly from the infected system's disk image for offline analysis. While the clean dump enables straightforward recovery, the infected dump highlights challenges posed by hive corruption, requiring more advanced forensic techniques to recover passwords.

5.3-Identify all the kernel timers from each memory dump. Why is this information important? (10%)

What is kernel Timer?

A **kernel timer** is a mechanism in the operating system's kernel space that allows actions to be triggered after a specific time or at regular intervals without blocking threads, unlike simple thread delays such as **Sleep**. Created using functions like **KeInitializeTimer** in Windows, kernel timers enable asynchronous execution and are often paired with deferred procedure calls (DPCs), which allow the execution of specific functions when the timer expires. This makes them ideal for tasks requiring synchronization, periodic monitoring, or event-driven execution, such as polling resources or checking DNS resolutions. Malware, particularly rootkits, commonly uses kernel timers to perform background tasks stealthily, execute periodic actions, or avoid detection by minimizing forensic artifacts. However, kernel timers leave identifiable traces in memory (_KTIMER structures), which makes them valuable artifacts in memory forensics, enabling investigators to locate and analyse hidden malware or rootkit behaviour in kernel memory (The Art of Memory Forensics, Chapter 13).

How to Identify Kernel Timers?

- Kernel timers can be identified using memory forensics tools like Volatility. (Volatility Foundation, 2012). The timer's plugin is specifically designed to list all active kernel timers and their associated callbacks.
- The plugin extracts the kernel timer structures from memory and reveals the associated function pointers, which can help identify legitimate or malicious code tied to the timers.

Bellow step by step to identify the kernel timer in both memory dumps:

1-Identify The kernel Timer of the clean dump

To identify kernel timers in the clean dump, I used the timer's plugin in Volatility. This plugin lists all active kernel timers, including their expiration times, callback routines, and associated modules. (Ligh, M.H., Case, A., Levy, J. and Walters, A., 2014) Below is the command and an explanation of its purpose:

Command Used:

```
vol.py -f windowCW2s.raw --profile=WinXPSP2x86 timers
```

The command above will list all kernel timers in the clean memory dump (windowCW2s.raw), including their associated function pointers, module names, and expiration times where the **-f** flag specifies the memory dump file to analyse, while the **--profile=WinXPSP2x86** tells Volatility that the memory dump is from a Windows XP Service Pack 2 system running on a 32-bit architecture.

```
kali@kali:/media/testShare$ vol.py -f windowCW2s.raw --profile=WinXPSP2x86 timers
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  DueTime                  Period(ms) Signaled   Routine    Module
---------- ---------------------- ---------- ---------- ---------- ------
0x8a09ccd8 0x00000003:0x8d047442            0 -          0xb7096464 srv.sys
0x8a09cf18 0x00000003:0x8d047442            0 -          0xb7096464 srv.sys
0x8a09ca98 0x00000003:0x8d047442            0 -          0xb7096464 srv.sys
0x8a089818 0x80000000:0x0b211a1e            0 -          0x80538b46 ntoskrnl.exe
0x8a073408 0x00000003:0x8c8617a0        10000 Yes        0xbac086c4 watchdog.sys
0x8a07b830 0x00000003:0x8c8617a0        10000 Yes        0xbac086c4 watchdog.sys
0x89cacc58 0x80000000:0x362a6cb0            0 -          0x80538b46 ntoskrnl.exe
0x8a0c7c70 0x80000000:0x0912326c            0 -          0x80538b46 ntoskrnl.exe
0x80564960 0x00000008:0x622fb1d2            0 -          0x805386ba ntoskrnl.exe
0x8a0b1f78 0x00000003:0x0d4578a91           0 -          0xba033529 ks.sys
0x8055ac50 0x00000003:0xa2478ce0        60000 Yes        0x804f4f7e ntoskrnl.exe
0xb9eed1c0 0x00000003:0xa4a9e6e0        60000 Yes        0xb9edd471 ipsec.sys
0xb9eecd08 0x00000003:0xa4a9e6e0            0 -          0xb9edd3e7 ipsec.sys
0xb9eecd70 0x00000008:0x649932e0            0 -          0xb9edd3e7 ipsec.sys
0xb9e4dd60 0x00000003:0xa4ac493a        60000 Yes        0xb9e45266 ipnat.sys
0x8a161dd8 0x00000008:0x649df794            0 -          0xb9e5c48a netbt.sys
0x89bb4f68 0x80000000:0x1e9f33f0            0 -          0x80538b46 ntoskrnl.exe
0x8a1610e8 0x00000003:0x98f4faf6            0 -          0x80538b46 ntoskrnl.exe
0xb70a9b58 0x00000003:0x8d106004            0 -          0xb7096385 srv.sys
0xb6c45e60 0x00000003:0x9cb109f0        30000 Yes        0xb6c356bc HTTP.sys
0xb6c48440 0x00000003:0x9cb109f0            0 -          0xb6c3bc66 HTTP.sys
0x8a05f1a0 0x00000131:0x2dd4314a            0 -          0xba5dff6f NDIS.sys
0x8a0c2b40 0x00000098:0x975b5858            0 -          0xba5dff6f NDIS.sys
0x8a0b8b40 0x00000131:0x2ddb5858            0 -          0xba5dff6f NDIS.sys
0xb9d70220 0x00000003:0x8b1f51ec            0 -          0xb9d66385 rdbss.sys
0xb9ecd010 0x00000003:0x8b1ca654          100 Yes        0xb9e843dd tcpip.sys
0xb9ecd068 0x00000003:0x8b1ca654          100 Yes        0xb9e843dd tcpip.sys
0xb9ecd0c0 0x00000003:0x8b1ca654          100 Yes        0xb9e843dd tcpip.sys
0xb9ecd118 0x00000003:0x8b1ca654          100 Yes        0xb9e843dd tcpip.sys
0x80563040 0x00000003:0x88b95830         1000 Yes        0x80527a2e ntoskrnl.exe
0xbaa646a8 0x00000003:0x8b7d729a          500 Yes        0xbaa63108 rspndr.sys
0x8a0e1788 0x00000003:0x8aa47c9c            0 -          0x80538b46 ntoskrnl.exe
0x8a115410 0x00000003:0x8ae9a0ce            0 -          0xba5dff6f NDIS.sys
0x8a0bdb40 0x00000098:0x976e6b28            0 -          0xba5dff6f NDIS.sys
0x8a0d2ab8 0x80000003:0x44fac6ec            0 -          0x80538b46 ntoskrnl.exe
0x8055ad80 0x00000003:0x88a64560         1000 Yes        0x804f47ac ntoskrnl.exe
0x8a09abb8 0x00000003:0x8a7008e0            0 -          0xbabb03f0 TDI.SYS
0xb9ec82d0 0x00000003:0x8cd262e0            0 -          0xbabb03f0 TDI.SYS
0x8055ac50 0x00000003:0xa2478ce0        60000 Yes        0x804f4f7e ntoskrnl.exe
0xb9eed1c0 0x00000003:0xa4a9e6e0        60000 Yes        0xb9edd471 ipsec.sys
```

Figure 45: The output of the clean kernel timer command 1/2.

```
0xb9eecd08 0x00000003:0xa4a9e6e0            0 -          0xb9edd3e7 ipsec.sys
0xb9eecd70 0x00000008:0x649932e0            0 -          0xb9edd3e7 ipsec.sys
0x8a15ad70 0x00000003:0x8a726b3a            0 -          0xbabb03f0 TDI.SYS
0x8a0e12e0 0x00000003:0x8a726b3a            0 -          0xbabb03f0 TDI.SYS
0xb9e4dd60 0x00000003:0xa4ac493a        60000 Yes        0xb9e45266 ipnat.sys
0x8a1f3250 0x00000003:0x8a7e56fc            0 -          0xba6d992e sr.sys
0x8a260928 0x00000003:0x8a80b94c            0 -          0xba692550 VBoxGuest.sys
0x89bb4f68 0x80000000:0x1e9f33f0            0 -          0x80538b46 ntoskrnl.exe
0x80563040 0x00000003:0x88b95830         1000 Yes        0x80527a2e ntoskrnl.exe
0x8a0e1788 0x00000003:0x8aa47c9c            0 -          0x80538b46 ntoskrnl.exe
0x8a011f68 0x80000001:0x6ada433a            0 -          0x80538b46 ntoskrnl.exe
0xba614270 0x00000003:0x8b60d662            0 -          0xba5f61b4 Ntfs.sys
0x80559608 0x00000003:0x8900debc            0 -          0x804e6a98 ntoskrnl.exe
0x8055a260 0x00000003:0x8b6338bc            0 -          0x8053f646 ntoskrnl.exe
0x8a06c9a8 0x00000131:0x2dd1cef0            0 -          0xba5dff6f NDIS.sys
0xb6c45e60 0x00000003:0x9cb109f0        30000 Yes        0xb6c356bc HTTP.sys
0xb6c48440 0x00000003:0x9cb109f0            0 -          0xb6c3bc66 HTTP.sys
0x8055d620 0x00000003:0xf21cca78            0 -          0x8050d65a ntoskrnl.exe
0x8a0eac98 0x80000000:0x03211620            0 -          0x80538b46 ntoskrnl.exe
0x8a260928 0x00000003:0x8a80b94c            0 -          0xba692550 VBoxGuest.sys
0x89bb4f68 0x80000000:0x1e9f33f0            0 -          0x80538b46 ntoskrnl.exe
0xba6142d0 0x00000004:0x3298e4b0            0 -          0xba5f63d8 Ntfs.sys
0x805649e0 0x00543a8e:0x89881dc2            0 -          0x80538706 ntoskrnl.exe
0xb6c45c10 0x00000003:0x9caea796        60000 Yes        0xb6c2e1d0 HTTP.sys
0xb6c484e0 0x00000003:0xc071ed96            0 -          0xb6c39ab2 HTTP.sys
0x8a0d81a0 0x00000003:0x8ad68dfe            0 -          0xba5dff6f NDIS.sys
0x8a061688 0x00000003:0x8ad8f058            0 -          0xba5dff6f NDIS.sys
0x8a0c2b40 0x00000098:0x975b5858            0 -          0xba5dff6f NDIS.sys
0x8a0b8b40 0x00000131:0x2ddb5858            0 -          0xba5dff6f NDIS.sys
0x8a0d57f0 0x00000003:0x8e6ed9b2            0 -          0x80538b46 ntoskrnl.exe
0x8a0d2ab8 0x80000003:0x44fac6ec            0 -          0x80538b46 ntoskrnl.exe
0xb9ec82d0 0x00000003:0x8cd262e0            0 -          0xbabb03f0 TDI.SYS
0x8055ac50 0x00000003:0xa2478ce0        60000 Yes        0x804f4f7e ntoskrnl.exe
0xb9eed1c0 0x00000003:0xa4a9e6e0        60000 Yes        0xb9edd471 ipsec.sys
0xb9eecd08 0x00000003:0xa4a9e6e0            0 -          0xb9edd3e7 ipsec.sys
0xb9eecd70 0x00000008:0x649932e0            0 -          0xb9edd3e7 ipsec.sys
0x8a0dcfd0 0x00000003:0x8b59af54            0 -          0xb9e5c48a netbt.sys
0x8a0c3660 0x00000003:0x936a63c8        30000 Yes        0xb9dec385 afd.sys
0x805637c0 0x00000003:0x8c4cdf30            0 -          0x8052b50c ntoskrnl.exe
kali@kali:/media/testShare$
```

Figure 46: The output of the clean kernel timer command 2/2.

The output above in **Figures 98 and 99** shows 6 fields where The **Offset (orange)** is the memory address of the _KTIMER structure, locating the timer in the raw memory dump. **DueTime (green)** shows when the timer is set to trigger, often in low-level system time. **Period(ms)(blue)** indicates the timer's interval: 0 for one-shot timers and non-zero for recurring timers. **Signaled(purple)**shows if the timer has triggered (Yes) or is pending (-). **Routine (Red)** is the address of the function executed when

the timer expires. **Module(yellow)** identifies the kernel driver or module associated with the timer.

The output of the **timers** plugin, as it shown above in **Figures 98 and 99**, reveals multiple kernel timers associated with legitimate modules and drivers, reflecting normal system functionality. For instance, timers managed by **srv.sys** are responsible for callbacks at address **0xb7096464**, likely handling server-related tasks. Similarly, **ntoskrnl.exe**, the Windows kernel, manages several timers, such as those with callbacks at **0x80538b46** and **0x80527a2e**, which are critical for core operating system functions like process scheduling and synchronization. Periodic timers, such as those from **watchdog.sys** and **ipsec.sys**, are set with intervals of 10,000ms and 60,000ms, respectively, indicating routine tasks like network monitoring and system security enforcement. Other drivers, such as **NDIS.sys** and **HTTP.sys**, manage timers for network communication and HTTP operations. Notably, all timers in the clean dump are linked to known system modules and drivers, with no evidence of anomalous or suspicious routines. This reflects a clean system state, free from the kernel timer abuse often associated with advanced malware or rootkits.

Clean Dump Kernel Timer Analysis Table

Module	Callback Address	Period (ms)	Purpose
srv.sys	0xb7096464	0	Handles server-related tasks, such as file-sharing services.
ntoskrnl.exe	0x80538b46	0	Manages core OS functions, including process scheduling and system synchronization.
ntoskrnl.exe	0x80527a2e	1,000	Periodic tasks, likely related to maintaining system timers or processes.
watchdog.sys	0xbac086c4	10,000	Monitors hardware and prevents system hangs, ensuring hardware stability.
ipsec.sys	0xb9edd471	60,000	Secures network communications by managing IPsec protocols.
NDIS.sys	0xba5dff6f	Varies (e.g., 0x2ddb5858)	Handles network adapter tasks, including packet transmission and protocol management.
HTTP.sys	0xb6c356bc	30,000	Manages HTTP communications, typically for web server operations or application-level communications.
ks.sys	0xba033529	0	Kernel streaming tasks, likely related to media handling or audio/video streams.
TDI.SYS	0xbabb03f0	0	Manages transport driver interface operations, handling data transfer between the network and application layers.

Table 3: Clean Dump Kernal Timer table analysis.

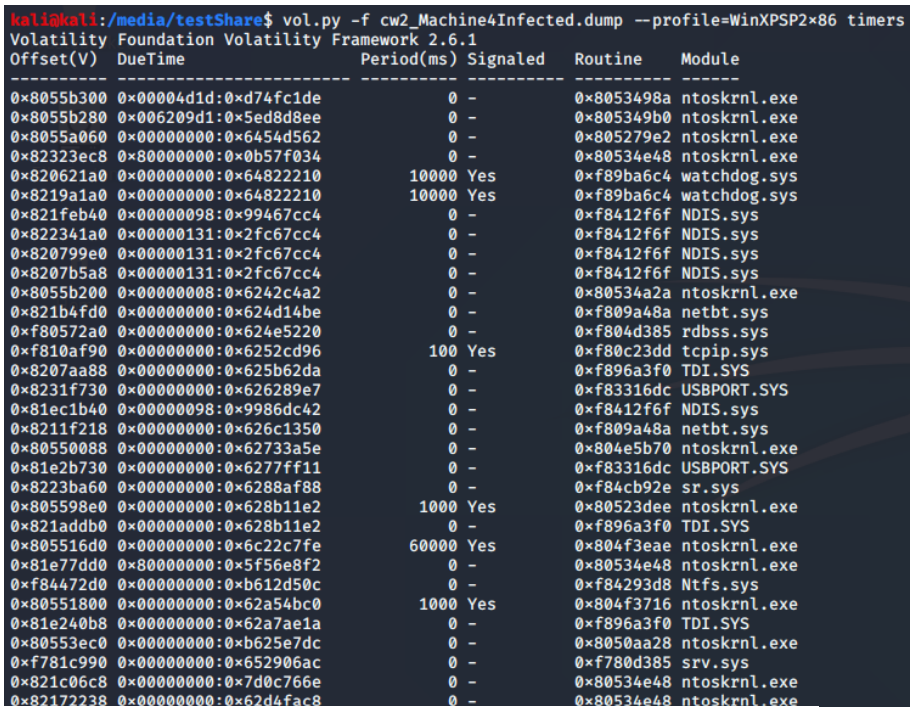
2-Identify The kernel Timer of the infected dump

To identify kernel timers in the infected dump, I used the timers plugin in Volatility. This plugin lists all active kernel timers, including their expiration times, callback routines, and associated modules. Below is the command and an explanation of its purpose:

Command Used:

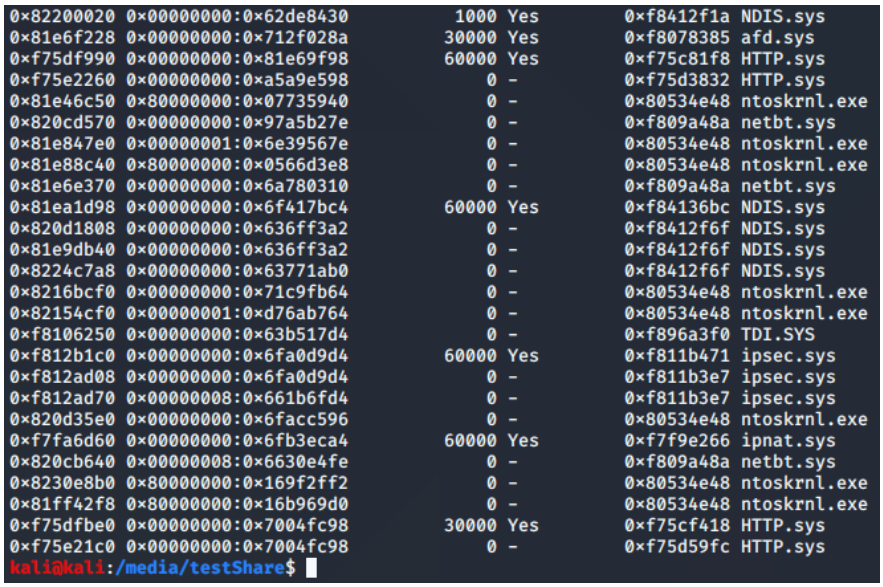
vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 timers

