Module 1

A journey from high level languages, through assembly, to the running process

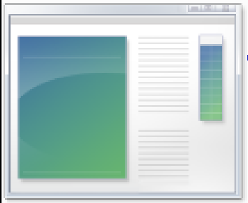
https://github.com/hasherezade/malware_training_vol1

Running executables: process

Process: basics

Process

- When we run an EXE file, the system creates a Process



sample.exe

Address	Size	Info	Content	Type	Protection	Initial
00010000	00010000			MAP	-RW--	-RW--
00020000	00010000			MAP	-RW--	-RW--
00030000	00004000			MAP	-R---	-R---
00040000	00001000			MAP	-R---	-R---
00050000	00001000			PRV	-RW--	-RW--
00060000	00003000			PRV	-RW--	-RW--
00063000	000FD000	Reserved (00060000)		PRV		-RW--
00160000	00067000	\Device\HarddiskVolum		MAP	-R---	-R---
001D0000	000FC000	Reserved		PRV		-RW--
002CC000	00004000	Thread FE8 Stack		PRV	-RW-G	-RW--
01190000	00001000	sample.exe		IMG	-R---	ERWC-
01191000	0000E000	".text"	Executable code	IMG	ER---	ERWC-
0119F000	00003000	".rdata"	Read-only initialized data	IMG	-R---	ERWC-
011A2000	00003000	".data"	Initialized data	IMG	-RWC-	ERWC-
011A5000	00001000	".rsrc"	Resources	IMG	-R---	ERWC-
011A6000	00001000	".reloc"	Base relocations	IMG	-R---	ERWC-
757E0000	00001000	kernelbase.dll		IMG	-R---	ERWC-
757E1000	00043000	".text"	Executable code	IMG	ER---	ERWC-
75824000	00002000	".data"	Initialized data	IMG	-RW--	ERWC-
75826000	00001000	".rsrc"	Resources	IMG	-R---	ERWC-
75827000	00003000	".reloc"	Base relocations	IMG	-R---	ERWC-
77020000	00001000	kernel32.dll		IMG	-R---	ERWC-
77021000	000C5000	".text"	Executable code	IMG	ER---	ERWC-
770E6000	00001000	".data"	Initialized data	IMG	-RW--	ERWC-
770E7000	00001000	".rsrc"	Resources	IMG	-R---	ERWC-
770E8000	0000C000	".reloc"	Base relocations	IMG	-R---	ERWC-
77520000	00001000	ntdll.dll		IMG	-R---	ERWC-
77521000	000D5000	".text"	Executable code	IMG	ER---	ERWC-
775F6000	00001000	"RT"		IMG	ER---	ERWC-
775F7000	00009000	".data"	Initialized data	IMG	-RW--	ERWC-
77600000	00057000	".rsrc"	Resources	IMG	-R---	ERWC-
77657000	00005000	".reloc"	Base relocations	IMG	-R---	ERWC-
77760000	00001000			IMG	-R---	ERWC-
7F6F0000	00005000			MAP	-R---	-R---
7F6F5000	000FB000	Reserved (7F6F0000)		MAP		-R---
7FFB0000	00023000			MAP	-R---	-R---
7FFD6000	00001000			PRV	-RW--	-RW--
7FFDF000	00001000	Thread FE8 TEB		PRV	-RW--	-RW--
7FFE0000	00001000	KUSER_SHARED_DATA		PRV	-R---	-R---
7FFE1000	0000F000	Reserved (7FFE0000)		PRV	-----	-R---

