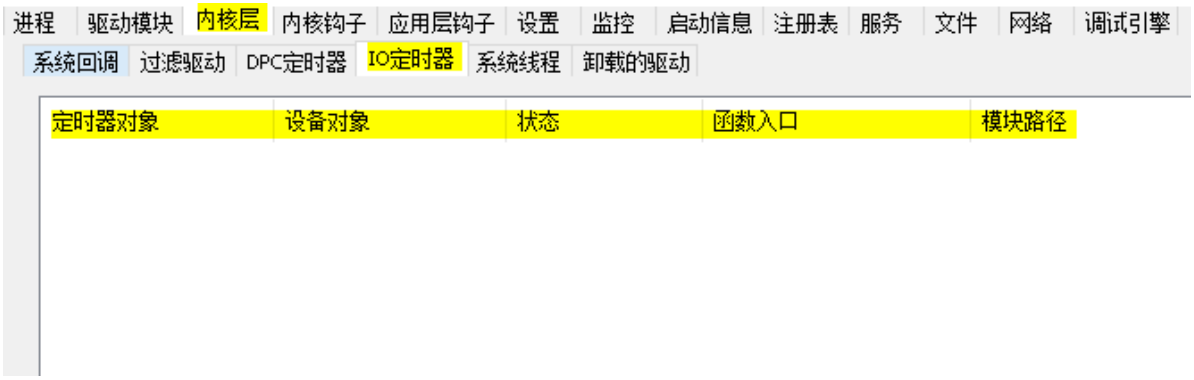
今天继续分享内核枚举系列知识，这次我们来学习如何通过代码的方式枚举内核`IoTimer`定时器，内核定时器其实就是在内核中实现的时钟，该定时器的枚举非常简单，因为在`IoInitializeTimer`初始化部分就可以找到`IopTimerQueueHead`地址，该变量内存储的就是定时器的链表头部。枚举IO定时器的案例并不多见，即便有也是无法使用过时的，此教程学到肯定就是赚到了。



枚举Io定时器过程是这样的：

- 1.找到`IoInitializeTimer`函数，该函数可以通过`MmGetSystemRoutineAddress`得到。
- 2.找到地址以后，我们向下增加`0xFF`偏移量，并搜索特征定位到`IopTimerQueueHead`链表头。
- 3.将链表头转换为`IO_TIMER`结构体，并循环链表头输出。

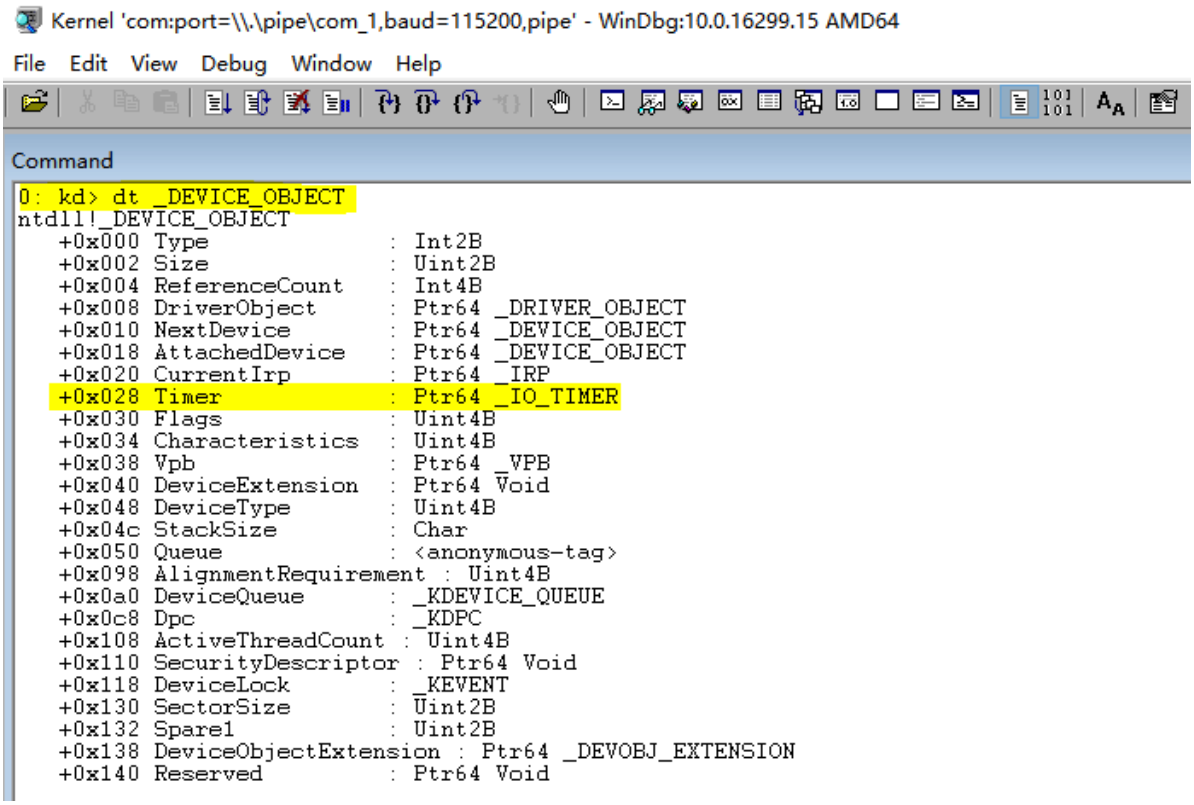
这里解释一下为什么要找`IoInitializeTimer`这个函数他是一个初始化函数，既然是初始化里面一定会涉及到链表的存储问题，找到他就能找到定时器链表基址，该函数的定义如下。

```
NTSTATUS
  IoInitializeTimer(
    IN PDEVICE_OBJECT  DeviceObject,     // 设备对象指针
    IN PIO_TIMER_ROUTINE  TimerRoutine,  // 定时器例程
    IN PVOID  Context                    // 传给定时器例程的函数
    );
```