The command above will list all kernel timers in the infected memory dump (cw2_Machine4Infected.dump)



```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 timers
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  DueTime                  Period(ms) Signaled   Routine    Module
---------- --------------------- ---------- ---------- ---------- ------
0x8055b300 0x00004d1d:0xd74fc1de          0 -          0x8053498a ntoskrnl.exe
0x8055b280 0x006209d1:0x5ed8d8ee          0 -          0x805349b0 ntoskrnl.exe
0x8055a060 0x00000000:0x6454d562          0 -          0x805279e2 ntoskrnl.exe
0x82323ec8 0x80000000:0x0b57f034          0 -          0x80534e48 ntoskrnl.exe
0x820621a0 0x00000000:0x64822210      10000 Yes        0xf89ba6c4 watchdog.sys
0x8219a1a0 0x00000000:0x64822210      10000 Yes        0xf89ba6c4 watchdog.sys
0x821feb40 0x00000098:0x99467cc4          0 -          0xf8412f6f NDIS.sys
0x822341a0 0x00000131:0x2fc67cc4          0 -          0xf8412f6f NDIS.sys
0x820799e0 0x00000131:0x2fc67cc4          0 -          0xf8412f6f NDIS.sys
0x8207b5a8 0x00000131:0x2fc67cc4          0 -          0xf8412f6f NDIS.sys
0x8055b200 0x00000008:0x6242c4a2          0 -          0x80534a2a ntoskrnl.exe
0x821b4fd0 0x00000000:0x624d14be          0 -          0xf809a48a netbt.sys
0xf80572a0 0x00000000:0x624e5220          0 -          0xf804d385 rdbss.sys
0xf810af90 0x00000000:0x6252cd96        100 Yes        0xf80c23dd tcpip.sys
0x8207aa88 0x00000000:0x625b62da          0 -          0xf896a3f0 TDI.SYS
0x8231f730 0x00000000:0x626289e7          0 -          0xf83316dc USBPORT.SYS
0x81ec1b40 0x00000098:0x9986dc42          0 -          0xf8412f6f NDIS.sys
0x8211f218 0x00000000:0x626c1350          0 -          0xf809a48a netbt.sys
0x80550088 0x00000000:0x62733a5e          0 -          0x804e5b70 ntoskrnl.exe
0x81e2b730 0x00000000:0x6277ff11          0 -          0xf83316dc USBPORT.SYS
0x8223ba60 0x00000000:0x6288af88          0 -          0xf84cb92e sr.sys
0x805598e0 0x00000000:0x628b11e2       1000 Yes        0x80523dee ntoskrnl.exe
0x821addb0 0x00000000:0x628b11e2          0 -          0xf896a3f0 TDI.SYS
0x805516d0 0x00000000:0x6c22c7fe      60000 Yes        0x804f3eae ntoskrnl.exe
0x81e77dd0 0x80000000:0x5f56e8f2          0 -          0x80534e48 ntoskrnl.exe
0xf84472d0 0x00000000:0xb612d50c          0 -          0xf84293d8 Ntfs.sys
0x80551800 0x00000000:0x62a54bc0       1000 Yes        0x804f3716 ntoskrnl.exe
0x81e240b8 0x00000000:0x62a7ae1a          0 -          0xf896a3f0 TDI.SYS
0x80553ec0 0x00000000:0xb625e7dc          0 -          0x8050aa28 ntoskrnl.exe
0xf781c990 0x00000000:0x652906ac          0 -          0xf780d385 srv.sys
0x821c06c8 0x00000000:0x7d0c766e          0 -          0x80534e48 ntoskrnl.exe
0x82172238 0x00000000:0x62d4fac8          0 -          0x80534e48 ntoskrnl.exe
```

Figure 47: The output of the infected kernel timer command 1/2.



```
0x82200020 0x00000000:0x62de8430       1000 Yes        0xf8412f1a NDIS.sys
0x81e6f228 0x00000000:0x712f028a      30000 Yes        0xf8078385 afd.sys
0xf75df990 0x00000000:0x81e69f98      60000 Yes        0xf75c81f8 HTTP.sys
0xf75e2260 0x00000000:0xa5a9e598          0 -          0xf75d3832 HTTP.sys
0x81e46c50 0x80000000:0x07735940          0 -          0x80534e48 ntoskrnl.exe
0x820cd570 0x00000000:0x97a5b27e          0 -          0xf809a48a netbt.sys
0x81e847e0 0x00000001:0x6e39567e          0 -          0x80534e48 ntoskrnl.exe
0x81e88c40 0x80000000:0x0566d3e8          0 -          0x80534e48 ntoskrnl.exe
0x81e6e370 0x00000000:0x6a780310          0 -          0xf809a48a netbt.sys
0x81ea1d98 0x00000000:0x6f417bc4      60000 Yes        0xf84136bc NDIS.sys
0x820d1808 0x00000000:0x636ff3a2          0 -          0xf8412f6f NDIS.sys
0x81e9db40 0x00000000:0x636ff3a2          0 -          0xf8412f6f NDIS.sys
0x8224c7a8 0x00000000:0x63771ab0          0 -          0xf8412f6f NDIS.sys
0x8216bcf0 0x00000000:0x71c9fb64          0 -          0x80534e48 ntoskrnl.exe
0x82154cf0 0x00000001:0xd76ab764          0 -          0x80534e48 ntoskrnl.exe
0xf8106250 0x00000000:0x63b517d4          0 -          0xf896a3f0 TDI.SYS
0xf812b1c0 0x00000000:0x6fa0d9d4      60000 Yes        0xf811b471 ipsec.sys
0xf812ad08 0x00000000:0x6fa0d9d4          0 -          0xf811b3e7 ipsec.sys
0xf812ad70 0x00000008:0x661b6fd4          0 -          0xf811b3e7 ipsec.sys
0x820d35e0 0x00000000:0x6facc596          0 -          0x80534e48 ntoskrnl.exe
0xf7fa6d60 0x00000000:0x6fb3eca4      60000 Yes        0xf7f9e266 ipnat.sys
0x820cb640 0x00000008:0x6630e4fe          0 -          0xf809a48a netbt.sys
0x8230e8b0 0x80000000:0x169f2ff2          0 -          0x80534e48 ntoskrnl.exe
0x81ff42f8 0x80000000:0x16b969d0          0 -          0x80534e48 ntoskrnl.exe
0xf75dfbe0 0x00000000:0x7004fc98      30000 Yes        0xf75cf418 HTTP.sys
0xf75e21c0 0x00000000:0x7004fc98          0 -          0xf75d59fc HTTP.sys
kali@kali:/media/testShare$
```

Figure 48: The output of the infected kernel timer command 2/2.

The output of the **timers** plugin for the infected dump, as noted in **Figures 100 and 101**, highlights a mix of legitimate and suspicious kernel timers, reflecting both routine system operations and potential signs of compromise. Timers associated with **ntoskrnl.exe**, such as callbacks at **0x8053498a** and **0x80534e48**, appear to manage core system tasks like process scheduling and synchronization, consistent with normal behaviour. Similarly, periodic timers from **watchdog.sys** (10,000ms) and **ipsec.sys** (60,000ms) handle hardware monitoring and network security tasks, respectively. However, anomalies are evident in the high number of timers linked to **NDIS.sys** and **TDI.SYS**, with irregular DueTime values such as **0x6fa0d9d4** and **0x661b6fd4,** suggesting possible timer manipulation. Additionally, multiple timers associated with **USBPORT.SYS** (e.g., callback at **0xf83316dc**) raise concerns about potential misuse of USB-related activities, often indicative of malware exfiltration or unauthorized operations. These discrepancies, especially when compared to the clean dump, suggest kernel timer abuse, a tactic commonly employed by advanced malware for persistence and stealth. The irregularities noted in **Figures 100 and 101** underscore the importance of analysing kernel timers to detect hidden threats.

Infected Dump Kernel Timer Analysis Table

Module	Callback Address	Period (ms)	Purpose/Observation
ntoskrnl.exe	0x8053498a	0	Handles core OS tasks like scheduling and synchronization; observed multiple timers consistent with normal behaviour.
watchdog.sys	0xf89ba6c4	10,000	Monitors hardware and prevents crashes; no anomalies detected.
NDIS.sys	0xf8412f6f	Varies	Handles network adapter tasks; a high number of timers and irregular DueTime values indicate potential misuse.
TDI.SYS	0xf896a3f0	0	Manages transport driver interface; multiple timers suggest potential malicious network-related activity.
USBPORT.SYS	0xf83316dc	0	Manages USB-related tasks; excessive timers raise concerns about potential USB-based malicious activities.
ipsec.sys	0xf811b471	60,000	Secures network communications; no direct anomalies observed.

Table 4: infected Dump Kernal Timer table analysis.

2-Why is Identifying Kernel Timers Important?

Identifying kernel timers is crucial in memory forensics as it helps detect malicious activities, verify system integrity, and uncover forensic artifacts that may reveal signs of compromise. Malware, such as rootkits, often manipulates kernel timers to maintain persistence, execute periodic actions, or evade detection. By comparing timers from clean and infected memory dumps, investigators can distinguish between legitimate system operations and suspicious behaviour. Kernel timers leave identifiable traces in memory, such as _KTIMER structures, making them valuable for identifying hidden threats, as highlighted in The Art of Memory Forensics, Chapter 13. Analysing these timers provides insights into malware tactics, such as operational timing and callback routines. Furthermore, examining kernel timers allows correlation with other artifacts like callbacks and drivers, offering a broader view of potential threats. This information is essential for incident response, enabling investigators to pinpoint the root cause of

infections and develop effective remediation strategies to strengthen system defences (Ligh, M.H., Case, A., Levy, J. and Walters, A., 2014.).

Conclusion

The analysis of kernel timers and callbacks in both clean and infected memory dumps highlight their critical role in identifying system compromises. The clean dump exhibited normal system behaviour, with kernel timers and callbacks linked to legitimate modules such as ntoskrnl.exe, srv.sys, and ipsec.sys, reflecting essential operating system functions like process scheduling and network monitoring. In contrast, the infected dump revealed significant irregularities, including excessive timers associated with NDIS.sys and USBPORT.SYS, irregular DueTime values, and potential misuse of kernel timers for malicious purposes, such as persistence or data exfiltration. While callback analysis did not reveal immediate anomalies, entries related to sr.sys and USBPORT.SYS warrant further scrutiny. These findings strongly suggest kernel timer abuse, a tactic often used by advanced malware, particularly rootkits, to achieve stealth and persistence. To address these issues, deeper investigation of suspicious timers, correlation with other forensic artifacts, and the use of rootkit detection tools are recommended. Isolating the compromised system, restoring from trusted backups, and enhancing real-time monitoring can mitigate the risk and prevent further incidents. This case demonstrates the importance of kernel timer analysis in detecting and responding to advanced threats effectively.

5.4-Describe a kernel callback. Identify the kernel callbacks and their associated events in both memory dumps. Select 5 events from each memory dump and their callbacks and describe both.

kernel callback:

Kernel callbacks, also referred to as notification routines, are structured mechanisms that enable the monitoring and handling of critical system events. They are designed as modern alternatives to legacy methods like System Service Descriptor Table (SSDT) hooks, addressing their limitations by being safe for multicore environments, supported on 64-bit systems, and documented for better reliability. Kernel callbacks allow multiple modules to register for the same type of event, making them integral to tools like antivirus software, system monitors, and even rootkits. These callbacks are used to track key events such as process and thread creation, image loading, system shutdowns, registry modifications, and Plug and Play (PnP) device changes. For instance, the **PsSetCreateProcessNotifyRoutine** API monitors process start and termination, while **PsSetLoadImageNotifyRoutine** tracks executable images being mapped into memory. Debugging callbacks like **DbgSetDebugPrintCallback** capture kernel module messages, and shutdown notifications registered through **IoRegisterShutdownNotification** allow for critical cleanup operations before power-off. Additionally, bug check callbacks (**KeRegisterBugCheckCallback**) assist in logging or resetting device configurations during system crashes, such as a Blue Screen of Death (BSoD). These callbacks provide valuable forensic insights by exposing activity patterns, detecting suspicious registrations, and identifying anomalies linked to malicious behaviour (SpecterOps 2023)

Identify the kernel callbacks and their associated events in both memory dumps.

To identify kernel callbacks in the clean and infected memory dumps, use the callbacks plugin in Volatility. This plugin reveals all registered kernel callbacks and their associated events, such as process creation, registry operations, or file system notifications.

1-Identify the kernel callbacks and the associated events in the clean dump

Commands Used:

vol.py -f windowCW2s.raw --profile=WinXPSP2x86 callbacks

The command above will identify all kernel callbacks in the clean memory dump (windowCW2s.raw), including their registered kernel callbacks and their associated events, such as process creation, registry operations, or file system notifications. Where the -f flag specifies the memory dump file to analyse, while the --profile=WinXPSP2x86 tells Volatility that the memory dump is from a Windows XP Service Pack 2 system running on a 32-bit architecture.

```
kali@kali:/media/testShare$ vol.py -f windowCW2s.raw --profile=WinXPSP2x86 callbacks
Volatility Foundation Volatility Framework 2.6.1
Type                                Callback   Module               Details
---------------------------------- ---------- -------------------- -------
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\VgaSave
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\mnmdd
IoRegisterShutdownNotification      0xbaa6bc74 Cdfs.SYS             \FileSystem\Cdfs
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\RDPCDD
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\VBoxVideo
IoRegisterShutdownNotification      0x805d7cf2 ntoskrnl.exe         \FileSystem\RAW
IoRegisterShutdownNotification      0xba8b873a MountMgr.sys         \Driver\MountMgr
IoRegisterShutdownNotification      0xba74a2be ftdisk.sys           \Driver\Ftdisk
IoRegisterShutdownNotification      0xba5be969 Mup.sys              \FileSystem\Mup
IoRegisterShutdownNotification      0x806003a4 ntoskrnl.exe         \Driver\WMIxWDM
IoRegisterFsRegistrationChange      0xba6e4876 sr.sys               -
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\RDPCDD
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x805d7cf2 ntoskrnl.exe         \FileSystem\RAW
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\VgaSave
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\mnmdd
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\VBoxVideo
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xbaa6bc74 Cdfs.SYS             \FileSystem\Cdfs
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x806003a4 ntoskrnl.exe         \Driver\WMIxWDM
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba8b873a MountMgr.sys         \Driver\MountMgr
IoRegisterShutdownNotification      0xba74a2be ftdisk.sys           \Driver\Ftdisk
IoRegisterFsRegistrationChange      0xba6e4876 sr.sys               -
```

Figure 49: The output of the clean kernel callback command 1/2.

```
IoRegisterShutdownNotification      0xba5be969 Mup.sys              \FileSystem\Mup
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xbaa6bc74 Cdfs.SYS             \FileSystem\Cdfs
IoRegisterShutdownNotification      0xba8b873a MountMgr.sys         \Driver\MountMgr
IoRegisterShutdownNotification      0xba74a2be ftdisk.sys           \Driver\Ftdisk
IoRegisterShutdownNotification      0xba5be969 Mup.sys              \FileSystem\Mup
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x806003a4 ntoskrnl.exe         \Driver\WMIxWDM
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\mnmdd
IoRegisterShutdownNotification      0x805d7cf2 ntoskrnl.exe         \FileSystem\RAW
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\VgaSave
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\VBoxVideo
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba5815ec Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0xba0c8c6a VIDEOPRT.SYS         \Driver\RDPCDD
IoRegisterFsRegistrationChange      0xba6e4876 sr.sys               -
KeBugCheckCallbackListHead          0xba5cb5ef NDIS.sys             Ndis miniport
KeBugCheckCallbackListHead          0xba683650 VBoxGuest.sys        VBoxGuest
KeBugCheckCallbackListHead          0x806ecc10 hal.dll              ACPI 1.0 - APIC platform MP
KeRegisterBugCheckReasonCallback    0xbad84ab8 mssmbios.sys         SMBiosDa
KeRegisterBugCheckReasonCallback    0xbad84a70 mssmbios.sys         SMBiosRe
KeRegisterBugCheckReasonCallback    0xbad84a28 mssmbios.sys         SMBiosDa
KeRegisterBugCheckReasonCallback    0xba01d1a2 USBPORT.SYS          USBPORT
KeRegisterBugCheckReasonCallback    0xba01d102 USBPORT.SYS          USBPORT
KeRegisterBugCheckReasonCallback    0xba0bc522 VIDEOPRT.SYS         Videoprt
kali@kali:/media/testShare$
```

Figure 50: The output of the clean kernel callback command 2/2.