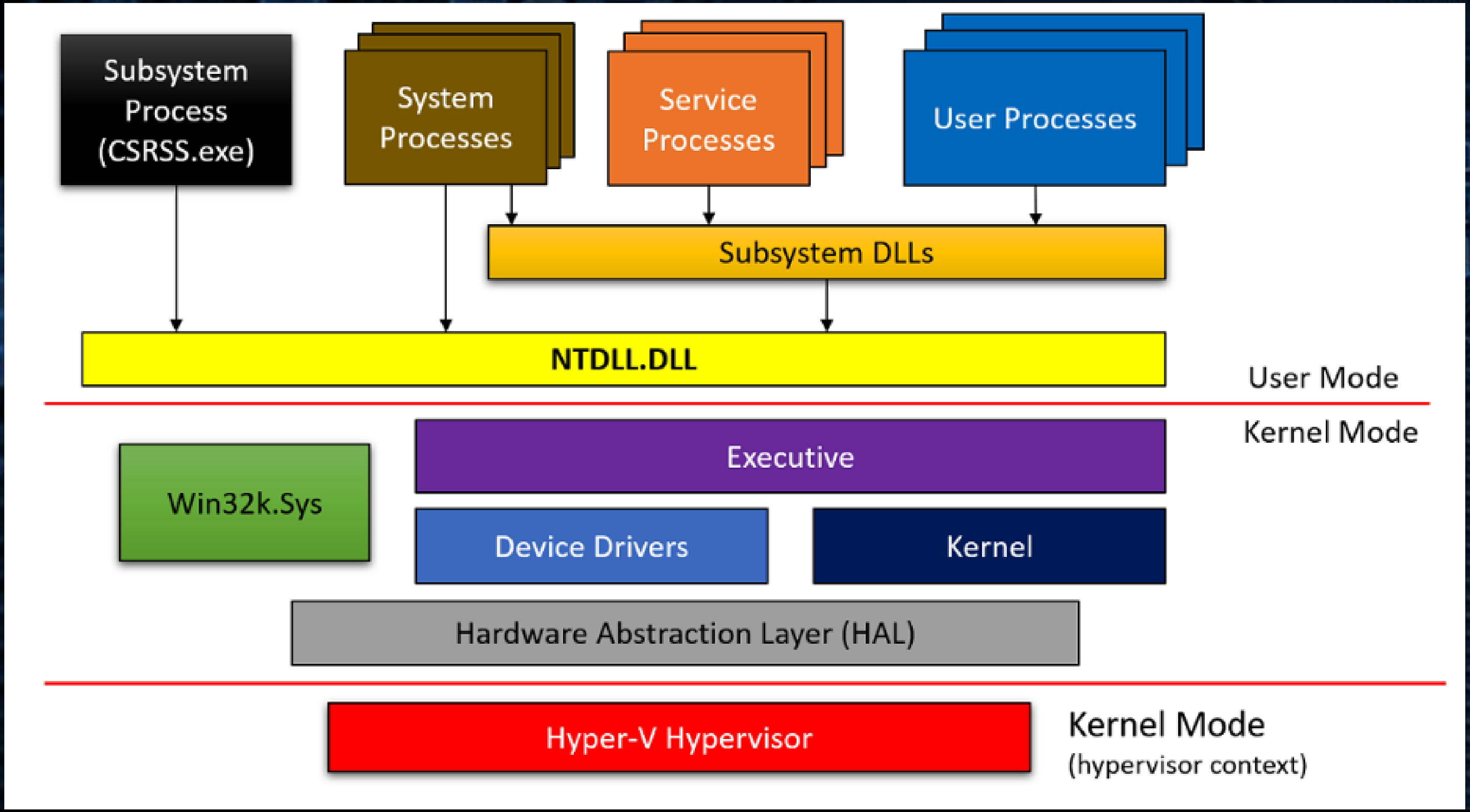
Process

- A process is a container for all the resources that the application needs to run
- A process by itself doesn't run code: threads execute it
- Each process has its own, private address space, that is independent from other proceses (different processes may have different memory content at the same addreses)
- Has its own access token, defining its security context

Process

- Types of processes on Windows:
  - System process
  - Subsystem process
  - Service
  - User processes (our applications)

Processes on Windows



From: „Windows Kernel Programming" by Pavel Yosifovich

Process

- A process is identified by its PID (Process ID)
  - unique throughout the system at the time of running
  - after the process terminates, its PID may be reused by a new process
- Each process has one or more threads. They are identified by Thread IDs.
  - Thread IDs, same as process IDs, are unique throughout the system
  - After the thread terminates, its ID may be reused
- Processes may access each other (via handles), if their security context allows it

