Anti-Debugging - Multiple Techniques

Introduction

Security researchers and malware analysts will use debugging to enhance their understanding of malware samples. This enables them to write better detection rules against these samples. As a malware developer, one should always arm themselves with anti-debugging techniques to make the process more time-consuming for analysts.

This module discusses several anti-debugging techniques.

Detecting Debuggers Via IsDebuggerPresent

One of the easiest anti-debugging techniques is to use the IsDebuggerPresent WinAPI. This function returns `TRUE` if a debugger is attached to the calling process or `FALSE` if there isn't. The following code snippet shows the function to detect a debugger.

```
if (IsDebuggerPresent()) {
  printf("[i] IsDebuggerPresent detected a debugger \n");
  // Run harmless code..
}
```

IsDebuggerPresent Replacement (1)

Calling the `IsDebuggerPresent` WinAPI is suspicious even if it is well hidden through API hashing. The WinAPI is considered a very basic approach to detect debuggers and can be bypassed with tools like ScyllaHide which is an anti anti-debugger plugin for xdbg.

A better approach is to create a custom version of the `IsDebuggerPresent` WinAPI. Recall the *Windows Processes - beginner module* which showed the PEB structure having a `BeingDebugged` member that is set to 1 when the process is being debugged. A simple `IsDebuggerPresent` WinAPI replacement involves checking the `BeingDebugged` value as shown in the custom function below.

The `IsDebuggerPresent2` function returns `TRUE` if the `BeingDebugged` element is set to 1.

```
BOOL IsDebuggerPresent2() {

  // getting the PEB structure
#ifdef _WIN64
        PPEB                                        pPeb = (PEB*)
(__readgsqword(0x60));
#elif _WIN32
        PPEB                                        pPeb = (PEB*)
(__readfsdword(0x30));
```

```
#endif

  // checking the 'BeingDebugged' element
  if (pPeb->BeingDebugged == 1)
    return TRUE;

   return FALSE;
}
```

IsDebuggerPresent Replacement (2)

Another way to make a custom-made version of the `IsDebuggerPresent` WinAPI is by utilizing the undocumented NtGlobalFlag flag which is also found within the PEB structure. The `NtGlobalFlag` member is set to `0x70` (hex) if the process is being debugged otherwise it's 0. It's important to note that the `NtGlobalFlag` element is set to `0x70` only when the process is created by the debugger. Therefore, this method will fail in detecting a debugger if it was attached after execution.

The value `0x70` is derived from the combination of the following flags:

- `FLG_HEAP_ENABLE_TAIL_CHECK` - `0x10`
- `FLG_HEAP_ENABLE_FREE_CHECK` - `0x20`
- `FLG_HEAP_VALIDATE_PARAMETERS` - `0x40`

The `IsDebuggerPresent3` function returns `TRUE` if the `NtGlobalFlag` element is set to `0x70`.

```
#define FLG_HEAP_ENABLE_TAIL_CHECK   0x10
#define FLG_HEAP_ENABLE_FREE_CHECK   0x20
#define FLG_HEAP_VALIDATE_PARAMETERS 0x40

BOOL IsDebuggerPresent3() {

  // getting the PEB structure
#ifdef _WIN64
        PPEB                                        pPeb = (PEB*)
(__readgsqword(0x60));
#elif _WIN32
        PPEB                                        pPeb = (PEB*)
(__readfsdword(0x30));
#endif

  // checking the 'NtGlobalFlag' element
  if (pPeb->NtGlobalFlag == (FLG_HEAP_ENABLE_TAIL_CHECK |
FLG_HEAP_ENABLE_FREE_CHECK | FLG_HEAP_VALIDATE_PARAMETERS))
```

```
    return TRUE;

  return FALSE;
}
```

Detecting Debugger Via NtQueryInformationProcess

The `NtQueryInformationProcess` syscall will be utilized to detect debuggers via two flags, `ProcessDebugPort` and `ProcessDebugObjectHandle`.