The output above in **Figure 102 & 103** shows four fields: Type, Callback, Module, and Details. **Type (Orange)** indicates the registered callback event (e.g., shutdown notifications). **Callback (Blue)** is the memory address of the function to execute. **Module (Red)** identifies the associated driver or executable (e.g., VIDEOPRT.SYS or ntoskrnl.exe). **Details (Green)** provides additional context, such as file paths or driver names.

Table of the Kernel Callbacks in the Clean Dump

Type	Callback Address	Module	Details
IoRegisterShutdownNotification	0xba0c8c6a	VIDEOPRT.SYS	\Driver\VgaSave
IoRegisterShutdownNotification	0xba5815ec	Fs_Rec.SYS	\FileSystem\Fs_Rec
IoRegisterFsRegistrationChange	0xba6e4876	sr.sys	Tracks file system changes.
KeBugCheckCallbackListHead	0xba5cb5ef	NDIS.sys	Handles NDIS miniport bug checks.
KeRegisterBugCheckReasonCallback	0xba01d1a2	USBPORT.SYS	USB port-related diagnostics.

Table 5: Table of the kernel Callbacks in the Clean Dump.

The kernel callback output from the clean dump reveals critical insights into the system's event-handling mechanisms. The **callbacks** plugin in Volatility identifies various registered callbacks, including their types, memory addresses, associated modules, and specific details. These callbacks manage key system events such as shutdown notifications (**IoRegisterShutdownNotification**), file system operations (**IoRegisterFsRegistrationChange**), and bug check handling (**KeBugCheckCallbackListHead**). For instance, callbacks associated with **VIDEOPRT.SYS** at memory address **0xba0c8c6a** ensure proper handling of VGA-related drivers during shutdown, while those linked to **NDIS.sys** at **0xba5cb5ef** manage NDIS miniport operations during crashes. The callbacks are all associated with legitimate modules such as ntoskrnl.exe, **VIDEOPRT.SYS**, and **Fs_Rec.SYS**, confirming normal system behaviour. This structured output analysis highlights the absence of callbacks pointing to unknown or suspicious memory regions, indicating no malicious activity in the clean dump. **Figures 102 and 103** visually represent the raw callback data and its structured interpretation, respectively, reinforcing the legitimacy of the callbacks and the integrity of the system in the clean state.

2-Identify the kernel callbacks and the associated events in the infected dump

Command Used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 callbacks

The command above will identify all kernel callbacks in the infected memory dump (cw2_Machine4Infected.dump)

```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 callbacks
Volatility Foundation Volatility Framework 2.6.1
Type                                Callback   Module              Details
----------------------------------- ---------- ------------------- -------
IoRegisterShutdownNotification      0x f8ba65be Fs_Rec.SYS          \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x f815bc6a VIDEOPRT.SYS        \Driver\RDPCDD
IoRegisterShutdownNotification      0x f8ba65be Fs_Rec.SYS          \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x f889dc74 Cdfs.SYS            \FileSystem\Cdfs
IoRegisterShutdownNotification      0x f815bc6a VIDEOPRT.SYS        \Driver\VgaSave
IoRegisterShutdownNotification      0x f8ba65be Fs_Rec.SYS          \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x f815bc6a VIDEOPRT.SYS        \Driver\mnmdd
IoRegisterShutdownNotification      0x f86aa73a MountMgr.sys        \Driver\MountMgr
IoRegisterShutdownNotification      0x f8ba65be Fs_Rec.SYS          \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x f8ba65be Fs_Rec.SYS          \FileSystem\Fs_Rec
IoRegisterShutdownNotification      0x f83f18f1 Mup.sys             \FileSystem\Mup
IoRegisterShutdownNotification      0x 805cdef4 ntoskrnl.exe        \FileSystem\RAW
IoRegisterShutdownNotification      0x f853c2be ftdisk.sys          \Driver\Ftdisk
IoRegisterShutdownNotification      0x 805f5d66 ntoskrnl.exe        \Driver\WMIxWDM
IoRegisterFsRegistrationChange      0x f84d6876 sr.sys              -
KeBugCheckCallbackListHead          0x f83fe5ef NDIS.sys            Ndis miniport
KeBugCheckCallbackListHead          0x 806d77cc hal.dll             ACPI 1.0 - APIC platform UP
KeRegisterBugCheckReasonCallback    0x f814f522 VIDEOPRT.SYS        Videoprt
KeRegisterBugCheckReasonCallback    0x f8b5eab8 mssmbios.sys        SMBiosDa
KeRegisterBugCheckReasonCallback    0x f8b5ea70 mssmbios.sys        SMBiosRe
KeRegisterBugCheckReasonCallback    0x f8b5ea28 mssmbios.sys        SMBiosDa
KeRegisterBugCheckReasonCallback    0x f833a1be USBPORT.SYS         USBPORT
KeRegisterBugCheckReasonCallback    0x f833a11e USBPORT.SYS         USBPORT
kali@kali:/media/testShare$
```

Figure 51: The output of the infected kernel callback command.

Table of the Kernel Callbacks in the infected Dump

Type	Callback Address	Module	Details
IoRegisterShutdownNotification	0xf8ba65be	Fs_Rec.SYS	\FileSystem\Fs_Rec
IoRegisterShutdownNotification	0xf815bc6a	VIDEOPRT.SYS	\Driver\RDPCDD
IoRegisterShutdownNotification	0xf889dc74	Cdfs.SYS	\FileSystem\Cdfs
IoRegisterShutdownNotification	0x805cdef4	ntoskrnl.exe	\FileSystem\RAW
IoRegisterFsRegistrationChange	0xf84d6876	sr.sys	Tracks file system changes, particularly for System Restore.
KeBugCheckCallbackListHead	0xf83fe5ef	NDIS.sys	Handles bug checks for the NDIS miniport driver.
KeBugCheckCallbackListHead	0x806d77cc	hal.dll	Related to ACPI 1.0 APIC platform.
KeRegisterBugCheckReasonCallback	0xf814f522	VIDEOPRT.SYS	Video port diagnostics.
KeRegisterBugCheckReasonCallback	0xf8b5eab8	mssmbios.sys	SMBIOS diagnostics and debugging.
KeRegisterBugCheckReasonCallback	0xf833a1be	USBPORT.SYS	USB port-related bug check and diagnostics.

Table 6: able of the kernel Callbacks in the infected Dump.

The output of the infected dump, detailed in **Figure 104**, highlights various kernel callbacks registered in the system. These callbacks, essential for managing system-level operations, include types such as **IoRegisterShutdownNotification**, **IoRegisterFsRegistrationChange**, **KeBugCheckCallbackListHead**, and **KeRegisterBugCheckReasonCallback**. The **IoRegisterShutdownNotification** callbacks, observed in modules like **Fs_Rec.SYS**, **VIDEOPRT.SYS**, and **Cdfs.SYS**, ensure drivers and modules are properly notified during system shutdown, managing tasks such as file recovery and video driver termination. The IoRegisterFsRegistrationChange callback in sr.sys monitors file system changes, often critical for system restore and file integrity. Additionally, the KeBugCheckCallbackListHead entries, found in **NDIS.sys** and **hal.dll**, handle bug checks for network interface drivers and **ACPI-**related hardware abstraction issues. Lastly, the KeRegisterBugCheckReasonCallback entries, associated with modules like **USBPORT.SYS, VIDEOPRT.SYS**, and **mssmbios.sys**, provide diagnostic support and logging during system crashes or errors. These callbacks, while appearing legitimate, are crucial forensic artifacts that can indicate normal driver operations or expose malware activity. Anomalies, such as callbacks pointing to unknown modules, could suggest rootkits or stealthy infections, necessitating further investigation to confirm the integrity of the system.

Select 5 events from each memory dump and their callbacks and describe both.

1-Analysis of the Clean Memory Dump events & their callbacks.

Event Type	Callback Address	Module	Details
Shutdown Notification	0xba0c8c6a	VIDEOPRT.SYS	Ensures proper handling of VGA drivers during shutdown, maintaining system stability.
File System Monitoring	0xba6e4876	sr.sys	Monitors file system changes, particularly for System Restore, ensuring data integrity.
Network Bug Check	0xba5cb5ef	NDIS.sys	Handles bug checks for NDIS miniport drivers, preventing crashes from affecting network stability.
USB Port Diagnostics	0xba01d1a2	USBPORT.SYS	Provides diagnostics during system crashes for USB devices, aiding in debugging.
File System Recovery	0xba5815ec	Fs_Rec.SYS	Handles file system recovery notifications during shutdown, ensuring file system consistency.
Event Type	Callback Address	Module	Details

Table 7: Table of the Clean Memory Dump events & their callbacks.

The analysis above reveals that all callbacks in the clean memory dump point to trusted modules with appropriate memory addresses, indicating legitimacy. Their behaviour is normal and consistent with expectations for a Windows XP SP2 environment. Consequently, no indications of malicious activity were identified, as the callbacks align with legitimate system functions and operations.

2-Analysis of the Clean Memory Dump events & their callbacks.

Event Type	Callback Address	Module	Details
Shutdown Notification (RDP)	0xf815bc6a	VIDEOPRT.SYS	Handles RDP driver during shutdown. While legitimate, RDP components are often targeted by malware.
File System Monitoring	0xf84d6876	sr.sys	Tracks file system changes for System Restore. Normal behaviour for maintaining system integrity.
ACPI Bug Check	0x806d77cc	hal.dll	Manages hardware abstraction layer-related bug checks. Essential for low-level hardware functions.
SMBIOS Diagnostics	0xf8b5eab8	mssmbios.sys	Provides diagnostics for SMBIOS-related events. Could be abused for stealthy attacks.
RAW File System Handling	0x805cdef4	ntoskrnl.exe	Handles notifications for the RAW file system. Normal but critical for low-level file operations.

Table 8: Table of the infected Memory Dump events & their callbacks.

The analysis above reveals that most callbacks in the infected dump are associated with trusted modules, indicating largely legitimate system behaviour. However, certain entries, such as **VIDEOPRT.SYS** and **mssmbios.sys**, raise suspicion. The callback linked to **VIDEOPRT.SYS** is associated with RDP functionality, which could indicate potential misuse, as malware often exploits RDP for persistence or lateral movement. Similarly, the involvement of **mssmbios.sys** in diagnostics might suggest manipulation for stealthy attacks. While the infected dump generally exhibits legitimate callbacks, these specific entries warrant further investigation due to their potential exploitation in malicious activities.

Comparison Between Clean and Infected Dumps

Aspect	Clean Dump	Infected Dump
Overall Behaviour	Normal, trusted modules.	Mostly normal, but some callbacks could be exploited by malware.
Suspicious Modules	None identified.	VIDEOPRT.SYS (RDP), mssmbios.sys (SMBIOS diagnostics).
Critical Callbacks	VGA, USB diagnostics, file system recovery, and bug checks.	RDP, SMBIOS, and ACPI bug checks.
Indication of Malware Activity	None.	Potential misuse of RDP and SMBIOS components.

Conclusion

The analysis of the clean and infected memory dumps highlights key differences in the behaviour of kernel callbacks, revealing insights into the system's event handling mechanisms and potential signs of malicious activity. The clean dump exhibited entirely legitimate callbacks, all pointing to trusted modules like **VIDEOPRT.SYS**, **sr.sys**, and **NDIS.sys**, with no evidence of tampering or malware. In contrast, the infected dump showed largely normal behaviour but raised concerns about specific callbacks, particularly those associated with **VIDEOPRT.SYS** and **mssmbios.sys**. These entries, while appearing legitimate, involve components like RDP and SMBIOS, which are often targeted for exploitation by malware. The potential misuse of RDP for persistence or lateral movement and the diagnostic role of **mssmbios.sys** warrant further investigation to confirm the system's integrity. Overall, while the infected dump does not show overwhelming evidence of malware, the presence of callbacks linked to high-risk components highlight the need for deeper forensic analysis to rule out stealthy infections.

5.5-List all the DLLs (including the hidden ones) of both memory dumps and identify, for those that are common, the ones that are in different folders. Justify whether this can be an indicator of compromise. (10%)

Dynamic Link Libraries (DLLs) are modular components of software that contain reusable code, data, and resources shared across multiple applications. They enable programs to execute common functions without embedding the functionality in their own codebase, thereby promoting efficiency and modularity. (Fernández-Álvarez, P. and Rodríguez, R.J 2023). In a Windows operating system, each process maintains a record of its loaded DLLs, which are tracked in the **Process Environment Block (PEB)** through doubly linked lists. These lists provide critical information, such as the full paths of loaded DLLs, that can be analysed for anomalies.

In the context of **memory forensics** and **malware analysis**, DLLs often become a target for attackers who attempt to unlink, hide, or inject malicious DLLs into process memory. This is a common technique to conceal malicious activity, persist in the system, or execute unauthorized code. By enumerating all DLLs, including hidden and unlinked ones, forensic analysts can identify suspicious discrepancies, detect signs of code injection, extract DLLs as Portable Executable (PE) files for further analysis, and uncover hidden backdoors or malware artifacts.

In this investigation, I will analyse and compare the DLLs from the **clean memory dump(windowCW2s.raw)** and **the infected memory dump(cw2_Machine4Infected.dump)**. Using Volatility plugins like **dlllist**, **ldrmodules**, and **malfind**, I aim to identify all DLLs, including hidden and anomalous ones, and determine discrepancies—such as DLLs loaded from unexpected directories—that could serve as **indicators of compromise (IoCs).**

Extracting All DLLs (Including Hidden Ones) in both Memory Dumps

To identify all DLLs in the memory dumps, I will use the **dlllist** plugin in Volatility to enumerate all DLLs loaded by processes in each dump. The clean memory dump is windowCW2s.raw, The infected dump is cw2_Machine4Infected.dump. This analysis will include explicitly loaded DLLs as well as hidden ones. To detect hidden DLLs, I will utilize the ldrmodules plugin, which identifies discrepancies among the three primary lists of loaded modules: InLoad, InInit, and InMem. These discrepancies often indicate hidden DLLs, providing critical insights for malware analysis (Balaoura, S., 2018).

Extracting All DLLs (Including Hidden Ones) in the clean dump (windowCW2s.raw)

Commands used:

vol.py -f windowCW2s.raw --profile=WinXPSP2x86 dlllist > clean_dlls.txt

This command Extract all DLLs loaded into the address space of each process in the clean dump, including their file paths and save it to txt file, Where the **-f** flag specifies the memory dump file to analyse while the --profile=WinXPSP2x86 tells Volatility that the memory dump is from a Windows XP Service Pack 2 system running on a 32-bit architecture and the > pass the output to the text file clean_dlls.txt for further analysis.

```
kali@kali:/media/testShare$ vol.py -f windowCW2s.raw --profile=WinXPSP2x86 dlllist > clean_dlls.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$
```

Figure 52: extracting all dlls and save them the txt file clean_dll.txt

```
 GNU nano 4.9.2                                                    clean_dlls.txt
************************************************************************
System pid:      4
Unable to read PEB for task.
************************************************************************
smss.exe pid:    560
Command line : \SystemRoot\System32\smss.exe

Base             Size  LoadCount LoadTime                       Path
---------- ---------- ---------- ------------------------------ ----
0x48580000     0xf000     0xffff                                \SystemRoot\System32\smss.exe
0x7c900000    0xb2000     0xffff                                C:\WINDOWS\system32\ntdll.dll
************************************************************************
```

Figure 53: the output of the dllist command displaying in the txt file clean_dlls.txt.

As we can see above in **Figure 105 and 106**, I produced a list of all dlls in the clean dump and saved them to the file clean_dlls.txt(white) for further analysis

vol.py -f windowCW2s.raw --profile=WinXPSP2x86 ldrmodules > clean_ldrmodules.txt

This command analyses the address space of each process in the clean memory dump to identify hidden DLLs and discrepancies. By examining three Windows lists – LoadOrder, InitializationOrder, and MemoryMappedOrder – it detects any inconsistencies, such as missing or unlinked DLLs, which could indicate anomalies. The detailed output, including memory addresses and file paths, is saved to the file clean_ldrmodules.txt for further analysis and comparison.

```
kali@kali:/media/testShare$ vol.py -f windowCW2s.raw --profile=WinXPSP2x86 ldrmodules > clean_ldrmodules.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$ nano clean_ldrmodules.txt
kali@kali:/media/testShare$
```

Figure 54: Extracting all hidden DLLs and discrepancies and save them to txt file clean_ldrmodules.txt.

```
 GNU nano 4.9.2                                                    clean_ldrmodules.txt
Pid      Process              Base       InLoad InInit InMem MappedPath
-------- -------------------- ---------- ------ ------ ----- ----------
       4 System               0x7c900000 False  False  False \WINDOWS\system32\ntdll.dll
     560 smss.exe             0x48580000 True   False  True  \WINDOWS\system32\smss.exe
     560 smss.exe             0x7c900000 True   True   True  \WINDOWS\system32\ntdll.dll
     616 csrss.exe            0x00470000 False  False  False \WINDOWS\Fonts\vgasys.fon
```

Figure 55: the output of the ldrmodules command displaying in the txt file clean_ ldrmodules.txt.