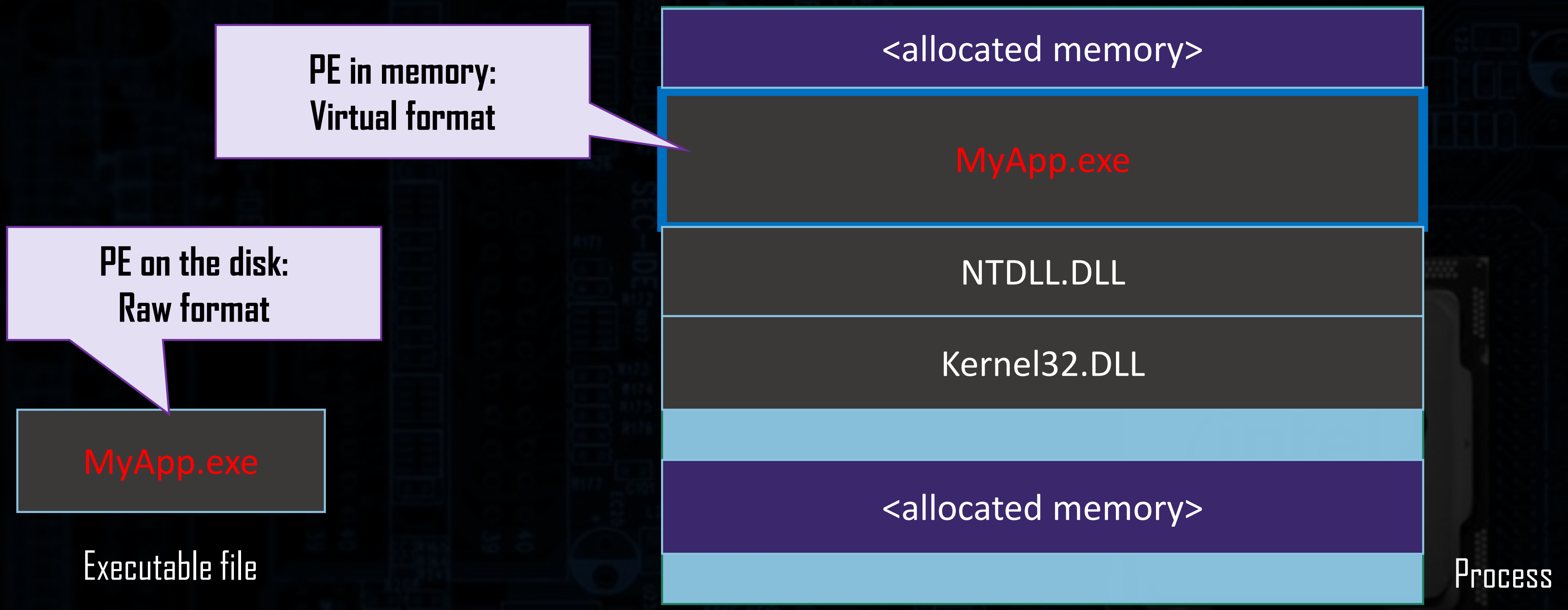
```
HANDLE OpenProcess(
  DWORD dwDesiredAccess,
  BOOL  bInheritHandle,
  DWORD dwProcessId // <- The Process ID
);
```

Process

- Process contains:
  - Mapped PE images (the main EXE + dependencies: DLLs with needed imports)
  - The workingset (all the memory that is used during its execution)
  - Threads: at least one (structures for execution of the code)
  - Open Handles (managing access to needed objects: i.e. Files, Mutexes, Events)
  - Access Tokens (representing security information, and specifying privileges of the process and threads)