Recall that `NtQueryInformationProcess` looks like the following

```
NTSTATUS NtQueryInformationProcess(
  IN    HANDLE           ProcessHandle,              // Process handle for which information is to be retrieved.
  IN    PROCESSINFOCLASS ProcessInformationClass,    // Type of process information to be retrieved
  OUT   PVOID            ProcessInformation,         // Pointer to the buffer into which the function writes the requested information
  IN    ULONG            ProcessInformationLength,   // The size of the buffer pointed to by the 'ProcessInformation' parameter
  OUT   PULONG           ReturnLength                // Pointer to a variable in which the function returns the size of the requested information
);
```

ProcessDebugPort Flag

Microsoft's documentation on the `ProcessDebugPort` flag states the following:

Retrieves a DWORD_PTR value that is the port number of the debugger for the process. A nonzero value indicates that the process is being run under the control of a ring 3 debugger

In other words, if `NtQueryInformationProcess` returns a non-zero value received by the `ProcessInformation` parameter, the process is being actively debugged.

ProcessDebugObjectHandle Flag

The undocumented flag, `ProcessDebugObjectHandle`, works like the former `ProcessDebugPort` flag and is used to get a handle to the debug object handle of the current process which is created if the process is being debugged. A non-zero value obtained by the `ProcessInformation` parameter through `NtQueryInformationProcess` implies active debugging of the process.

In the case where `NtQueryInformationProcess` fails to retrieve the debug object handle, it means it did not detect a debugger and will return the error code `0xC0000353`. Based on Microsoft's documentation on NTSTATUS Values, the error code is equivalent to `STATUS_PORT_NOT_SET`.

NtQueryInformationProcess Anti-Debugging Code

The `NtQIPDebuggerCheck` function uses both `ProcessDebugPort` & `ProcessDebugObjectHandle` to detect debuggers. The function returns `TRUE` if `NtQueryInformationProcess` returns a valid handle using both `ProcessDebugPort` and `ProcessDebugObjectHandle` flags.

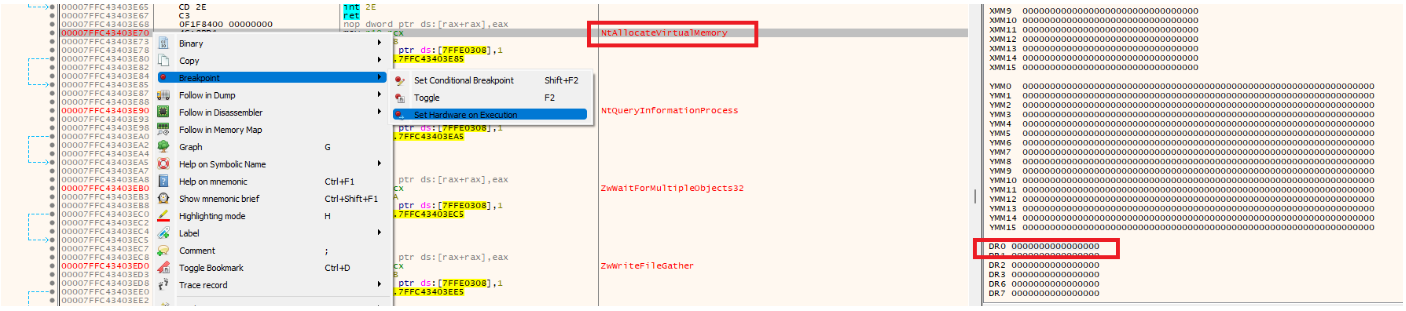
```
BOOL NtQIPDebuggerCheck() {

        NTSTATUS                        STATUS                          = NULL;
        fnNtQueryInformationProcess     pNtQueryInformationProcess      = NULL;
        DWORD64                         dwIsDebuggerPresent             = NULL;
        DWORD64                         hProcessDebugObject             = NULL;

        // Getting NtQueryInformationProcess address
        pNtQueryInformationProcess =
(fnNtQueryInformationProcess)GetProcAddress(GetModuleHandle(TEXT("NTDLL.DLL")),
 "NtQueryInformationProcess");
        if (pNtQueryInformationProcess == NULL) {
                printf("\t[!] GetProcAddress Failed With Error : %d \n",
GetLastError());
                return FALSE;
        }

        // Calling NtQueryInformationProcess with the 'ProcessDebugPort' flag
        STATUS = pNtQueryInformationProcess(
                GetCurrentProcess(),
                ProcessDebugPort,
                &dwIsDebuggerPresent,
                sizeof(DWORD64),
                NULL
        );

        if (STATUS != 0x0) {
                printf("\t[!] NtQueryInformationProcess [1] Failed With
Status : 0x%0.8X \n", STATUS);
                return FALSE;
        }

        // If NtQueryInformationProcess returned a non-zero value, the handle
is valid, which means we are being debugged
        if (dwIsDebuggerPresent != NULL) {
        // detected a debugger
                return TRUE;
        }

        // Calling NtQueryInformationProcess with the
'ProcessDebugObjectHandle' flag
```