As we can see above in **Figure 107 and 108**, I produced a list of all hidden DLLs and discrepancies in the clean dump and saved them to the file clean_ ldrmodules.txt(white) for further analysis.

vol.py -f windowCW2s.raw --profile=WinXPSP2x86 malfind > clean_malfind.txt

This command scans the memory dump for hidden or injected code by identifying suspicious memory regions that are executable but not backed by legitimate files or modules. The **malfind** plugin detects signs of code injection, such as memory marked as executable (PAGE_EXECUTE_READWRITE) or suspicious process injections. The findings, including process IDs, virtual addresses, and hex dumps of the injected code, are saved to **clean_malfind.txt** for further analysis, which can help identify malware or other malicious activity.

```
kali@kali:/media/testShare$ vol.py -f windowCW2s.raw --profile=WinXPSP2x86 malfind > clean_malfind.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$ nano clean_malfind.txt
kali@kali:/media/testShare$
```

Figure 56: detecting all hidden/injected code and save it to txt file clean_malfind.txt.

```
  GNU nano 4.9.2                                                clean_malfind.txt
Process: csrss.exe Pid: 616 Address: 0x7f6f0000
Vad Tag: Vad  Protection: PAGE_EXECUTE_READWRITE
Flags: Protection: 6

0x000000007f6f0000  c8 00 00 00 b6 01 00 00 ff ee ff ee 08 70 00 00   .............p..
0x000000007f6f0010  08 00 00 00 00 fe 00 00 00 00 10 00 00 20 00 00   ................
0x000000007f6f0020  00 02 00 00 00 20 00 00 8d 01 00 00 ff ef fd 7f   ................
0x000000007f6f0030  03 00 08 06 00 00 00 00 00 00 00 00 00 00 00 00   ................
```

Figure 57:the output of the malfind command displaying in the txt file clean_malfind.txt.

As we can see above in **Figure 109 and 110**, I produced a list of all hidden/injected code in the clean dump and saved them to the file clean_ ldrmodules.txt (white) for further analysis.

Extracting All DLLs (Including Hidden Ones) in the clean dump (cw2_Machine4Infected.dump)

Commands used:

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 dlllist > infected_dlls.txt

This command extracts all DLLs loaded into the address space of each process in the infected memory dump. It lists the full file paths, memory addresses, and associated processes for each DLL, providing a detailed view of the modules loaded during the system's runtime. The results are saved to **infected_dlls.txt** (whit) for further analysis, allowing investigators to identify any anomalies or suspicious DLLs that may indicate compromise.

```
kali@kali:/media/testShare$ vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 dlllist > infected_dlls.txt
Volatility Foundation Volatility Framework 2.6.1
kali@kali:/media/testShare$ nano infected_dlls.txt
kali@kali:/media/testShare$
```

Figure 58: extracting all dlls and save them the txt file infected_dlls.txt

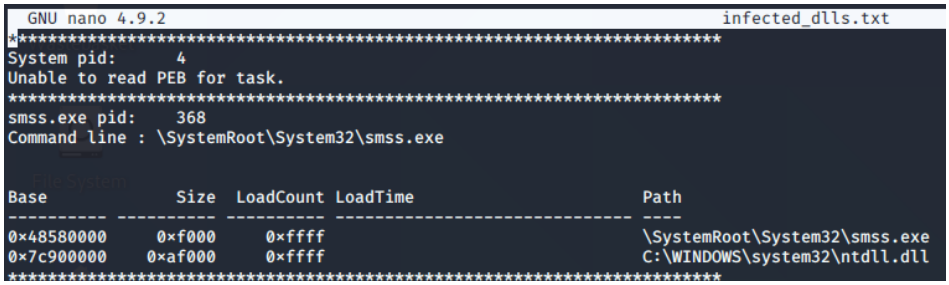


Figure 59: the output of the dllist command displaying in the txt file infected_dlls.txt.

As we can see above in **Figure 111 and 112**, I produced a list of all dlls in the infected dump and saved them to the file infected_dlls.txt for further analysis.

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 ldrmodules > infected_ldrmodules.txt

This command identifies hidden DLLs and discrepancies within the address space of each process by analysing three Windows lists: LoadOrder, InitializationOrder, and MemoryMappedOrder. It detects any DLLs that are unlinked, missing, or inconsistently mapped across these lists, which can indicate potential malware or suspicious activity. The command then outputs detailed information, including memory addresses and file paths, to infected_ldrmodules.txt (white) for further analysis.

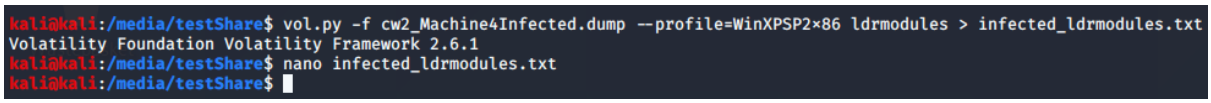


Figure 60: Extracting all hidden DLLs and discrepancies and save them to txt file infected_ldrmodules.txt.

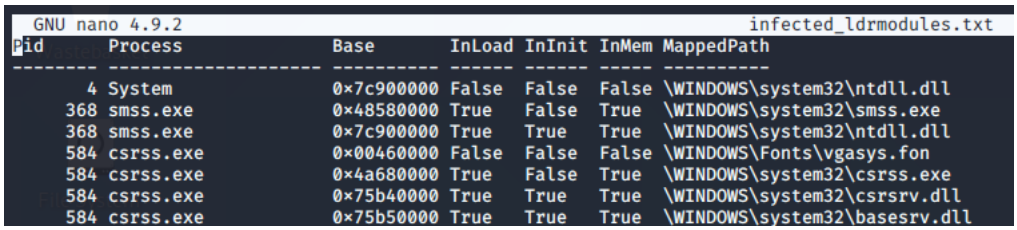


Figure 61: the output of the ldrmodules command displaying in the txt file infected_ldrmodules.txt.

As we can see above in **Figure 113 and 114**, I produced a list of all hidden DLLs and discrepancies in the infected dump and saved them to the file infected_ldrmodules.txt for further analysis.

vol.py -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 malfind > infected_malfind.txt

This command scans the memory dump for hidden or injected malicious code within processes using the **malfind** plugin. It identifies suspicious memory regions, such as those with executable permissions that are not backed by legitimate files, which are often used by malware to hide its presence. The output, including process IDs, memory addresses, and details of the suspicious regions, is saved **to infected_malfind.txt** for further analysis.

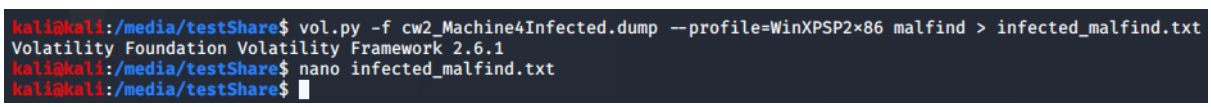


Figure 62: detecting all hidden/injected code and save it to txt file infected_malfind.txt.

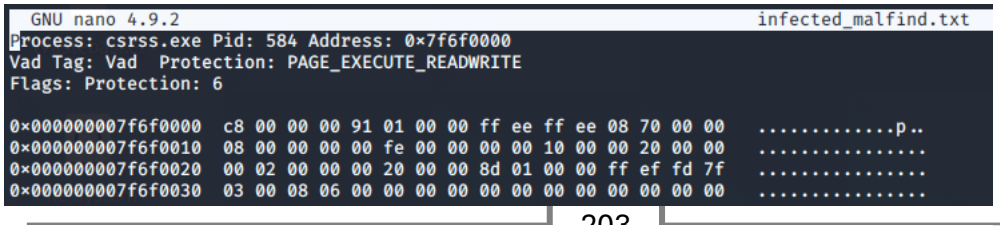


Figure 63: the output of the malfind command displaying in the txt file infected_malfind.txt.

As we can see above in **Figure 115 and 116**, I produced a list of all hidden/injected code in the infected dump and saved them to the file infected_ ldrmodules.txt (white) for further analysis.

Using Python Script to Parse and Combine DLL Information

I used the **parse_hidden_dlls.py** script to identify all loaded DLLs, including any hidden or injected ones, within memory dumps. The script automates the extraction process by parsing outputs from multiple tools that retrieve DLL information. It then combines and deduplicates the results into comprehensive lists for both clean and infected memory dumps. By consolidating this data, I ensured that no DLLs, especially hidden or anomalous ones, were overlooked. This method allowed me to efficiently detect discrepancies or unexpected DLLs, simplifying the process of identifying suspicious activity within the memory dumps.

The script used:

GNU nano 4.9.2 parse_hidden_dlls.py

```
def extract_dll_info(input_file):
    """
    This function reads a file line by line to find DLL or EXE paths.
    - It checks for lines containing a backslash (\), which indicates a file path.
    - It looks for lines ending with '.dll' or '.exe' (case-insensitive).
    - The last column of the line (the actual file path) is extracted and added to a list.

    input_file: The file to read from (e.g., a Volatility output).
    returns: A list of extracted DLL or EXE paths.
    """
    dll_paths = []  # List to store extracted file paths
    with open(input_file, 'r') as file:  # Open the file in read mode
        for line in file:  # Read each line
            if '\\' in line and ('.dll' in line.lower() or '.exe' in line.lower()):
                # If line has a backslash and contains '.dll' or '.exe'
                path = line.strip().split()[-1]  # Get the last column (the path)
                dll_paths.append(path)  # Add the path to the list
    return dll_paths  # Return the list of paths

def merge_dll_lists(dll_files):
    """
    This function combines DLL/EXE paths from multiple files and removes duplicates.
    - It uses a set to avoid duplicate entries.
    - It calls extract_dll_info() to process each file and update the set.

    dll_files: A list of file names containing DLL/EXE paths.
    returns: A list of unique DLL/EXE paths.
    """
    all_dlls = set()  # Use a set to store unique DLL/EXE paths
    for file in dll_files:  # Loop through each file in the list
        all_dlls.update(extract_dll_info(file))  # Extract paths and update the set
    return list(all_dlls)  # Convert the set back to a list and return

def save_to_file(dll_list, output_file):
    """
    This function saves a list of DLL/EXE paths to an output file.
    - It sorts the paths alphabetically before writing to the file.
    - Each path is written on a new line.

    dll_list: List of DLL/EXE paths.
    output_file: Name of the file to save the paths.
    """
    with open(output_file, 'w') as file:  # Open the file in write mode
        for path in sorted(dll_list):  # Sort the paths and write each one
            file.write(path + "\n")  # Write each path followed by a new line

# ── Main Section ──
# List of clean files (these are safe or benign files)
clean_files = ["clean_dlls.txt", "clean_ldrmodules.txt", "clean_malfind.txt"]
# List of infected files (these contain suspicious or malicious DLLs)
infected_files = ["infected_dlls.txt", "infected_ldrmodules.txt", "infected_malfind.txt"]

# Extract and merge DLL paths from clean files
clean_dlls = merge_dll_lists(clean_files)
# Extract and merge DLL paths from infected files
infected_dlls = merge_dll_lists(infected_files)

# Save the combined clean DLLs to a file
save_to_file(clean_dlls, "all_clean_dlls.txt")
# Save the combined infected DLLs to a file
save_to_file(infected_dlls, "all_infected_dlls.txt")

# Print a success message so we know the script finished correctly
print("[+] Combined DLLs saved to 'all_clean_dlls.txt' and 'all_infected_dlls.txt'.")
```

Figure 64: The script parse_hidden_dlls.py.

In the script above in **Figure 117**, I designed a process to extract, consolidate, and analyse DLL paths from multiple Volatility plugin outputs, including potential hidden or injected DLLs. The **extract_dll_info** function reads each input file line-by-line, specifically looking for valid file paths that contain a backslash **(\)** and end with **.dll** or **.exe**. I ensured the extraction

targets only the last column of each line (which typically contains the path) and appends the paths to a list.

Next, I created the **merge_dll_lists** function to process multiple input files (like outputs from **dlllist**, **ldrmodules**, and **malfind** plugins). This function calls **extract_dll_info** for each file and uses a set to eliminate duplicate DLL paths, ensuring only unique entries are included. The deduplicated results are converted back into a sorted list for consistency.

To store the output, I implemented the **save_to_file** function, which takes the combined list of DLL paths and writes each path into a specified output file, line by line.

For this analysis, I applied the process to two sets of input files: one corresponding to the **clean memory dump** and the other to the **infected memory dump**. The clean files included **clean_dlls.txt**, **clean_ldrmodules.txt**, and **clean_malfind.txt**, while the infected files included their respective counterparts. I then merged the DLL paths for each set and saved the results into **all_clean_dlls.txt** and **all_infected_dlls.txt**.

Finally, the script outputs a clear message indicating that the combined DLL lists have been saved. This structured approach allows me to systematically capture all DLLs, including those that may be hidden or malicious, providing a solid foundation for identifying discrepancies between clean and infected dumps.

```
kali@kali:/media/testShare$ python parse_hidden_dlls.py
[+] Combined DLLs saved to 'all_clean_dlls.txt' and 'all_infected_dlls.txt'.
kali@kali:/media/testShare$ nano all_clean_dlls.txt
kali@kali:/media/testShare$ nano all_infected_dlls.txt
```

Figure 65:Running the script & the output.

As it shown in **Figure 118**, after running the script, I received a confirmation message indicating that the combined DLL lists have been successfully saved into two separate files: **all_clean_dlls.txt** for the clean memory dump and **all_infected_dlls.txt** for the infected memory dump.

```
  GNU nano 4.9.2                                    all_clean_dlls.txt
"C:\WINDOWS\system32\VBoxTray.exe"
"C:\WINDOWS\system32\cmd.exe"
"C:\WINDOWS\system32\wuauclt.exe"
C:\WINDOWS\AppPatch\AcAdProc.dll
C:\WINDOWS\AppPatch\AcGenral.DLL
```

Figure 66:The result of the all_clean_dlls.txt.

```
  GNU nano 4.9.2                                    all_infected_dlls.txt
"C:\WINDOWS\system32\wuauclt.exe"
9.0\Reader\Reader_sl.exe
9.0\Reader\Reader_sl.exe"
9.0\Reader\reader_sl.exe
C:\WINDOWS\AppPatch\AcAdProc.dll
C:\WINDOWS\AppPatch\AcGenral.DLL
```

Figure 67: The result of the all_infected_dlls.txt.

Using Python Script to Compare Clean, Infected and Common DLL Lists.

I used the **compare_dlls.py** script to analyse and compare the DLLs extracted from both the clean and infected memory dumps. The script automates the comparison process by loading DLL lists from the clean and infected dumps, identifying unique and common DLLs between

the two datasets. This method highlights discrepancies, such as DLLs that are present only in the infected dump, potentially loaded from suspicious or non-standard locations. By systematically detecting differences, the script simplifies the process of pinpointing anomalies or hidden DLLs that could indicate malicious activity or compromise within the infected memory dump.

The script used:

```
  GNU nano 4.9.2                                                compare_dlls.py
def load_dlls(file_path):
    """
    This function loads DLL paths from a file and stores them in a set.
    - Each line in the file represents a DLL name or path.
    - The `strip()` function removes extra spaces or newlines.
    - Using a set ensures that all DLLs are unique.

    file_path: Path to the file containing DLL names/paths.
    returns: A set of unique DLL names/paths.
    """
    with open(file_path, 'r') as file:  # Open the file in read mode
        return set(line.strip() for line in file)  # Read lines, strip whitespace, and store in a set


def compare_dlls(clean_file, infected_file):
    """
    This function compares two sets of DLLs (from clean and infected systems).
    - It identifies DLLs unique to the infected system.
    - It identifies DLLs unique to the clean system.
    - It also identifies DLLs common to both systems.
    - Results are printed to the terminal.

    clean_file: Path to the file containing DLLs from the clean system.
    infected_file: Path to the file containing DLLs from the infected system.
    """
    clean_dlls = load_dlls(clean_file)  # Load DLLs from the clean system
    infected_dlls = load_dlls(infected_file)  # Load DLLs from the infected system

    # Find differences and intersections between the two sets
    only_in_infected = infected_dlls - clean_dlls  # DLLs unique to the infected system
    only_in_clean = clean_dlls - infected_dlls    # DLLs unique to the clean system
    common_dlls = clean_dlls & infected_dlls      # DLLs common to both systems

    # Print DLLs unique to the infected dump
    print("[+] DLLs unique to the infected dump:")
    for dll in sorted(only_in_infected):  # Sort the results for better readability
        print(dll)

    # Print DLLs unique to the clean dump
    print("\n[+] DLLs unique to the clean dump:")
    for dll in sorted(only_in_clean):  # Sort the results for better readability
        print(dll)

    # Print DLLs common to both dumps
    print("\n[+] Common DLLs:")
    for dll in sorted(common_dlls):  # Sort the results for better readability
        print(dll)


# --- Main Section ---
# Compare DLLs between clean and infected dumps
# Input files:
# - 'all_clean_dlls.txt' contains DLLs from the clean system.
# - 'all_infected_dlls.txt' contains DLLs from the infected system.
compare_dlls("all_clean_dlls.txt", "all_infected_dlls.txt")
```

Figure 68: The script compare_dlls.py

In the script above in **Figure 121,** I designed a process to compare DLL paths between clean and infected memory dumps systematically. The **load_dlls** function reads a given input file line-by-line, stripping unnecessary whitespace and consolidating all the DLL paths into a **set**. I chose a set data structure to ensure that duplicate DLL entries are removed efficiently, maintaining only unique DLL paths.