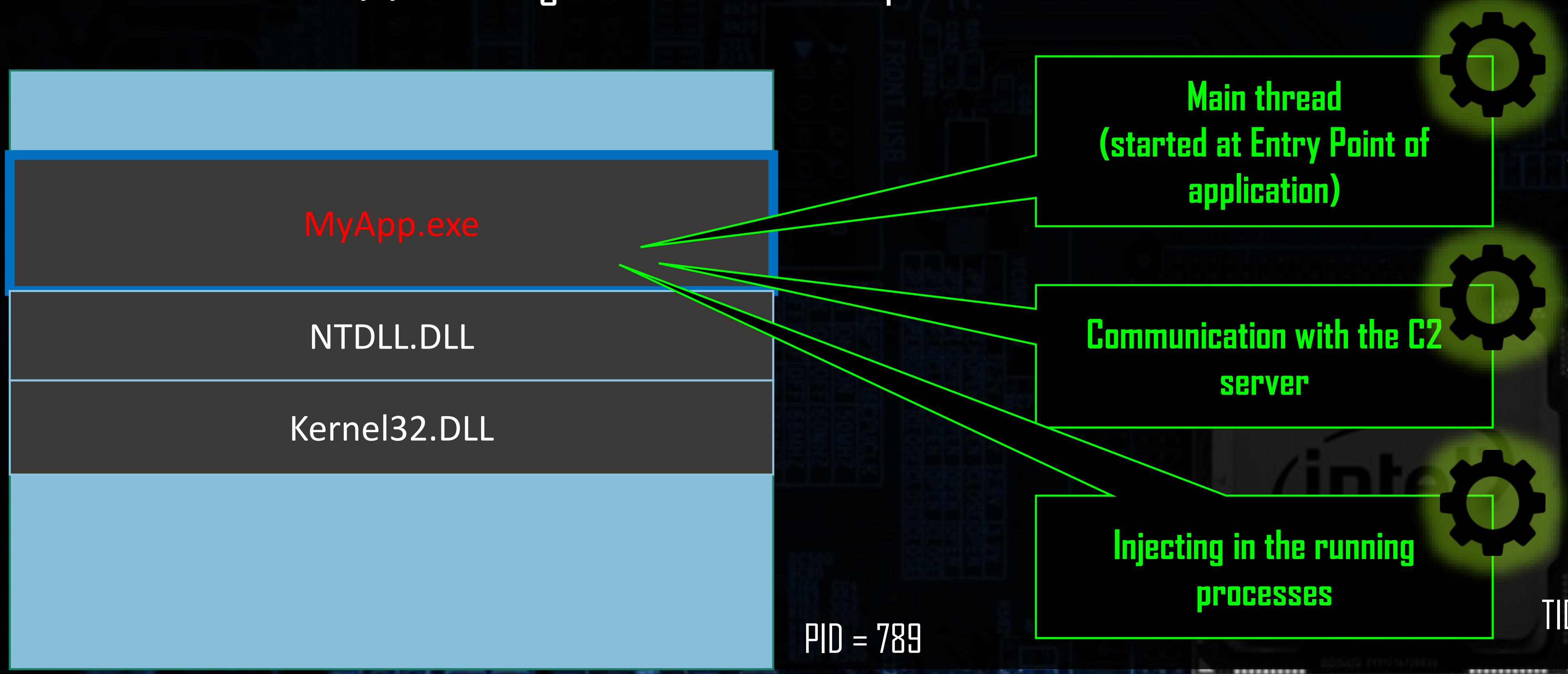
Process

- Contains PE files in a virtual format



Process

- Contains thread(s) running the code – example:



Process initialization

Process Initialization

- What happens when we create a process?

```
BOOL CreateProcessA(
  LPCSTR                lpApplicationName,
  LPSTR                 lpCommandLine,
  LPSECURITY_ATTRIBUTES lpProcessAttributes,
  LPSECURITY_ATTRIBUTES lpThreadAttributes,
  BOOL                  bInheritHandles,
  DWORD                 dwCreationFlags,
  LPVOID                lpEnvironment,
  LPCSTR                lpCurrentDirectory,
  LPSTARTUPINFOA        lpStartupInfo,
  LPPROCESS_INFORMATION lpProcessInformation
);
```

Process Initialization

1. Create a new process object and allocation of the memory
2. Map NTDLL.dll and the initial EXE into the memory (MEM_IMAGE)
3. Create a first thread and allocate a space for it
4. Resume the first thread: `NTDLL.LdrpInitialize` function is called
5. NTDLL.LdprInitialization function:
   - Load all imported DLLs -> run each's DllMain with DLL_PROCESS_ATTACH
   - Call `Kernel32.BaseProcessStart`
6. `Kernel32.BaseProcessStart`: calls initial EXE's Entry Point