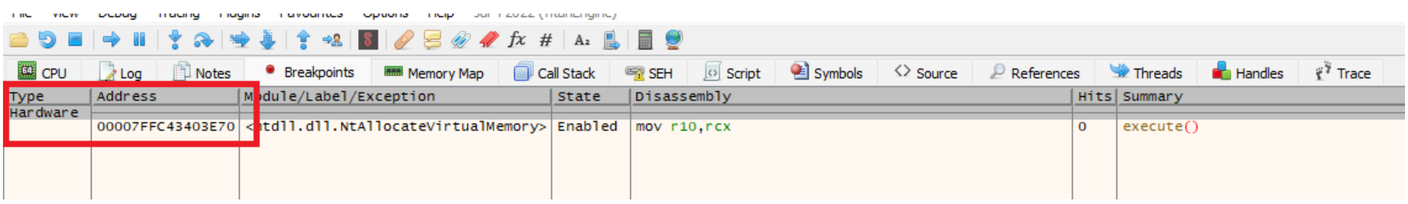
```
        STATUS = pNtQueryInformationProcess(
                GetCurrentProcess(),
                ProcessDebugObjectHandle,
                &hProcessDebugObject,
                sizeof(DWORD64),
                NULL
        );

        // If STATUS is not 0 and not 0xC0000353 (that is
'STATUS_PORT_NOT_SET')
        if (STATUS != 0x0 && STATUS != 0xC0000353) {
                printf("\t[!] NtQueryInformationProcess [2] Failed With
Status : 0x%0.8X \n", STATUS);
                return FALSE;
        }

        // If NtQueryInformationProcess returned a non-zero value, the handle
is valid, which means we are being debugged
        if (hProcessDebugObject != NULL) {
        // detected a debugger
                return TRUE;
        }

        return FALSE;
}
```

Detecting Debugger Via Hardware Breakpoints

This method is only valid if hardware breakpoints are set during debugging. Hardware breakpoints, also known as hardware debug registers, are a feature of modern microprocessors that pauses the process's execution when a specific memory address or event is triggered. Hardware breakpoints are implemented in the processor itself and are therefore faster and more efficient than the normal software breakpoints, which rely on the operating system or debugger to periodically check the program's execution.

When hardware breakpoints are set, specific registers change in value. The values of these registers can be used to determine if a debugger is attached to the process. If the registers `Dr0`, `Dr1`, `Dr2` and `Dr3` contain a non-zero value, then the hardware breakpoint is set. The following example places a hardware breakpoint on the `NtAllocateVirtualMemory` syscall using the xdbg debugger. Notice how the value of `Dr0` is changed from zero to `NtAllocateVirtualMemory`'s address.





Retrieving The Value Of The Registers

To retrieve the value of the `Dr` registers, the `GetThreadContext` WinAPI can be used. Recall the usage of `GetThreadContext` from the *Thread Hijacking* modules in which it was used to retrieve the context of a specified thread. The context was returned as a `CONTEXT` structure. This structure also includes the values of the `Dr0`, `Dr1`, `Dr2` and `Dr3` registers.

The `HardwareBpCheck` function detects the presence of a debugger by checking the values of the aforementioned registers. The function returns `TRUE`if a debugger is detected.

```
BOOL HardwareBpCheck() {

	CONTEXT		Ctx		= { .ContextFlags = 
CONTEXT_DEBUG_REGISTERS };

	if (!GetThreadContext(GetCurrentThread(), &Ctx)) {
		printf("\t[!] GetThreadContext Failed With Error : %d \n", 
GetLastError());
		return FALSE;
	}

	if (Ctx.Dr0 != NULL || Ctx.Dr1 != NULL || Ctx.Dr2 != NULL || Ctx.Dr3 
!= NULL)
		return TRUE; // Detected a debugger

	return FALSE;
}
```

Detecting Debuggers Via BlackListed Arrays

Another way to detect debugging processes can be done by checking the names of currently running processes against a list of known debugger names. This "blacklist" of names is stored in a hardcoded array. If a match is found between the name of a process and the blacklist, then a debugger application is running on the system.