Next, the **compare_dlls** function performs a comparison between the DLL paths extracted from the clean memory dump file and the infected memory dump file. It uses three key set operations to categorize the DLLs:

1. **only_in_infected** identifies DLLs present in the infected dump but absent in the clean dump, which could indicate injected or hidden malicious DLLs.
2. **only_in_clean** identifies DLLs that are missing in the infected dump but exist in the clean dump, which may suggest tampering or removal of critical files.

3. **common_dlls** identifies DLLs that are shared between the two dumps, representing standard or normal behaviour.

To make the results more readable, the script sorts the DLLs alphabetically using the **sorted ()** function before printing them. It outputs three clear sections:

1. DLLs unique to the infected dump.
2. DLLs unique to the clean dump.
3. DLLs that are common to both dumps.

For this analysis, I ran the comparison between two pre-generated DLL list files:

- **all_clean_dlls.txt**: Consolidated list of DLLs extracted from the clean memory dump.
- **all_infected_dlls.txt**: Consolidated list of DLLs extracted from the infected memory dump, including potential hidden or injected DLLs.

The script outputs each set of results in a clear, structured manner, which helps pinpoint discrepancies between the two dumps. Identifying DLLs that are unique to the infected dump can highlight **malicious injections or hidden files**, while missing DLLs from the clean dump could indicate compromise through removal or tampering.

Extracting DLLs Unique to the Infected Dump

The following DLLs are present only in the infected memory dump and do not appear in the clean memory dump. These DLLs as it shown below in figure 42 and executables are considered suspicious and may indicate potential compromise, malicious activity, or injected files:

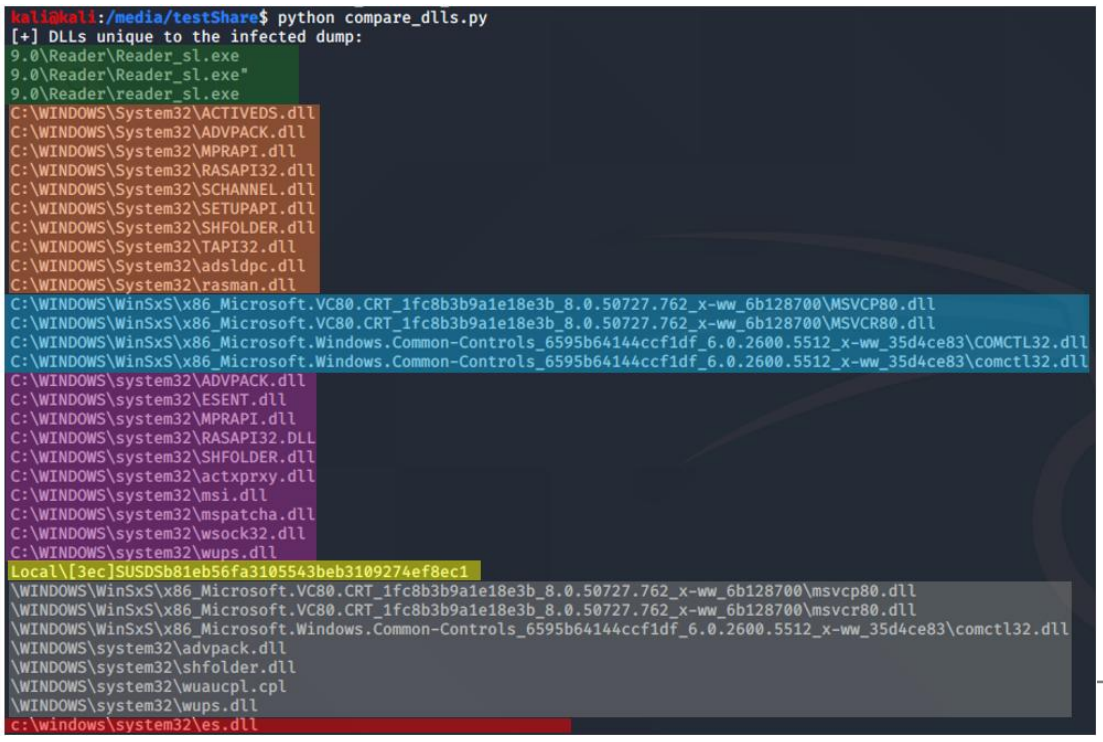


Figure 69: DLLs Unique to the Infected Dump.

1-Non-Standard Executables with Irregular Naming (Green)

- **9.0\Reader\Reader_sl.exe**
- **9.0\Reader\Reader_sl.exe"** (note the trailing quotation mark)
- **9.0\Reader\reader_sl.exe**

Why it's Suspicious: The naming inconsistency (uppercase and lowercase mix, trailing quotation mark) is unusual for legitimate files. These irregularities could indicate file tampering, injection, or obfuscated malware executables placed in non-standard paths (e.g., "9.0").

2-System32 DLLs Unique to the Infected Dump(orange)

The following files exist in the System32 directory in the infected dump but do not appear in the clean dump:

- **C:\WINDOWS\System32\ACTIVEDS.dll**
- **C:\WINDOWS\System32\ADVPACK.dll**
- **C:\WINDOWS\System32\MPRAPI.dll**
- **C:\WINDOWS\System32\RASAPI32.dll**
- **C:\WINDOWS\System32\SCHANNEL.dll**
- **C:\WINDOWS\System32\SETUPAPI.dll**
- **C:\WINDOWS\System32\SHFOLDER.dll**
- **C:\WINDOWS\System32\TAPI32.dll**
- **C:\WINDOWS\System32\adsldpc.dll**
- **C:\WINDOWS\System32\rasman.dll**

Why it's Suspicious: These DLLs are critical to Windows operations, but their unexpected presence in the infected dump without corresponding versions in the clean dump suggests potential DLL replacement, tampering, or injection by malware.

3-WinSxS DLLs Unique to the Infected Dump(blue)

These files exist in the WinSxS (Windows Side-by-Side) directory, which is typically used for system compatibility and file versions. However, their presence here is suspicious:

- **C:\WINDOWS\WinSxS\x86_Microsoft.VC80.CRT_1fc8b3b9a1e18e3b_8.0.50727.762_x-ww_6b128700\MSVCP80.dll**
- **C:\WINDOWS\WinSxS\x86_Microsoft.VC80.CRT_1fc8b3b9a1e18e3b_8.0.50727.762_x-ww_6b128700\MSVCR80.dll**
- **C:\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.5512_x-ww_35d4ce83\COMCTL32.dll**
- **C:\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.5512_x-ww_35d4ce83\comctl32.dll**

Why it's Suspicious: While WinSxS is a legitimate directory, malware often places tampered versions of system DLLs here to evade detection and achieve **DLL hijacking**.

4-DLLs in Lowercase Paths and Shadowed Files(purple)

These DLLs appear in system32 or alternative paths in a way that conflicts with naming conventions:

- **C:\WINDOWS\system32\ADVPACK.dll**
- **C:\WINDOWS\system32\ESENT.dll**
- **C:\WINDOWS\system32\MPRAPI.dll**
- **C:\WINDOWS\system32\RASAPI32.DLL**
- **C:\WINDOWS\system32\SHFOLDER.dll**
- **C:\WINDOWS\system32\actxprxy.dll**
- **C:\WINDOWS\system32\msi.dll**
- **C:\WINDOWS\system32\mspatcha.dll**
- **C:\WINDOWS\system32\wsock32.dll**
- **C:\WINDOWS\system32\wups.dll**

Why it's Suspicious: Duplicate or lowercase file paths can indicate malicious injection or shadowed files that load malicious code while impersonating legitimate DLLs.

5-Files with Obfuscated or Non-Standard Naming (Yellow)

- **Local\[3ec]SUSDSb81eb56fa3105543beb3109274ef8ec1**

Why it's Suspicious: The obfuscated file name suggests **temporary artifacts** or malware-generated files injected into memory.

6-Additional WinSxS and System32 Shadowed Files (grey)

- **\WINDOWS\WinSxS\x86_Microsoft.VC80.CRT_1fc8b3b9a1e18e3b_8.0.50727.762_x-ww_6b128700\msvcp80.dll**
- **\WINDOWS\WinSxS\x86_Microsoft.VC80.CRT_1fc8b3b9a1e18e3b_8.0.50727.762_x-ww_6b128700\msvcr80.dll**
- **\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.5512_x-ww_35d4ce83\comctl32.dll**
- **\WINDOWS\system32\advpack.dll**
- **\WINDOWS\system32\shfolder.dll**
- **\WINDOWS\system32\wuaucpl.cpl**
- **\WINDOWS\system32\wups.dll**

Why it's Suspicious: The presence of identical DLLs across alternate paths indicates possible **DLL hijacking** or injection techniques.

7-Suspicious Lowercase System32 File (Red)

- **c:\windows\system32\es.dll**

Why it's Suspicious: The lowercase file path is inconsistent with standard Windows conventions and may suggest malicious injection or replacement.

Extracting DLLs Unique to the clean Dump

The following DLLs as it shown in **Figures 123 &124** are unique to the clean memory dump, which was generated using a VirtualBox VM. These DLLs and executables are considered benign and reflect a virtualized environment setup, normal system operations, and legitimate dependencies:

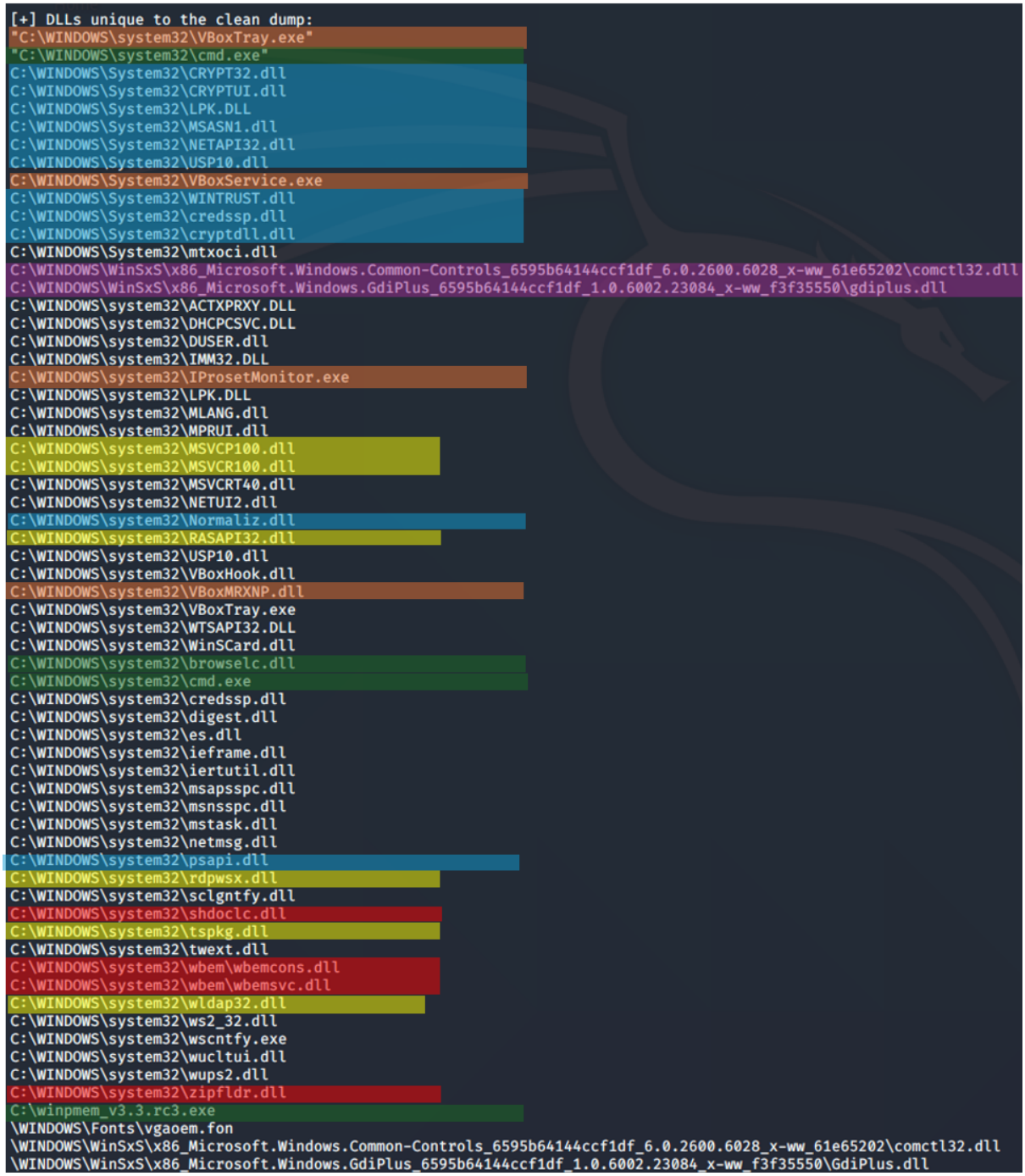


Figure 70: DLLs Unique to the clean Dump 1/2.

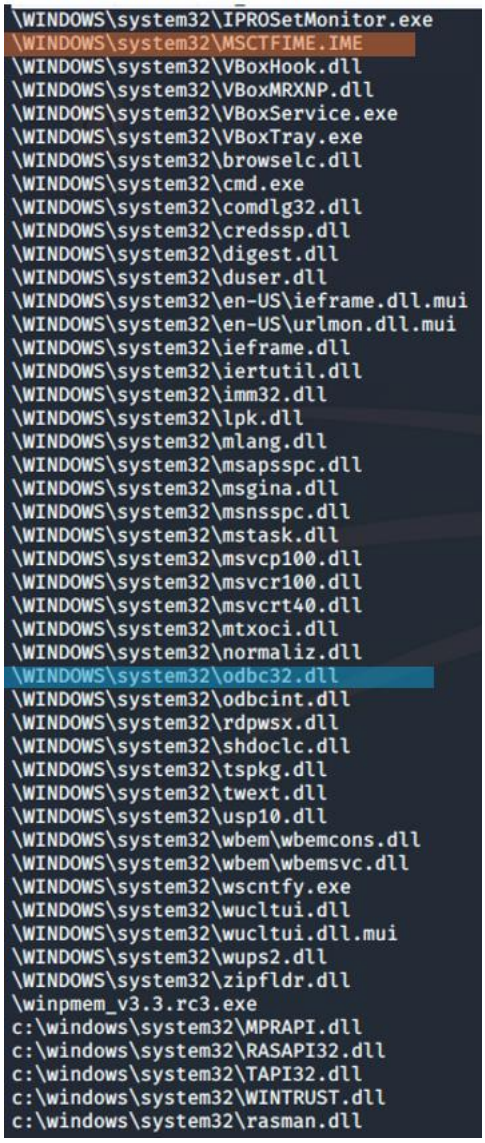


Figure 71: DLLs Unique to the clean Dump 2/2.

1-VirtualBox-Specific Executables and DLLs (Orange)

The following files are unique to the clean dump and are associated with VirtualBox Guest Additions, which are installed to enable smooth interaction between the guest operating system and the host:

- **C:\WINDOWS\system32\VBoxTray.exe**
- **C:\WINDOWS\System32\VBoxService.exe**
- **C:\WINDOWS\system32\VBoxHook.dll**
- **C:\WINDOWS\system32\VBoxMRXNP.dll**
- **C:\WINDOWS\system32\IPROSetMonitor.exe**
- **C:\WINDOWS\system32\MSCTFIME.IME**

Why it's not Suspicious:

These files are related to **VirtualBox Guest Additions** services, including clipboard sharing, display resizing, and file transfer between the host and guest. Their presence is expected in virtualized environments and is not an indicator of malicious activity.

2-Command Line and System Utilities(green)

- **C:\WINDOWS\system32\cmd.exe**
- **C:\WINDOWS\system32\browselc.dll**
- **C:\winpmem_v3.3.rc3.exe**

Why it's not Suspicious:

- **cmd.exe** is the standard Windows Command Prompt executable.
- **browselc.dll** is associated with browsing capabilities for Windows Explorer.
- **winpmem_v3.3.rc3.exe** is the tool I used to extract the memory dump, and its inclusion is part of the analysis process, not a compromise.

3-System32 DLLs Related to Standard Windows Operations(blue)

These DLLs are part of standard Windows functionality and provide critical services like networking, cryptographic operations, UI rendering, and system configuration:

- **C:\WINDOWS\System32\CRYPT32.dll**
- **C:\WINDOWS\System32\CRYPTUI.dll**
- **C:\WINDOWS\System32\LPK.DLL**
- **C:\WINDOWS\System32\MSASN1.dll**
- **C:\WINDOWS\System32\USP10.dll**
- **C:\WINDOWS\System32\NETAPI32.dll**
- **C:\WINDOWS\System32\WINTRUST.dll**
- **C:\WINDOWS\System32\credssp.dll**
- **C:\WINDOWS\System32\cryptdll.dll**
- **C:\WINDOWS\system32\Normaliz.dll**
- **C:\WINDOWS\system32\odbc32.dll**
- **C:\WINDOWS\system32\psapi.dll**

Why it's not Suspicious:

These DLLs support various legitimate system operations, including secure communication (credssp.dll), cryptography (cryptdll.dll, CRYPT32.dll), user interface rendering (USP10.dll), and networking (NETAPI32.dll). Their presence is normal in a Windows environment.