Process Initialization

Windows Loader
CreateProcess

- Creates process and allocates a virtual memory for its use
- Loads the initial EXE and NDTLL.DLL
- Creates a first thread and the stack for its use

Windows Loader
LdrpInitialize

- Called when the first thread resumes
- Goes through the Import Table, loads all required DLLs, and initializes them (calls DllMain with DLL_PROCESS_ATTACH)

Windows Loader
BaseProcessStart

- Call Entry Point of the original application

The run EXE
Entry Point

- Execute the code at the Entry Point

Process Initialization

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Process Initialization

demo_cpp.exe (8728) Properties

General | Statistics | Performance | Threads | Token | Modules | Memory | Environment | Handles | GPU | Comment

☑ Hide free regions

Strings... | Refresh

Base address	Type	Size	Protect...	Use	Total WS	Private WS	Sha
0x7ffe0000	Private	4 kB	R	USER_SHARED_DATA			
0x7ffec000	Private	4 kB	R		4 kB		
0x5c692c0000	Private	1,024 kB	RW	Stack (thread 9360)	4 kB	4 kB	
0x5c69400000	Private	2,048 kB	RW	PEB	12 kB	12 kB	
0x17a402f0000	Private	128 kB	RW		8 kB	8 kB	
0x17a40310000	Mapped	104 kB	R		4 kB		
0x17a40330000	Mapped	16 kB	R		4 kB		
0x17a40340000	Private	8 kB	RW		8 kB	8 kB	
0x7ff51b740000	Mapped	4 kB	R		4 kB		
0x7ff51b750000	Mapped	140 kB	R		4 kB		
0x7ff715250000	Image	108 kB	WCX	C:\Users\IEUser\Desktop\bin\demo_cpp.exe	72 kB	4 kB	
0x7ffbe39f0000	Image	1,972 kB	WCX	C:\Windows\System32\ntdll.dll	1,184 kB	32 kB	

A process created in a suspended mode – 64 bit example (viewed by Process Hacker)

Before the first thread is run, only:

- the main EXE
- NTDLL.DLL

are mapped

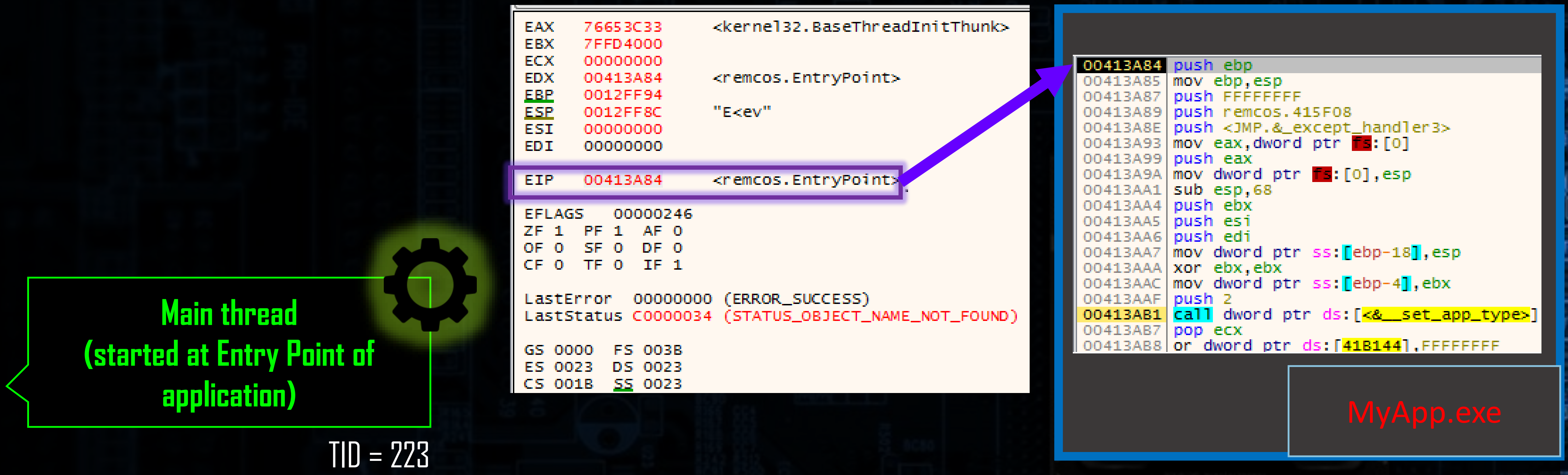
Process Initialization

- Notice that if we create a process as suspended, only the first part of the initialization process was run…
- This is important for Process Hollowing, that we will review in details later…

Threads

Thread

- Thread is an entity responsible for executing the code



Thread

- A thread contains: Context (state of the processor), 2 stacks, TLS (Thread Local Storage), may also has its own security token

User Mode stack

Kernel Mode stack

Main thread
(started at Entry Point of application)

TID = 223

```
EAX     76653C33      <kernel32.BaseThreadInitThunk>
EBX     7FFD4000
ECX     00000000
EDX     00413A84      <remcos.EntryPoint>
EBP     0012FF94
ESP     0012FF8C      "E<ev"
ESI     00000000
EDI     00000000

EIP     00413A84      <remcos.EntryPoint>

EFLAGS     00000246
ZF  1   PF  1   AF  0
OF  0   SF  0   DF  0
CF  0   TF  0   IF  1

LastError   00000000 (ERROR_SUCCESS)
LastStatus  C0000034 (STATUS_OBJECT_NAME_NOT_FOUND)

GS 0000   FS 003B
ES 0023   DS 0023
CS 001B   SS 0023
```

Context

Thread Management

- Threads are executed by the processor, and managed by the Operating System (kernel mode):
  - Scheduler: a kernel mode controler, that decides which thread gets to run for how long and performing the context switch

- Additionally, Windows (only 64-bit) implements also User Mode Scheduling (UMS). It is it an optimization to make the operation of thread switching less resource-consuming. UMS threads differ from classic threads. They can switch context between themselves in user mode, while from the kernel perspective, it looks like one thread is running. Due to this, concurrent UMS Threads cannot run on multiple processors.