Enumerating the processes running on the machine can be from any of the previously discussed techniques. For this scenario, the `CreateToolhelp32Snapshot` process enumeration technique will be used.

The blacklist array used is represented as the following

```
#define BLACKLISTARRAY_SIZE 5 // Number of elements inside the array

WCHAR* g_BlackListedDebuggers[BLACKLISTARRAY_SIZE] = {
                L"x64dbg.exe",                  // xdbg debugger
                L"ida.exe",                     // IDA disassembler
                L"ida64.exe",                   // IDA disassembler
                L"VsDebugConsole.exe",          // Visual Studio debugger
                L"msvsmon.exe"                  // Visual Studio debugger
};
```

The blacklist array should contain as many debugger names as possible in order to detect a wider range of debuggers. Additionally, the strings should be obfuscated via string hashing as debugger names in the binary could be used as IoCs.

The `BlackListedProcessesCheck` function uses the `g_BlackListedDebuggers` array as the blacklist processes array. It will return `TRUE` in case a process name matches with an element of `g_BlackListedDebuggers`

```
BOOL BlackListedProcessesCheck() {

        HANDLE                          hSnapShot               = NULL;
        PROCESSENTRY32W         ProcEntry               = { .dwSize =
sizeof(PROCESSENTRY32W) };
        BOOL                            bSTATE                  = FALSE;


        hSnapShot = CreateToolhelp32Snapshot(TH32CS_SNAPPROCESS, NULL);
        if (hSnapShot == INVALID_HANDLE_VALUE) {
                printf("\t[!] CreateToolhelp32Snapshot Failed With Error : %d
\n", GetLastError());
                goto _EndOfFunction;
        }

        if (!Process32FirstW(hSnapShot, &ProcEntry)) {
```

```
                printf("\t[!] Process32FirstW Failed With Error : %d \n", 
GetLastError());
                goto _EndOfFunction;
        }

        do {
                // Loops through the 'g_BlackListedDebuggers' array and 
comparing each element to the
                // Current process name captured from the snapshot
                for (int i = 0; i < BLACKLISTARRAY_SIZE; i++){
                        if (wcscmp(ProcEntry.szExeFile, 
g_BlackListedDebuggers[i]) == 0) {
                                // Debugger detected
                                wprintf(L"\t[i] Found \"%s\" Of Pid : %d \n", 
ProcEntry.szExeFile, ProcEntry.th32ProcessID);
                                bSTATE = TRUE;
                                break;
                        }
                }

        } while (Process32Next(hSnapShot, &ProcEntry));


_EndOfFunction:
        if (hSnapShot != NULL)
                CloseHandle(hSnapShot);
        return bSTATE;
}
```

Breakpoint Detection Via GetTickCount64

Breakpoints are used to pause the execution of a program at a specific point, allowing one to inspect the memory, registers state, variables and more.

The pause of execution can be detected by using the GetTickCount64 WinAPI. This function retrieves the number of milliseconds that have elapsed since the system was started. Analyzing the time taken by the processor between two `GetTickCount64` can indicate whether the malware is being debugged. If the time took longer than expected, it's safe to assume the malware is being debugged.

Time of execution between the 2 calls = T1 - T0

Detecting Delays

Breakpoints can be detected by calculating the average of T1 - T0 and storing it as a hardcoded value. When the output of T1 - T0 exceeds this value, the delay is likely caused by breakpoints. For example, if the output of T1 - T0 on the host machine is 20 seconds, but the output is greater than that during runtime, then there is a strong possibility that the delay between these two points is caused by a breakpoint. The original value should be increased slightly to account for processors that may be slower.

GetTickCount64 Anti-Debugging Code

The `TimeTickCheck1` function uses the described approach to detect breakpoints. The function returns `TRUE` if `dwTime2 - dwTime1` exceeds the average value of executing code in between, which is 50.

```
BOOL TimeTickCheck1() {

        DWORD   dwTime1         = NULL,
                    dwTime2             = NULL;

        dwTime1 = GetTickCount64();

/*
                OTHER CODE
*/

        dwTime2 = GetTickCount64();

        printf("\t[i] (dwTime2 - dwTime1) : %d \n", (dwTime2 - dwTime1));

        if ((dwTime2 - dwTime1) > 50) {
                return TRUE;
        }
```

```
        return FALSE;
}
```

Breakpoint Detection Via QueryPerformanceCounter

The QueryPerformanceCounter WinAPI is the same as the previously shown `GetTickCount64` WinAPI. The difference is that `QueryPerformanceCounter` uses a high-resolution performance counter provided by the hardware which can measure time in increments of nanoseconds whereas `GetTickCount64` uses a time counter that increments every millisecond. Note that `QueryPerformanceCounter` retrieves the performance-counter value in counts rather than milliseconds.