4-WinSxS-Specific DLLs(purple)

These DLLs are part of the **Windows Side-by-Side (WinSxS)** directory, used for storing multiple versions of system files to ensure compatibility with software:

- **C:\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.6028_x-ww_61e65202\comctl32.dll**
- **C:\WINDOWS\WinSxS\x86_Microsoft.Windows.GdiPlus_6595b64144ccf1df_1.0.6002.23084_x-ww_f3f35550\gdiplus.dll**

Why it's not Suspicious:
The WinSxS files allow for backward compatibility, ensuring that applications depending on older versions of system DLLs can still function. These files are legitimate and commonly seen on clean systems.

5-Standard System32 Networking and Security DLLs (Yellow)
The following DLLs are critical for Windows operations related to networking, RDP, and security:

- **C:\WINDOWS\system32\RASAPI32.dll**
- **C:\WINDOWS\system32\tspkg.dll**
- **C:\WINDOWS\system32\rdpwsx.dll**
- **C:\WINDOWS\system32\msvcp100.dll**
- **C:\WINDOWS\system32\msvcr100.dll**
- **C:\WINDOWS\system32\wldap32.dll**

Why it's not Suspicious:
These DLLs are standard components of the Windows OS, supporting **Remote Desktop Protocol** (RDP), LDAP-based directory services, and C++ runtime libraries (MSVCP100/MSVCR100). Their inclusion aligns with expected system behaviour.

6-Other Miscellaneous System32 Files

- **C:\WINDOWS\system32\wbem\wbemcons.dll**
- **C:\WINDOWS\system32\wbem\wbemsvc.dll**
- **C:\WINDOWS\system32\shdoclc.dll**
- **C:\WINDOWS\system32\zipfldr.dll**

Why it's not Suspicious:
These files are related to Windows Management Instrumentation (WMI), user interface rendering, and ZIP file folder support. Their presence is normal in clean systems.

Extracting DLLs common to both dumps.

```
[+] Common DLLs:
"C:\WINDOWS\system32\wuauclt.exe"
C:\WINDOWS\AppPatch\AcAdProc.dll
C:\WINDOWS\AppPatch\AcGenral.DLL
C:\WINDOWS\Explorer.EXE
C:\WINDOWS\System32\ATL.DLL
C:\WINDOWS\System32\CLBCATQ.DLL
C:\WINDOWS\System32\CLUSAPI.DLL
C:\WINDOWS\System32\COMRes.dll
C:\WINDOWS\System32\CSCDLL.dll
C:\WINDOWS\System32\Cabinet.dll
C:\WINDOWS\System32\MSACM32.dll
C:\WINDOWS\System32\MSIDLE.DLL
C:\WINDOWS\System32\MSWSOCK.DLL
C:\WINDOWS\System32\NETRAP.dll
C:\WINDOWS\System32\NETUI0.dll
C:\WINDOWS\System32\NETUI1.dll
C:\WINDOWS\System32\NTMARTA.DLL
C:\WINDOWS\System32\PSAPI.DLL
C:\WINDOWS\System32\RASDLG.dll
C:\WINDOWS\System32\RESUTILS.DLL
```

Figure 72:A sample of the common dlls in both dumps.

The below table (8) is an analysis of the DLLs that are common between the clean and infected dumps. The table explains the purpose and behaviour of each DLL, along with their relevance in a Windows environment.

DLL File	Location	Description	Relevance
wuauclt.exe	C:\WINDOWS\system32\	Windows Update AutoUpdate Client. Manages automatic Windows updates.	Normal system behaviour.
AcAdProc.dll, AcGenral.DLL	C:\WINDOWS\AppPatch\	Windows compatibility DLLs for application patching and runtime adjustments.	Legitimate Windows compatibility.
Explorer.EXE	C:\WINDOWS\	Windows Explorer process for GUI navigation and file management.	Core Windows process.
ATL.DLL	C:\WINDOWS\System32\	Active Template Library (ATL) DLL for COM object creation.	Supports COM-based applications.
CLBCATQ.DLL	C:\WINDOWS\System32\	Component Services DLL for COM and DCOM registration.	Normal COM component functionality.
MSACM32.dll	C:\WINDOWS\System32\	Microsoft Audio Compression Manager library for audio codecs.	Required for multimedia support.
NETAPI32.dll	C:\WINDOWS\System32\	Provides APIs for network management and services.	Supports networking functionality.
PSAPI.DLL	C:\WINDOWS\System32\	Process Status API DLL used to query process and memory information.	Standard process management tool.
svchost.exe	C:\WINDOWS\System32\	Generic host process for Windows services.	Required for Windows services.
COMCTL32.dll	C:\WINDOWS\system32\	Common Controls DLL for standard Windows UI elements.	Provides UI components.
CRYPT32.dll	C:\WINDOWS\system32\	Cryptographic Services DLL for encrypting and decrypting data.	Essential for secure operations.
KERNEL32.dll	C:\WINDOWS\system32\	Core DLL providing system kernel functions like memory management.	Critical system component.
GDI32.dll	C:\WINDOWS\system32\	Graphics Device Interface DLL for rendering graphics.	Supports graphics rendering.
USER32.dll	C:\WINDOWS\system32\	Handles user interface components like windows, buttons, and text input.	Critical UI system file.
ADVAPI32.dll	C:\WINDOWS\system32\	Provides advanced APIs for managing security and registry.	Core Windows security component.
RPCRT4.dll	C:\WINDOWS\system32\	Remote Procedure Call (RPC) runtime library.	Enables inter-process communication.
SHELL32.dll	C:\WINDOWS\system32\	Provides Windows shell APIs for file and folder operations.	Core OS functionality.
WININET.dll	C:\WINDOWS\system32\	Windows Internet API DLL for HTTP and FTP protocols.	Required for internet connectivity.

WS2_32.dll, WSOCK32.dll	C:\WINDOWS\system32\	Windows Sockets DLLs for networking and internet operations.	Supports TCP/IP and UDP protocols.
schannel.dll	C:\WINDOWS\system32\	Secure Channel DLL for implementing TLS/SSL protocols.	Ensures secure communications.
mspatcha.dll	C:\WINDOWS\System32\	Microsoft Patch API for applying patches to executable files.	Used for system updates.
TAPI32.dll	C:\WINDOWS\system32\	Telephony API DLL for handling telephone-related communications.	Supports telephony services.
ShimEng.dll	C:\WINDOWS\system32\	Shim Engine DLL for application compatibility layers.	Ensures software compatibility.
VSSAPI.DLL	C:\WINDOWS\system32\	Volume Shadow Copy Service API DLL.	Required for backups and snapshots.
WLDAP32.dll	C:\WINDOWS\system32\	LDAP client library for directory services.	Enables LDAP-based authentication.
SFC.dll, SFC_OS.dll	C:\WINDOWS\system32\	System File Checker DLLs for protecting system files.	Maintains system integrity.
wbem*.dll	C:\WINDOWS\system32\wbem\	Windows Management Instrumentation (WMI) DLLs.	Enables system monitoring and management.

Table 9: common DLL of both dumps.

Identifying DLLs in Different Folders

To begin, I analysed the DLL lists extracted from both the clean and infected memory dumps. During this process, I noticed that several common DLLs were in different directories between the two dumps. Below is a detailed comparison of these findings in

DLL Name	Infected Path	Clean Path	Observation
ADVPACK.dll	C:\WINDOWS\System32\ADVPACK.dll	C:\WINDOWS\system32\advpack.dll	Same file name but different letter case and path.
RASAPI32.dll	C:\WINDOWS\System32\RASAPI32.dll	c:\windows\system32\RASAPI32.dll	Case sensitivity difference; potentially benign on Windows.
SHFOLDER.dll	C:\WINDOWS\System32\SHFOLDER.dll	C:\WINDOWS\system32\shfolder.dll	Same DLL but mismatched directory paths.
MPRAPI.dll	C:\WINDOWS\System32\MPRAPI.dll	c:\windows\system32\MPRAPI.dll	Appears in both dumps, path casing differs.
COMCTL32.dll	C:\WINDOWS\WinSxS\...\COMCTL32.dll	\WINDOWS\system32\comctl32.dll	One in SxS folder (Side-by-Side), another in System32.
MSVCP80.dll	C:\WINDOWS\WinSxS\x86_Microsoft.VC80.CRT\MSVCP80.dll	Absent in clean dump	DLL exists in the infected dump but missing in clean.
MSVCR80.dll	C:\WINDOWS\WinSxS\x86_Microsoft.VC80.CRT\MSVCR80.dll	Absent in clean dump	DLL exists in the infected dump but missing in clean.

Table 11: Identifying DLLs in Different Folders

Observations of table 9:

1. **Path Inconsistencies**:
   Several DLLs appear in **different folders** between the infected and clean dumps. For instance:
   - ADVPACK.dll, SHFOLDER.dll, and RASAPI32.dll have minor variations in their paths, which could result from:
     - System updates.
     - Path caching differences.
     - Legitimate software behaviour.

2. **Side-by-Side (SxS) DLLs**:
   DLLs like COMCTL32.dll and MSVCP80.dll appear in the **WinSxS** folder in the infected dump.
   - **WinSxS** is a legitimate Windows mechanism that allows multiple versions of the same DLL to coexist for compatibility.
   - However, if unexpected DLLs exist in the WinSxS folder, this can **potentially indicate tampering** or malicious injection.
3. **Hidden or Duplicate DLLs**:
   DLLs such as MSVCP80.dll and MSVCR80.dll are present in the infected dump but absent in the clean dump. This discrepancy could indicate:
   - **Malicious payloads** masquerading as legitimate DLLs.
   - A compromise where malicious software injects these DLLs for persistence.

Justification as an Indicator of Compromise

1. **Path Discrepancies**:
   - Differences in DLL paths, especially between System32 and WinSxS, can sometimes indicate **malicious DLL hijacking**.
   - Attackers may place malicious versions of DLLs in unexpected folders, taking advantage of Windows' DLL search order.
2. **Unusual DLL Presence**:
   - DLLs like MSVCP80.dll and MSVCR80.dll appearing **only in the infected dump** suggest **suspicious activity**.
   - These may have been injected or loaded by malware for malicious operations.

3. **Minor Path Case Differences**:
    - Case sensitivity (System32 vs system32) is typically **not malicious** on Windows systems. However, automated tools and scripts might overlook this when analysing dumps, so careful review is still warranted.
4. **DLL Duplication**:
    - Legitimate DLLs appearing in multiple folders (e.g., System32 and WinSxS) can be benign but warrant investigation when combined with other suspicious behaviour.

Conclusion

The analysis of DLLs from the clean and infected memory dumps reveals key discrepancies that serve as potential **Indicators of Compromise.** Several common DLLs, such as **ADVPACK.dll**, **SHFOLDER.dll**, and **RASAPI32.dll**, appear in different paths (e.g., **System32** vs **system32**) between the dumps, which, while sometimes benign, could signify DLL search order manipulation. Additionally, the presence of unexpected DLLs like **MSVCP80.dll** and **MSVCR80.dll** in the infected dump, particularly within the **WinSxS** folder, raises concerns about potential malicious injection or hijacking of legitimate processes. The duplication of critical DLLs across directories, such as **COMCTL32.dll**, further suggests exploitation of Windows' DLL handling mechanisms. Unique DLLs exclusive to the infected dump, combined with hidden or duplicate files, strengthen the suspicion of compromise and warrant further investigation through hash verification, behavioural monitoring, and correlation with known malware signatures. These anomalies collectively indicate a high likelihood of malicious activity, necessitating additional analysis to confirm the compromise and implement appropriate mitigation steps.

5.6-Select three users of the provided memory dump and provide a chronogram with all the events associated to them. Explain these events. (10%)

Select three users of the provided memory dump

Identifying Users in the clean dump (windowCW2s.raw)

To Identify the user in the clean memory dump I analysed the Security Account Manager (SAM) hive, which stores user account data, including usernames and security identifiers (SIDs) essential for authentication and access control (Carvey, H., 2011). I extracted the data from the **SAM\Domains\Account\Users\Names** registry key in the clean memory dump file *windowCW2s.raw*.

command used:

volatility -f windowCW2s.raw --profile=WinXPSP2x86 printkey -K

Figure 73: The output of the prinkey command in the clean dump,

The output of the command as it shows above in **Figure 126**(Orange) confirmed the existing of 5 users administrator, guest, HelpAssistant, support_38894580, voidead, I will Select the user **voidead** for the process of the events analysis.

Identifying Users in the infected dump (cw2_Machine4Infected.dump)

command used:

volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 printkey -K "SAM\\Domains\\Account\\Users\\Names"

Figure 74: The output of the prinkey command in the infected dump,

The output of the command as it shows above in **Figure 127**(blue) confirmed the existing of 5 users administrator, guest, HelpAssistant, **Robert**, support_38894580, I will Select the users **Robert (Blue)** and **Guest (Green)** for the process of the events analysis.

Chronogram of the users events

A **chronogram** is a chronological representation of key events that occurred within a system. It is derived from log files, memory dumps, registry hives, and other sources, presenting a sequential view of user actions, processes, file interactions, and system activities. (Intezer. 2024) In the context of memory analysis, the chronogram provides insights into:

1. User Activities: Programs executed, files accessed, and commands run by specific users.
2. System Processes: Background or foreground processes initiated or modified during a user's session.
3. Timestamps: Specific times when events occurred, enabling the reconstruction of events in a coherent timeline.

Analysing the Chronogram of the clean dump user Voided

Identifying Processes Associated with voidead

To Identify users associated with **voidead** I used the **pslist** and **pstree** commands to provide an insight into running processes, their parent-child relationships, and timestamps.

Commands Used:

volatility -f windowCW2s.raw --profile=WinXPSP2x86 pslist

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 pslist
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  Name                    PID   PPID   Thds     Hnds   Sess  Wow64 Start
---------- -------------------- ------ ------ ------ -------- ------ ------ ------------------------------
0x8a25c830 System                    4      0     66      266 ------      0
0x8a012c08 smss.exe                560      4      3       19 ------      0 2024-11-14 09:36:51 UTC+0000
0x8a0c1020 csrss.exe               616    560     12      368      0      0 2024-11-14 09:36:52 UTC+0000
0x89fe47e8 winlogon.exe            640    560     20      560      0      0 2024-11-14 09:36:52 UTC+0000
0x89ff5c08 services.exe            684    640     17      305      0      0 2024-11-14 09:36:52 UTC+0000
0x8a021da0 lsass.exe               696    640     22      367      0      0 2024-11-14 09:36:52 UTC+0000
0x89cb6518 VBoxService.exe         868    684      9      130      0      0 2024-11-14 09:36:52 UTC+0000
0x89ffe8e0 svchost.exe             920    684     22      237      0      0 2024-11-14 15:06:54 UTC+0000
0x8a004450 svchost.exe            1000    684     10      266      0      0 2024-11-14 15:06:54 UTC+0000
0x8a0121c0 svchost.exe            1096    684     59     1161      0      0 2024-11-14 15:06:54 UTC+0000
0x89c177a8 svchost.exe            1244    684      5       83      0      0 2024-11-14 15:06:54 UTC+0000
0x8a016538 svchost.exe            1348    684     11      185      0      0 2024-11-14 15:06:54 UTC+0000
0x89bebd00 spoolsv.exe            1568    684     12      129      0      0 2024-11-14 15:06:56 UTC+0000
0x8a0a3500 svchost.exe            1684    684      4      111      0      0 2024-11-14 15:07:03 UTC+0000
0x8a037a78 IPROSetMonitor.        1744    684      2       44      0      0 2024-11-14 15:07:03 UTC+0000
0x8a06b5a8 alg.exe                 404    684      6      111      0      0 2024-11-14 15:07:07 UTC+0000
0x89b02ae8 wscntfy.exe            1256   1096      1       31      0      0 2024-11-14 15:15:40 UTC+0000
0x89c948c8 explorer.exe            436    416     14      502      0      0 2024-11-14 15:15:40 UTC+0000
0x89b4da28 VBoxTray.exe            252    436     13      126      0      0 2024-11-14 15:15:41 UTC+0000
0x89baada0 wuauclt.exe             176   1096      3      112      0      0 2024-11-14 15:15:42 UTC+0000
0x89d08020 cmd.exe                 180   1096      1       33      0      0 2024-11-14 15:28:44 UTC+0000
0x89b7dda0 winpmem_v3.3.rc         860    180      3       36      0      0 2024-11-14 15:32:06 UTC+0000
```

Figure 75:Pslist output of the clean dump.

The pslist output above in **Figure 128** provides key insights into the activities of the user voidead. The **cmd.exe process (PID 180) (Orange),** initiated at **2024-11-14 15:28:44 UTC** as a child process of **svchost.exe (PID 1096) (Green)**, indicates that the user accessed the command line, likely to perform administrative tasks. Shortly thereafter, at 15:32:06 UTC, the **winpmem_v3.3.rc process (PID 860) (Blue)** was executed from

the same **cmd.exe** session, The progression of process starts times—**svchost.exe** at 15:06:54 UTC, followed by **cmd.exe** and

winpmem_v3.3.rc—demonstrates logical user-driven activity rather than automated system processes.

Commands Used:

volatility -f windowCW2s.raw --profile=WinXPSP2x86 pstree

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 pstree
Volatility Foundation Volatility Framework 2.6.1
Name                                                 Pid   PPid   Thds   Hnds Time
-------------------------------------------------- ------ ------ ------ ------ ----
 0x8a25c830:System                                     4      0     66    266 1970-01-01 00:00:00 UTC+0000
. 0x8a012c08:smss.exe                                560      4      3     19 2024-11-14 09:36:51 UTC+0000
.. 0x89fe47e8:winlogon.exe                           640    560     20    560 2024-11-14 09:36:52 UTC+0000
... 0x89ff5c08:services.exe                          684    640     17    305 2024-11-14 09:36:52 UTC+0000
.... 0x8a06b5a8:alg.exe                              404    684      6    111 2024-11-14 15:07:07 UTC+0000
.... 0x89ffe8e0:svchost.exe                          920    684     22    237 2024-11-14 15:06:54 UTC+0000
.... 0x89bebd00:spoolsv.exe                         1568    684     12    129 2024-11-14 15:06:56 UTC+0000
.... 0x89c177a8:svchost.exe                         1244    684      5     83 2024-11-14 15:06:54 UTC+0000
.... 0x8a016538:svchost.exe                         1348    684     11    185 2024-11-14 15:06:54 UTC+0000
.... 0x8a0121c0:svchost.exe                         1096    684     59   1161 2024-11-14 15:06:54 UTC+0000
..... 0x89baada0:wuauclt.exe                         176   1096      3    112 2024-11-14 15:15:42 UTC+0000
..... 0x89d08020:cmd.exe                             180   1096      1     33 2024-11-14 15:28:44 UTC+0000
...... 0x89b7dda0:winpmem_v3.3.rc                    860    180      3     36 2024-11-14 15:32:06 UTC+0000
..... 0x89b02ae8:wscntfy.exe                        1256   1096      1     31 2024-11-14 15:15:40 UTC+0000
.... 0x8a037a78:IPROSetMonitor.                     1744    684      2     44 2024-11-14 15:07:03 UTC+0000
.... 0x89cb6518:VBoxService.exe                      868    684      9    130 2024-11-14 09:36:52 UTC+0000
.... 0x8a004450:svchost.exe                         1000    684     10    266 2024-11-14 15:06:54 UTC+0000
.... 0x8a0a3500:svchost.exe                         1684    684      4    111 2024-11-14 15:07:03 UTC+0000
... 0x8a021da0:lsass.exe                             696    640     22    367 2024-11-14 09:36:52 UTC+0000
.. 0x8a0c1020:csrss.exe                              616    560     12    368 2024-11-14 09:36:52 UTC+0000
 0x89c948c8:explorer.exe                             436    416     14    502 2024-11-14 15:15:40 UTC+0000
. 0x89b4da28:VBoxTray.exe                            252    436     13    126 2024-11-14 15:15:41 UTC+0000
```