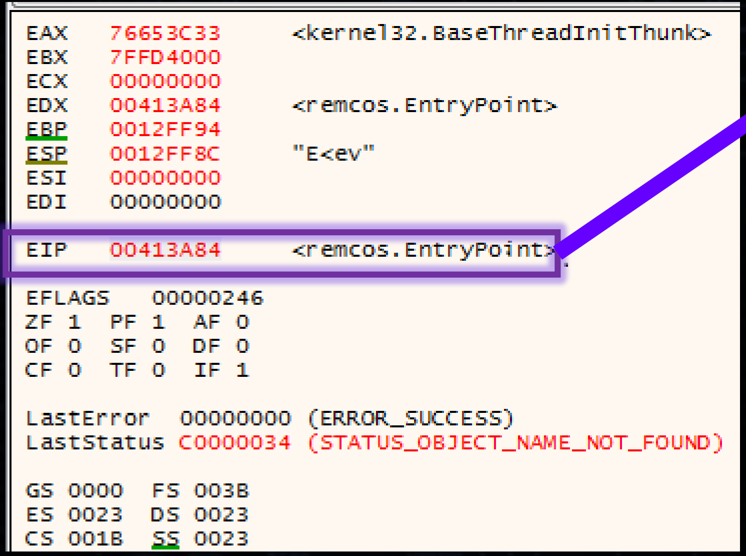
Thread Context

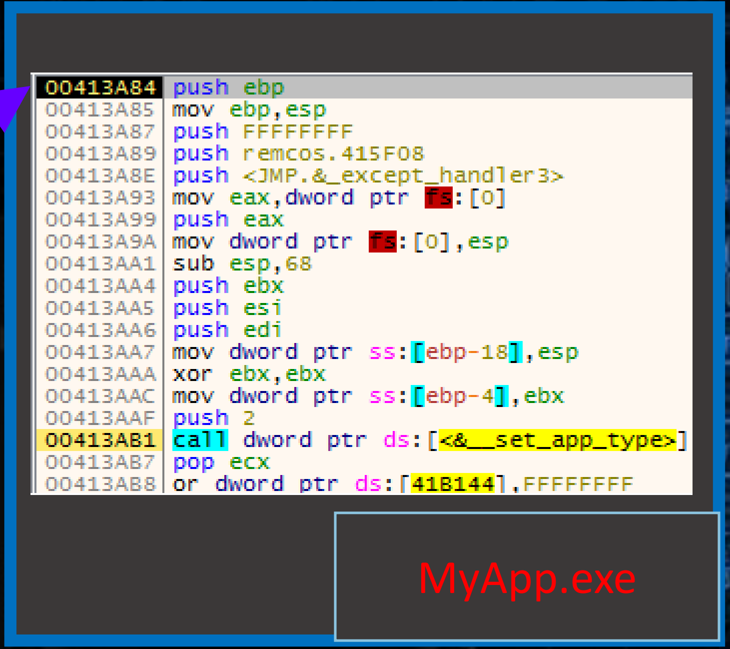
- Context switching:
  - When the processor is switched to another thead, first its context is saved
  - The thread context is a state of the processor when it was run the last time before the switch (saved snapshot with all the registers)
  - stack space is used to save off current state of thread when context switched
  - WindowsAPI allows to retieve the thread context (but first we need to `SuspendThread`):

```
BOOL GetThreadContext(
  HANDLE    hThread,
  LPCONTEXT lpContext
);
```

Thread Context

- Example





Main thread
(started at Entry Point of application)

TID = 223

EPROCESS, PEB, TEB...

Stuctures for Process Management

- Process is managed by the Operating System
- To manage the process, Windows uses the following structures:
  - EPROCESS, KPROCESS, ETHREAD, KTHREAD, PEB, TEB…

Stuctures for Process Management

- EPROCESS – the basic kernel-mode structure representing a process
  - Contains a linklist of all the threads belonging to the process
  - Contains a pointer to the PEB (Process Environment Block) that is available from usermode
- ETHREAD - the basic kernel-mode structure representing a thread
  - Contains a pointer to KTHREAD
    - Links to the TEB (Thread Environment Block) that is available from usermode

Obtaining PEB

```
typedef struct _EPROCESS
{
    KPROCESS Pcb;
    EX_PUSH_LOCK ProcessLock;
    LARGE_INTEGER CreateTime;
    LARGE_INTEGER ExitTime;
    EX_RUNDOWN_REF RundownProtect;
    PVOID UniqueProcessId;
    LIST_ENTRY ActiveProcessLinks;
[...]
    ULONG ActiveThreads;
    ULONG ImagePathHash;
    ULONG DefaultHardErrorProcessing;
    LONG LastThreadExitStatus;
    PPEB Peb;
    EX_FAST_REF PrefetchTrace;
[...]
    UCHAR PriorityClass;
    MM_AVL_TABLE VadRoot;
    ULONG Cookie;
    ALPC_PROCESS_CONTEXT AlpcContext;
} EPROCESS, *PEPROCESS;
```

Kernel Mode

```
typedef struct _PEB
{
    UCHAR InheritedAddressSpace;
    UCHAR ReadImageFileExecOptions;
    UCHAR BeingDebugged;
    UCHAR BitField;
    ULONG ImageUsesLargePages: 1;
    ULONG IsProtectedProcess: 1;
    ULONG IsLegacyProcess: 1;
    ULONG IsImageDynamicallyRelocated: 1;
    ULONG SpareBits: 4;
    PVOID Mutant;
    PVOID ImageBaseAddress;
    PPEB_LDR_DATA Ldr;
[...]
    _FLS_CALLBACK_INFO * FlsCallback;
    LIST_ENTRY FlsListHead;
    PVOID FlsBitmap;
    ULONG FlsBitmapBits[4];
    ULONG FlsHighIndex;
    PVOID WerRegistrationData;
    PVOID WerShipAssertPtr;
} PEB, *PPEB;
```

```
typedef struct _TEB {
    PVOID Reserved1[12];
    PPEB  ProcessEnvironmentBlock;
    PVOID Reserved2[399];
    BYTE  Reserved3[1952];
    PVOID TlsSlots[64];
    BYTE  Reserved4[8];
    PVOID Reserved5[26];
    PVOID ReservedForOle;
    PVOID Reserved6[4];
    PVOID TlsExpansionSlots;
} TEB, *PTEB;
```