The `TimeTickCheck2` function uses the `QueryPerformanceCounter` WinAPI to detect breakpoints. It returns TRUE if `Time2.QuadPart - Time1.QuadPart` exceeds the average value of executing code in between, which is 100000 counts.

```
BOOL TimeTickCheck2() {

        LARGE_INTEGER   Time1    = { 0 },
                                Time2    = { 0 };

        if (!QueryPerformanceCounter(&Time1)) {
                printf("\t[!] QueryPerformanceCounter [1] Failed With Error :
%d \n", GetLastError());
                return FALSE;
        }

/*
                OTHER CODE
*/

        if (!QueryPerformanceCounter(&Time2)) {
                printf("\t[!] QueryPerformanceCounter [2] Failed With Error :
%d \n", GetLastError());
                return FALSE;
        }

        printf("\t[i] (Time2.QuadPart - Time1.QuadPart) : %d \n",
(Time2.QuadPart - Time1.QuadPart));

        if ((Time2.QuadPart - Time1.QuadPart) > 100000){
                return TRUE;
        }

        return FALSE;
}
```

Detecting Debugger Via DebugBreak

DebugBreak causes the breakpoint exception, `EXCEPTION_BREAKPOINT`, to occur in the current process. This exception is supposed to be handled by a debugger if it is attached to the current process. The technique is to trigger the exception and see if a debugger attempts to handle this exception.

A `__try` and `__except` code block will be used to handle the exception from the `DebugBreak` call, and a GetExceptionCode call will be used to fetch the exception code generated in which case there are two possible scenarios:

1. If the exception fetched is `EXCEPTION_BREAKPOINT` then `EXCEPTION_EXECUTE_HANDLER` is executed, this means the exception was not handled by a debugger.
2. If the exception is not `EXCEPTION_BREAKPOINT`, meaning a debugger handled the raised exception (and not our try-except code block), then `EXCEPTION_CONTINUE_SEARCH` is executed, this force the debugger to be responsible for handling the raised exception.

The following `DebugBreakCheck` function returns `FALSE` if the `DebugBreak` WinAPI is successfully executed and the exception is not caught/handled by a debugger, and instead handled by our try-except code block, indicating that no debugger is attached to the current process.

```
BOOL DebugBreakCheck() {

        __try {
                DebugBreak();
        }
        __except (GetExceptionCode() == EXCEPTION_BREAKPOINT ?
EXCEPTION_EXECUTE_HANDLER : EXCEPTION_CONTINUE_SEARCH) {
                // if the exception is equal to EXCEPTION_BREAKPOINT,
EXCEPTION_EXECUTE_HANDLER is executed and the function return FALSE
                return FALSE;
        }

        // if the exception is not equal to EXCEPTION_BREAKPOINT,
EXCEPTION_CONTINUE_SEARCH is executed and the function return TRUE
        return TRUE;
}
```

Detecting Debugger Via OutputDebugString

Another WinAPI that can be utilized in detecting debuggers is OutputDebugString. This function is used to send a string to the debugger to display. If a debugger exists, then `OutputDebugString` will succeed in performing its task.

One can run `OutputDebugString` and check if it failed using `GetLastError`, if it did, then `GetLastError` will return a non-zero error code. A non-zero error code in this case is equivalent to no debugger being present. If `GetLastError` returns zero then `OutputDebugString` succeeded in sending a string to a debugger.

The `OutputDebugStringCheck` function uses the above logic and returns `TRUE` if `OutputDebugStringW` succeeds. Additionally, it uses SetLastError to set the last error value to 1. This is simply to make sure that it is a non-zero value before the `OutputDebugString` call in order to reduce false positives.

```
BOOL OutputDebugStringCheck() {

	SetLastError(1);
	OutputDebugStringW(L"MalDev Academy");

	// if GetLastError is 0, then OutputDebugStringW succeeded
	if (GetLastError() == 0) {
		return TRUE;
	}

	return FALSE;
}
```