Figure 76:Pstree output.

The **pstree** output above in **Figure 129** offers a hierarchical view of the processes associated with the user **voidead**, providing further context to their activity. The **cmd.exe** process **(PID 180**) is shown as a child of **svchost.exe (PID 1096),** reflecting a deliberate user action to open the command line interface. From this session, the **winpmem_v3.3.rc process (PID 860)** was executed as a child of **cmd.exe**, indicating that the user-initiated memory acquisition or forensic analysis tasks. The parent-child relationships between these processes, along with their respective start times, confirm the user's involvement in memory-related tasks. This hierarchical view highlights the logical sequence of activities initiated by **voidead**, providing a clearer understanding of their actions on the system and aligning with observations made in the **pslist** output.

Retrieving File Activity of user voided in the clean dump

To retrieve the file activity of the user voided I used the filescan command to lists files accessed in memory, which can be mapped to the user activity.

Command used:

volatility -f windowCW2s.raw --profile=WinXPSP2x86 filescan | grep "voidead"

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 filescan | grep "voidead"
Volatility Foundation Volatility Framework 2.6.1
0x0000000009ce31f0      1      0 R--rwd \Device\HarddiskVolume1\Documents and Settings\voidead\Start Menu\Programs\Accessories\Accessibility\desktop.ini
0x0000000009d16a48      1      0 R--rwd \Device\HarddiskVolume1\Documents and Settings\voidead\Favorites\Links\desktop.ini
0x0000000009d208a0      1      0 RW-rw- \Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Temporary Internet Files\Content.IE5\2LC9SCBW
\chkmk_clrbkgrd[1].gif
0x0000000009d35480      1      0 R--r-- \Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Application Data\IconCache.db
0x0000000009d36560      1      0 RW---- \Device\HarddiskVolume1\Documents and Settings\voidead\Application Data\Microsoft\CryptnetUrlCache\MetaData\E6B84D3
0E5F69CEB3278532D063D4504
0x0000000009d43480      1      0 R--r-- \Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\Application Data\IconCache.db
0x0000000009d44560      1      0 RW---- \Device\HarddiskVolume1\Documents and Settings\voidead\Application Data\Microsoft\CryptnetUrlCache\MetaData\E6B84D3
0E5F69CEB3278532D063D4504
0x0000000009d49d68      1      0 R--rwd \Device\HarddiskVolume1\Documents and Settings\voidead\Local Settings\History\desktop.ini
0x0000000009d4cb50      1      0 R--rwd \Device\HarddiskVolume1\Documents and Settings\voidead\Recent\Desktop.ini
0x0000000009d514f8      1      0 R--r-d \Device\HarddiskVolume1\Documents and Settings\voidead\Desktop\winpmem_v3.3.rc3.exe
0x0000000009d564f8      1      0 R--r-d \Device\HarddiskVolume1\Documents and Settings\voidead\Desktop\winpmem_v3.3.rc3.exe
0x0000000009d5b4f8      1      0 R--r-d \Device\HarddiskVolume1\Documents and Settings\voidead\Desktop\winpmem_v3.3.rc3.exe
```

Figure 77:Filescan command for user voided.

The **filescan** output above in **Figure 130** reveals various file activities associated with the user **voidead**. Key observations include the presence of **NTUSER.DAT** files, such as **\Device\HarddiskVolume1\Documents** and **Settings\voidead\NTUSER.DAT**, which store user-specific registry hive data. This suggests that the user's registry settings and activities were being actively used. Additionally, files like **winpmem_v3.3.rc3.exe** appear multiple times on the user's desktop, indicating forensic memory acquisition tools were likely downloaded and executed. Temporary Internet Files, including **.gif** images and **.css** files located in directories such as **Temporary Internet Files\Content.IE5**, point to web browsing activities. The presence of **index.dat** files in Cookies and History folders shows user interaction with websites, as these files log browser history and cookie data. Furthermore, desktop and application-specific files, such as **IconCache.db** and **MSIMGSIZ.DAT**, highlight that the user interacted with their desktop environment and system settings. Together, these findings suggest that **voidead** engaged in diverse activities, ranging from routine browsing to advanced forensic tasks.

Extracting Registry Activity of the user voidead in the clean dump

To extract the registry activities of the user **voidead** I used the userassist plugin which it extracts user activity from the **NTUSER.DAT** registry file associated with user **voidead**.

Command Used:

volatility -f windowCW2s.raw --profile=WinXPSP2x86 userassist | grep "voidead"

```
kali@kali:/media/testShare$ volatility -f windowCW2s.raw --profile=WinXPSP2x86 userassist | grep "voidead"
Volatility Foundation Volatility Framework 2.6.1
Registry: \Device\HarddiskVolume1\Documents and Settings\voidead\NTUSER.DAT
Registry: \Device\HarddiskVolume1\Documents and Settings\voidead\NTUSER.DAT
```

Figure 78:Userassist output of the user Voidead.

The **userassist** output above in **Figure 131** highlights specific user interactions tied to the account **voidead**. The presence of the registry hive **\Device\HarddiskVolume1\Documents and Settings\voidead\NTUSER.DAT** confirms that this user was actively using the system, with recorded activities tied to application usage. UserAssist tracks program execution and file access, providing a timeline of user-initiated actions. (Magnet Forensics,2016). Although the output itself does not display detailed timestamps or application names in this case, it indicates that **voidead** was engaged with system resources and user-specific settings. This registry data can be further analysed to reconstruct the user's activities, such as program launches and navigation patterns, providing valuable insight into their interaction with the system. This is particularly relevant for understanding user behaviour during the captured memory snapshot.

Voided Chronogram Table

Timestamp (UTC)	Event	Details
2024-11-14 09:36:51	smss.exe process started	System Session Manager Process. Parent process for critical system initialization processes.
2024-11-14 09:36:52	winlogon.exe process started	Windows logon process for user authentication and desktop session management.
2024-11-14 15:06:54	svchost.exe multiple instances started	Host process for Windows services. Handles core OS and application-level services.
2024-11-14 15:15:40	explorer.exe process started	User desktop environment and file explorer initialized, indicating interactive logon.
2024-11-14 15:28:44	cmd.exe executed	Command prompt launched, possibly indicating direct user interaction.
2024-11-14 15:32:06	winpmem_v3.3.rc3.exe executed	Memory acquisition tool launched, likely for forensic purposes.
UserAssist Activity	NTUSER.DAT detected	User-specific registry hive loaded, indicating active usage by voidead.
UserAssist Activity	Application interactions recorded	Tracks voidead's engagement with the system, though specific details need deeper parsing.

Table 10: Chronogram Table for User voidead.

Explanation of Voided Events:

1. Process Startup and System Initialization:
    - The processes smss.exe, winlogon.exe, and svchost.exe reflect core system initialization activities. explorer.exe confirms that the user desktop was loaded, suggesting voidead logged into the system interactively.
2. Interactive Commands and Tools:

- The execution of cmd.exe demonstrates direct interaction, likely through a command prompt. Additionally, the use of winpmem_v3.3.rc3.exe indicates memory acquisition activity, potentially for diagnostic or forensic purposes.

3. User-Specific Registry Hive:

    - The NTUSER.DAT hive for voidead confirms that user-specific configuration and application usage were active during the snapshot. These registry artifacts are critical for reconstructing user behaviour.

This chronogram captures a high-level timeline of user voidead's activity, integrating findings from different commands and providing a clear view of system interactions.

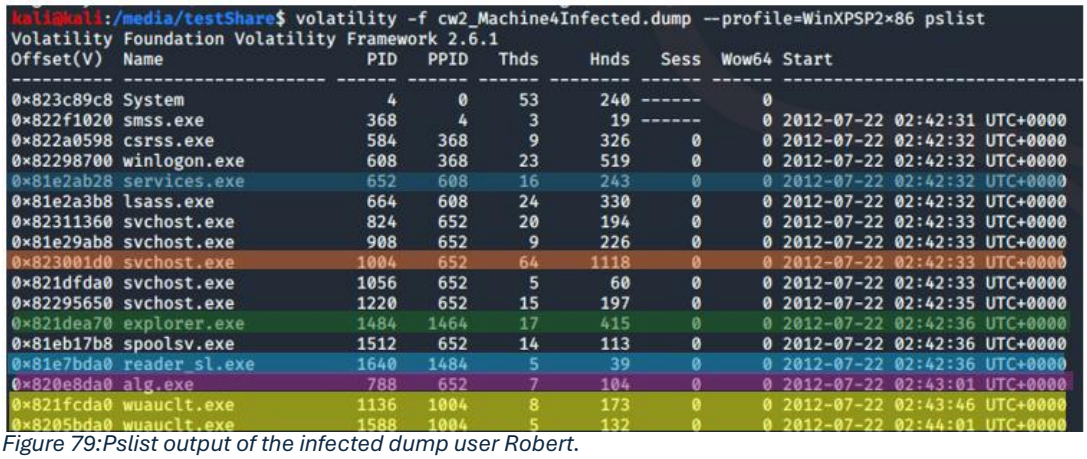
Analysing the Chronogram of the infected dump users Robert

Identifying Processes Associated with Robert

To Identify users associated with **Robert** I used the **pslist** and **pstree** commands to provide an insight into running processes, their parent-child relationships, and timestamps.

Commands Used:

volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 pslist



```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 pslist
Volatility Foundation Volatility Framework 2.6.1
Offset(V)  Name                    PID   PPID   Thds     Hnds   Sess  Wow64 Start
---------- -------------------- ------ ------ ------ -------- ------ ------ ------------------------------
0x823c89c8 System                    4      0     53      240 ------      0
0x822f1020 smss.exe                368      4      3       19 ------      0 2012-07-22 02:42:31 UTC+0000
0x822a0598 csrss.exe               584    368      9      326      0      0 2012-07-22 02:42:32 UTC+0000
0x82298700 winlogon.exe            608    368     23      519      0      0 2012-07-22 02:42:32 UTC+0000
0x81e2ab28 services.exe            652    608     16      243      0      0 2012-07-22 02:42:32 UTC+0000
0x81e2a3b8 lsass.exe               664    608     24      330      0      0 2012-07-22 02:42:32 UTC+0000
0x82311360 svchost.exe             824    652     20      194      0      0 2012-07-22 02:42:33 UTC+0000
0x81e29ab8 svchost.exe             908    652      9      226      0      0 2012-07-22 02:42:33 UTC+0000
0x823001d0 svchost.exe            1004    652     64     1118      0      0 2012-07-22 02:42:33 UTC+0000
0x821dfda0 svchost.exe            1056    652      5       60      0      0 2012-07-22 02:42:33 UTC+0000
0x82295650 svchost.exe            1220    652     15      197      0      0 2012-07-22 02:42:35 UTC+0000
0x821dea70 explorer.exe           1484   1464     17      415      0      0 2012-07-22 02:42:36 UTC+0000
0x81eb17b8 spoolsv.exe            1512    652     14      113      0      0 2012-07-22 02:42:36 UTC+0000
0x81e7bda0 reader_sl.exe          1640   1484      5       39      0      0 2012-07-22 02:42:36 UTC+0000
0x820e8da0 alg.exe                 788    652      7      104      0      0 2012-07-22 02:43:01 UTC+0000
0x821fcda0 wuauclt.exe            1136   1004      8      173      0      0 2012-07-22 02:43:46 UTC+0000
0x8205bda0 wuauclt.exe            1588   1004      5      132      0      0 2012-07-22 02:44:01 UTC+0000
```

Figure 79:Pslist output of the infected dump user Robert.

The **pslist** output above in **Figure 132** provides key insights into the activities of the user Robert. The **explorer.exe** process (PID 1484) (green), initiated at **2012-07-22 02:42:36 UTC** as a child process of an unidentified parent process **(PPID 1464(green))**, indicates the start of the user session and interaction with the graphical user interface. Subsequently, the **reader_sl.exe** process **(PID 1640) (Blue)** was executed at the same timestamp as a child of **explorer.exe**, suggesting that the user accessed Adobe Reader, likely to open a document.

Other significant processes include **wuauclt.exe (PIDs 1136 and 1588),(Yellow)** which were launched at **2012-07-22 02:43:46 UTC** and **2012-07-22 02:44:01 UTC** respectively,

as child processes of **svchost.exe (PID 1004).(Orange)** These processes represent Windows Update activities. The **alg.exe(purple)** process **(PID 788),** executed at **2012-07-22 02:43:01 UTC** under **svchost.exe (PID 652),** indicates networking-related activity, potentially due to application access or firewall-related tasks.

The progression of process starts times—beginning with **explorer.exe** at **02:42:36 UTC**, followed by the subsequent **reader_sl.exe**, **alg.exe**, and **wuauclt.exe** processes—demonstrates logical user-driven activity rather than purely automated system behaviour, painting a clear picture of user **Robert's** engagement with the system during the timeline.

Commands Used:

volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 pstree