User Mode

Obtaining TEB

```
.! ETHREAD
Tcb                     : _KTHREAD
CreateTime              : _LARGE_INTEGER
ExitTime                : _LARGE_INTEGER
KeyedWaitChain          : _LIST_ENTRY
PostBlockList           : _LIST_ENTRY
ForwardLinkShadow       : Ptr64 Void
StartAddress            : Ptr64 Void
TerminationPort         : Ptr64 _TERMINATION_PORT
ReaperLink              : Ptr64 _ETHREAD
KeyedWaitValue          : Ptr64 Void
ActiveTimerListLock     : Uint8B
ActiveTimerListHead     : _LIST_ENTRY
Cid                     : _CLIENT_ID
KeyedWaitSemaphore      : _KSEMAPHORE
AlpcWaitSemaphore       : _KSEMAPHORE
ClientSecurity          : _PS_CLIENT_SECURITY_CONTEXT
```

Kernel Mode

```
! _KTHREAD
Header                  : _DISPATCHER_HEADER
SListFaultAddress       : Ptr64 Void
QuantumTarget           : Uint8B
InitialStack            : Ptr64 Void
StackLimit              : Ptr64 Void
StackBase               : Ptr64 Void

WaitStatus              : Int8B
WaitBlockList           : Ptr64 _KWAIT_BLOCK
WaitListEntry           : _LIST_ENTRY
SwapListEntry           : _SINGLE_LIST_ENT
Queue                   : Ptr64 _DISPAT   _HEADER
Teb                     : Ptr64 Void
RelativeTimerBias       : Uint8B
Timer                   : _KTIMER
WaitBlock               : [4] _KWAIT_BLOCK
WaitBlockFill4          : [20] UChar
ContextSwitches         : Uint4B
WaitBlockFill5          : [68] UChar
State                   : UChar
```

Via registry:
FS (32 bit)
GS (64 bit)

```c
typedef struct _TEB {
  PVOID Reserved1[12];
  PPEB  ProcessEnvironmentBlock;
  PVOID Reserved2[399];
  BYTE  Reserved3[1952];
  PVOID TlsSlots[64];
  BYTE  Reserved4[8];
  PVOID Reserved5[26];
  PVOID ReservedForOle;
  PVOID Reserved6[4];
  PVOID TlsExpansionSlots;
} TEB, *PTEB;
```

User Mode

PEB and TEB

- We can see PEB and TEB(s) mapped inside the process space (usually towards the end of the addresses)

77359000	00001000	".reloc"	Base relocations	IMG	-R---	ERWC-
77370000	00001000	nsi.dll		IMG	-R---	ERWC-
77371000	00002000	".text"	Executable code	IMG	ER---	ERWC-
77373000	00001000	".data"	Initialized data	IMG	-RWC-	ERWC-
77374000	00001000	".rsrc"	Resources	IMG	-R---	ERWC-
77375000	00001000	".reloc"	Base relocations	IMG	-R---	ERWC-
77440000	00001000			IMG	-R---	ERWC-
7F6F0000	00005000			MAP	-R---	-R---
7F6F5000	000FB000	Reserved (7F6F0000)		MAP		-R---
7FFB0000	00023000			MAP	-R---	-R---
7FFD6000	00001000	PEB		PRV	-RW--	-RW--
7FFDF000	00001000	Thread 87C TEB		PRV	-RW--	-RW--
7FFE0000	00001000	KUSER_SHARED_DATA		PRV	-R---	-R---
7FFE1000	0000F000	Reserved (7FFE0000)		PRV	-----	-R---

Exercise

- Following the given instructions, walk through the PEB and TEB using WinDbg. Familiarize yourself with the fields.