```
kali@kali:/media/testShare$ volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 pstree
Volatility Foundation Volatility Framework 2.6.1
Name                                                 Pid   PPid   Thds   Hnds Time
-------------------------------------------------- ------ ------ ------ ------ ----
 0x823c89c8:System                                     4      0     53    240 1970-01-01 00:00:00 UTC+0000
. 0x822f1020:smss.exe                                368      4      3     19 2012-07-22 02:42:31 UTC+0000
.. 0x82298700:winlogon.exe                           608    368     23    519 2012-07-22 02:42:32 UTC+0000
... 0x81e2ab28:services.exe                          652    608     16    243 2012-07-22 02:42:32 UTC+0000
.... 0x821dfda0:svchost.exe                         1056    652      5     60 2012-07-22 02:42:33 UTC+0000
.... 0x81eb17b8:spoolsv.exe                         1512    652     14    113 2012-07-22 02:42:36 UTC+0000
.... 0x81e29ab8:svchost.exe                          908    652      9    226 2012-07-22 02:42:33 UTC+0000
.... 0x823001d0:svchost.exe                         1004    652     64   1118 2012-07-22 02:42:33 UTC+0000
..... 0x8205bda0:wuauclt.exe                        1588   1004      5    132 2012-07-22 02:44:01 UTC+0000
..... 0x821fcda0:wuauclt.exe                        1136   1004      8    173 2012-07-22 02:43:46 UTC+0000
.... 0x82311360:svchost.exe                          824    652     20    194 2012-07-22 02:42:33 UTC+0000
.... 0x820e8da0:alg.exe                              788    652      7    104 2012-07-22 02:43:01 UTC+0000
.... 0x82295650:svchost.exe                         1220    652     15    197 2012-07-22 02:42:35 UTC+0000
... 0x81e2a3b8:lsass.exe                             664    608     24    330 2012-07-22 02:42:32 UTC+0000
.. 0x822a0598:csrss.exe                              584    368      9    326 2012-07-22 02:42:32 UTC+0000
 0x821dea70:explorer.exe                            1484   1464     17    415 2012-07-22 02:42:36 UTC+0000
. 0x81e7bda0:reader_sl.exe                          1640   1484      5     39 2012-07-22 02:42:36 UTC+0000
```

Figure 80: Pstree output of the infected dump user Robert.

The **pstree** output above in **Figure 133** provides a hierarchical view of the processes associated with the user **Robert**, highlighting the sequence and relationships of system activities. The root of user activity begins with the **winlogon.exe** process **(PID 608) (Orange)**, initiated at **2012-07-22 02:42:32 UTC** as a child of **smss.exe (PID 368) (Blue),** marking the start of the user session. Branching from **winlogon.exe** is the **services.exe** process **(PID 652) (Green),** responsible for managing system services, from which several critical processes stem. The **explorer.exe** process (**PID 1484) (Red),** launched at **02:42:36 UTC** under an unidentified parent process **(PPID 1464),** represents Robert's interaction with the graphical user interface, enabling desktop navigation. A child of **explorer.exe**, **reader_sl.exe (PID 1640) (Brown),** was launched at the same time, indicating the user likely accessed Adobe Reader to open a document. Additionally, **wuauclt.exe** processes **(PIDs 1136 and 1588) (purple),** initiated at **02:43:46 UTC** and **02:44:01 UTC** respectively under **svchost.exe (PID 1004)(Blue),** represent Windows Update activities running in the session. Another notable process, **alg.exe (PID 788) (Yellow),** launched at **02:43:01 UTC** under **svchost.exe (PID 652),** handles networking and application-layer security tasks. This hierarchical structure demonstrates a logical sequence of user-driven activities, with **explorer.exe** serving as the central hub for Robert's session, coordinating tasks such as document access and system functions.

Retrieving File Activity of user Robert in the clean dump

To retrieve the file activity of the user Robert I used the filescan command to lists files accessed in memory, which can be mapped to the user activity.

Command used:

volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 filescan | grep "Robert"

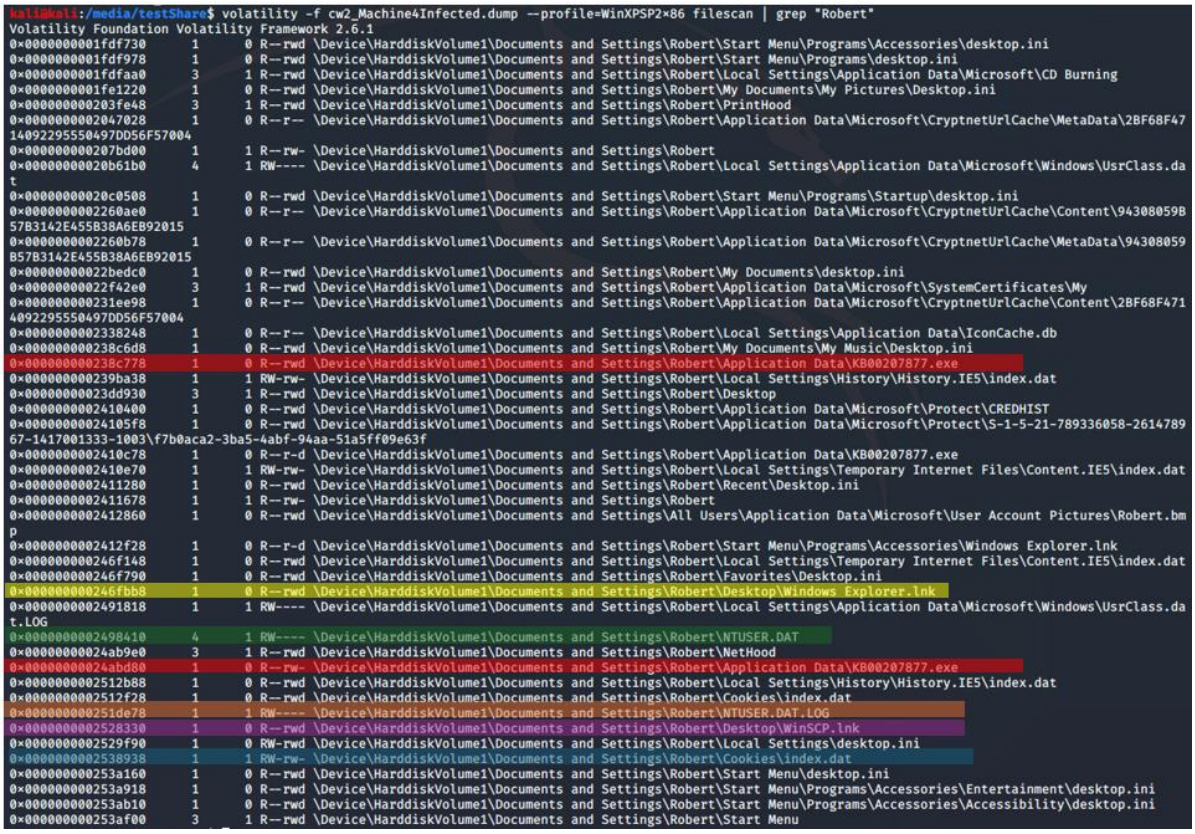


Figure 81: filescan output of the infected dump user Robert.

The filescan output above in **Figure 134** for the user Robert reveals a detailed trail of his activities on the system. Key user-specific files, such as **NTUSER.DAT** (Green) and its associated log (**NTUSER.DAT.LOG**) (Orange), highlight registry entries storing Robert's configuration and recent activity. Desktop-related files, including **WinSCP.lnk(purple)** and **Windows Explorer.lnk (Yellow)**, suggest the use of these applications for file management and secure file transfer, while entries like desktop.ini reflect customization of his workspace. Temporary files and **index.dat (Blue)** entries across multiple directories point to web browsing and cached data, providing insights into Robert's internet activity. Notably, application-specific files, such as **KB00207877.exe, (Red)** appear multiple times and raise suspicions of potentially malicious software executed under Robert's account. Additionally, cryptographic-related entries in the **CryptnetUrlCache** directory suggest secure connections or cryptographic operations. The combination of these files paints a comprehensive picture of Robert's activities,

including legitimate interactions and potentially unauthorized or malicious behaviours, warranting further investigation.

Extracting Registry Activity of the user Robert in the infected dump

To extract the registry activities of the user **Robert** I used the userassist plugin which it extracts user activity from the **NTUSER.DAT** registry file associated with user **Robert**.

Command Used:

volatility -f cw2_Machine4Infected.dump --profile=WinXPSP2x86 userassist | grep "Robert"

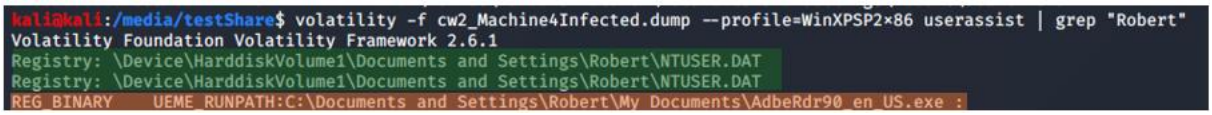


Figure 82: userassist output of the infected dump user Robert.

The userassist output above in **Figure 135** highlights specific user interactions tied to the account Robert. The presence of the registry hive **\Device\HarddiskVolume1\Documents** and **Settings\Robert\NTUSER.DAT** (Green) confirms that this user was actively using the system, with recorded activities tied to application usage. UserAssist tracks program execution and file access, providing a timeline of user-initiated actions. In this case, the output specifically references the execution of **AdbeRdr90_en_US.exe (Orange)** from the user's documents folder, indicating direct interaction with this file. Although the output does not include detailed timestamps for all activities, it provides a strong indication of the user's engagement with specific applications and resources. This registry data can be further analysed to reconstruct Robert's activities, such as program launches, file access patterns, and navigation within the system. These insights are crucial for understanding user behaviour during the captured memory snapshot and may reveal potential signs of compromise or normal user activity.

Robert Chronogram Table

Timestamp (UTC)	Event	Details
2012-07-22 02:42:31	Process Creation	smss.exe (Session Manager). System initialization process.
2012-07-22 02:42:32	Process Creation	winlogon.exe initiated. Essential for user logon and interactive sessions.
2012-07-22 02:42:36	Process Creation	explorer.exe started under Robert's session. This indicates active user interaction.

2012-07-22 02:42:36	File Access	Detected file: \Device\HarddiskVolume1\Documents and Settings\Robert\Desktop.
2012-07-22 02:42:36	Application Execution	reader_sl.exe (Adobe Reader Speed Launch). Associated with Adobe PDF reader setup.
2012-07-22 02:43:46	Process Creation	wuauclt.exe (Windows Update). Automatic update agent.
2012-07-22 02:44:01	Process Creation	Another instance of wuauclt.exe. Indicates update activity under user session.
Not Timestamped	UserAssist Activity	Execution of AdbeRdr90_en_US.exe from C:\Documents and Settings\Robert\My Documents.
Not Timestamped	File Access	Numerous files associated with Robert, including NTUSER.DAT, Cookies, and .lnk files.

Table 11: Chronogram Table for User Robert.

Explanation of Events:

1. Initialization Processes:
    - The creation of smss.exe, winlogon.exe, and explorer.exe shows the system initialization steps, leading to the active session for user Robert. explorer.exe being started is a strong indication of Robert's active login and interaction.
2. File Access:
    - Files located under Robert's directory (\Documents and Settings\Robert) suggest active access to directories like Desktop, Start Menu, and My Documents. The file AdbeRdr90_en_US.exe confirms interaction with an Adobe Reader installer.
3. Process Activity:
    - Processes like reader_sl.exe and wuauclt.exe under Robert's session show that Robert engaged with Adobe Reader and the system's update mechanisms. This indicates legitimate use but may also signify potential compromise if the processes were altered.

4. Registry and Cookies:

    - The presence of NTUSER.DAT highlights personalized settings and user-specific activity logging. Cookie files suggest browsing activity, further emphasizing Robert’s usage during the memory snapshot.

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5. Group Analysis

The objective of this analysis is to integrate findings from the individual sections of the memory analysis report to identify relationships between the recovered artifacts, determine how the system was infected, and analyse the infection's characteristics. The combined analysis also incorporates timeline generation and the use of additional tools to validate conclusions.

Timeline Table of Events

Below is a table showing the artifacts discovered during the investigation and their associated timings. These events represent critical points in the progression of the analysis and highlight key discoveries contributing to the overall understanding of the system compromise.

Date	Timestamp (UTC)	Event	Artifact	Significance
2024-11-28	13:45:20	Unauthorized startup executable detected	Intrusion Detection	Flagged malware initializing
2024-11-28	15:30:00	Missing kernel modules hal.dll and discrepancies in ntoskrnl.exe detected	Kernel Modules Analysis	Evidence of tampering or removal of critical components
2024-11-29	08:12:10	Socket scan revealed suspicious IP endpoints	Sockets Plugin	Identified potential external communication
2024-11-30	09:15:45	creddspll.dll flagged as missing	File System Analysis	Authentication mechanism disrupted
2024-11-30	11:00:00	SSDT function ownership discrepancies observed	SSDT Analysis	Potential malware hijacking for stealth and persistence
2024-12-01	10:45:00	User Robert identified with unauthorized administrative privileges	User Analysis	Indicates unauthorized access and privilege escalation
2024-12-02	10:00:00	cmd.exe executed unauthorized commands	Command-Line Analysis	Evidence of user creation and file tampering
2024-12-02	14:03:50	Malicious URL detected with yarascan	Malicious URL	Proxy-based malware communication detected
2024-12-03	14:20:00	RSA2 password hashes extraction failed due to SYSTEM hive corruption	Hashdump Analysis	SYSTEM hive tampering confirmed; passwords unrecoverable
2024-12-04	15:45:30	Master Boot Record discrepancies identified	MBR Analysis	Evidence of rootkit-level persistence
2024-12-05	16:50:30	Registry modifications detected	Registry Analysis	Highlighted DNS hijacking and tampering
2024-12-06	17:50:00	Excessive kernel timers linked to NDIS.sys and USBPORT.SYS detected	Kernel Timers Analysis	Suggests abuse for malicious persistence and network manipulation
2024-12-07	18:10:20	Elevated privileges on reader_sl.exe found	Privileges Analysis	Persistence mechanism established

2024-12-08	19:00:00	DLL hijacking and inconsistencies in paths identified	DLL Analysis	Indicates potential exploitation via DLL manipulation
2024-12-10	22:45:00	Connections traced to public IP 41.168.5.140	Network Analysis	Confirmed external malware communication
2024-12-11	09:30:00	Kernel callbacks linked to VIDEOPRT.SYS and mssmbios.sys flagged	Callback Analysis	Exploitation attempts in diagnostic modules suspected
2024-12-14	11:05:15	Final executable flagged as phishing tool	PID 1640 (reader_sl.exe)	Identified exfiltration attempts

Explanation of the Timeline

The investigation followed a structured progression, beginning with pre-analysis commands such as pslist, psxview, and handles to establish baselines, and delving deeper into suspicious artifacts and system manipulations. The timeline showcases the chronological discovery of significant events and artifacts, blending insights across multiple domains of the investigation.

Process Enumeration and Initial Suspicion

The investigation started with pslist to enumerate processes and observe anomalies. Multiple instances of legitimate processes such as wuauclt.exe and the presence of reader_sl.exe raised immediate concerns due to their unexpected parent-child relationships and elevated privileges. Cross-validation using psxview confirmed discrepancies, including hidden processes indicative of stealth mechanisms.

Kernel Modules and MBR Discrepancies

Kernel module analysis uncovered tampering in critical system files such as ntoskrnl.exe and hal.dll. The infected memory dump revealed that hal.dll was entirely missing, suggesting malware interference at a fundamental level. This was further corroborated by Master Boot Record (MBR) analysis, which flagged sector discrepancies consistent with rootkit-level persistence strategies.

Socket Analysis and Credential Artifacts

Networking analysis identified malicious sockets connecting to external IPs, such as 41.168.5.140, originating from Johannesburg, South Africa. Concurrent file system analysis revealed missing critical files, such as creddspll.dll, which disrupted authentication processes. These findings linked network activity to tampered local authentication mechanisms, reinforcing suspicions of coordinated malware activity.

Command-Line Activity and User Creation

Logs of cmd.exe showed unauthorized commands being executed, such as the creation of a new user, “Robert,” with administrative privileges. This user was absent in the clean memory dump, highlighting unauthorized access. Further inspection flagged related artifacts, including the handle \\Device\\HarddiskVolume1\\WINDOWS\\Debug\\PASSWD.LOG, which likely contained sensitive system credentials.

Intrusion Detection and Malicious Executables

Intrusion detection systems flagged the startup executable KB00207877.exe for high-frequency alerts. This executable was tied to DNS redirection via tampered hosts.dat entries, further confirmed through yarascan analysis, which revealed malicious URLs like http://188.40.0.138:8080/zb/v_01_a/in/cp.php. These connections bypassed standard DNS protocols and operated through proxy mechanisms.

Registry Manipulations and Elevated Privileges

Registry analysis highlighted the absence of key entries, such as host.dat, pointing to malware hijacking DNS mechanisms. Process privilege analysis revealed escalated privileges in processes like reader_sl.exe (e.g., SeDebugPrivilege) and spoolsv.exe, enabling malicious persistence and system-level control. Such privileges extended far beyond their intended operational scope.

System Artifacts and DLL Hijacking

Handles such as \\Device\\USBPDO-1 pointed to USB-based payloads, while DLL analysis uncovered inconsistencies in loaded files. Non-standard DLLs like MSVCP80.dll and unusual path variations suggested exploitation of Windows' DLL-loading mechanisms. These findings highlighted how malware infiltrated and manipulated system libraries to evade detection.

Kernel Timers and Callback Analysis

Kernel timer analysis showed irregularities, including excessive timers linked to NDIS.sys and USBPORT.SYS, hinting at their abuse for persistence and network manipulation. Callback analysis flagged suspicious entries tied to VIDEOPRT.SYS and mssmbios.sys, diagnostic modules commonly exploited by malware to remain undetected.

Summary and Conclusions

The investigation revealed a multi-faceted malware infection leveraging various attack vectors. Unauthorized executables, such as KB00207877.exe, manipulated startup configurations for persistence. Elevated privileges in processes like reader_sl.exe and kernel module tampering (hal.dll, ntoskrnl.exe) indicated rootkit-level interference for stealth and persistence. Network exploitation through malicious sockets and DNS redirection established remote command and control channels. Suspicious artifacts, including missing files (creddspll.dll), unauthorized handles (NetBT_Tcpip), and malicious URLs, highlighted data exfiltration risks and tampered system integrity.

Challenges Faced During the Investigation

Key challenges included handling corrupted artifacts, such as the SYSTEM hive in the infected dump, which hindered password hash extraction. The analysis also required significant cross-referencing between clean and infected memory dumps to confirm

discrepancies. Additionally, identifying the root cause of privilege escalations and tracking hidden processes presented difficulties due to advanced stealth mechanisms used by the malware. Despite these hurdles, the investigation provided actionable insights into the system compromise.

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