接着我们需要得到IO定时器的结构定义，在`DEVICE_OBJECT`设备对象指针中存在一个`Timer`属性。

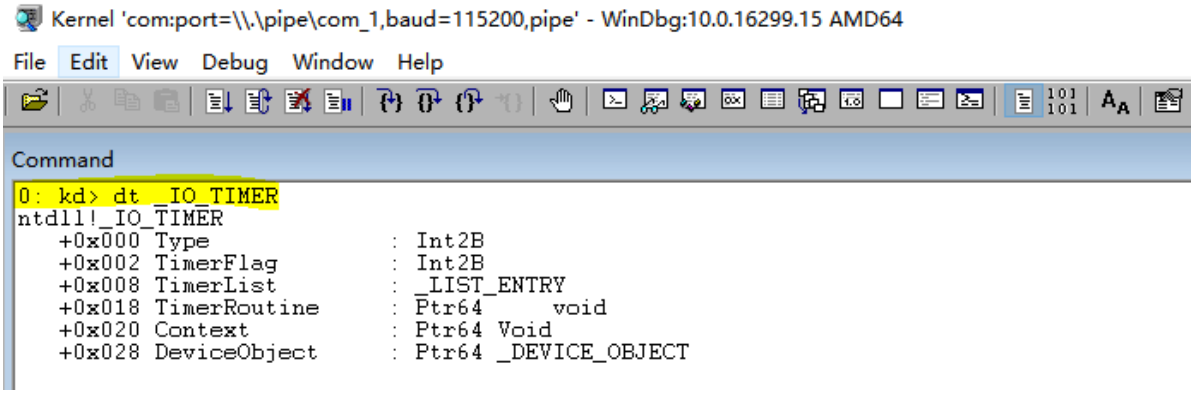
```
lyshark.com: kd> dt _DEVICE_OBJECT
ntdll!_DEVICE_OBJECT
   +0x000 Type             : Int2B
   +0x002 Size             : Uint2B
   +0x004 ReferenceCount   : Int4B
   +0x008 DriverObject     : Ptr64 _DRIVER_OBJECT
   +0x010 NextDevice       : Ptr64 _DEVICE_OBJECT
   +0x018 AttachedDevice   : Ptr64 _DEVICE_OBJECT
   +0x020 CurrentIrp       : Ptr64 _IRP
   +0x028 Timer            : Ptr64 _IO_TIMER
   +0x030 Flags            : Uint4B
   +0x034 Characteristics  : Uint4B
   +0x038 Vpb              : Ptr64 _VPB
   +0x040 DeviceExtension  : Ptr64 Void
   +0x048 DeviceType       : Uint4B
   +0x04c StackSize        : Char
   +0x050 Queue            : <anonymous-tag>
   +0x098 AlignmentRequirement : Uint4B
   +0x0a0 DeviceQueue      : _KDEVICE_QUEUE
```

```
    +0x0c8 Dpc              : _KDPC
    +0x108 ActiveThreadCount : Uint4B
    +0x110 SecurityDescriptor : Ptr64 Void
    +0x118 DeviceLock       : _KEVENT
    +0x130 SectorSize       : Uint2B
    +0x132 Spare1           : Uint2B
    +0x138 DeviceObjectExtension : Ptr64 _DEVOBJ_EXTENSION
    +0x140 Reserved         : Ptr64 Void
```



这里的这个`+0x028 Timer`定时器是一个结构体`_IO_TIMER`其就是IO定时器的所需结构体。

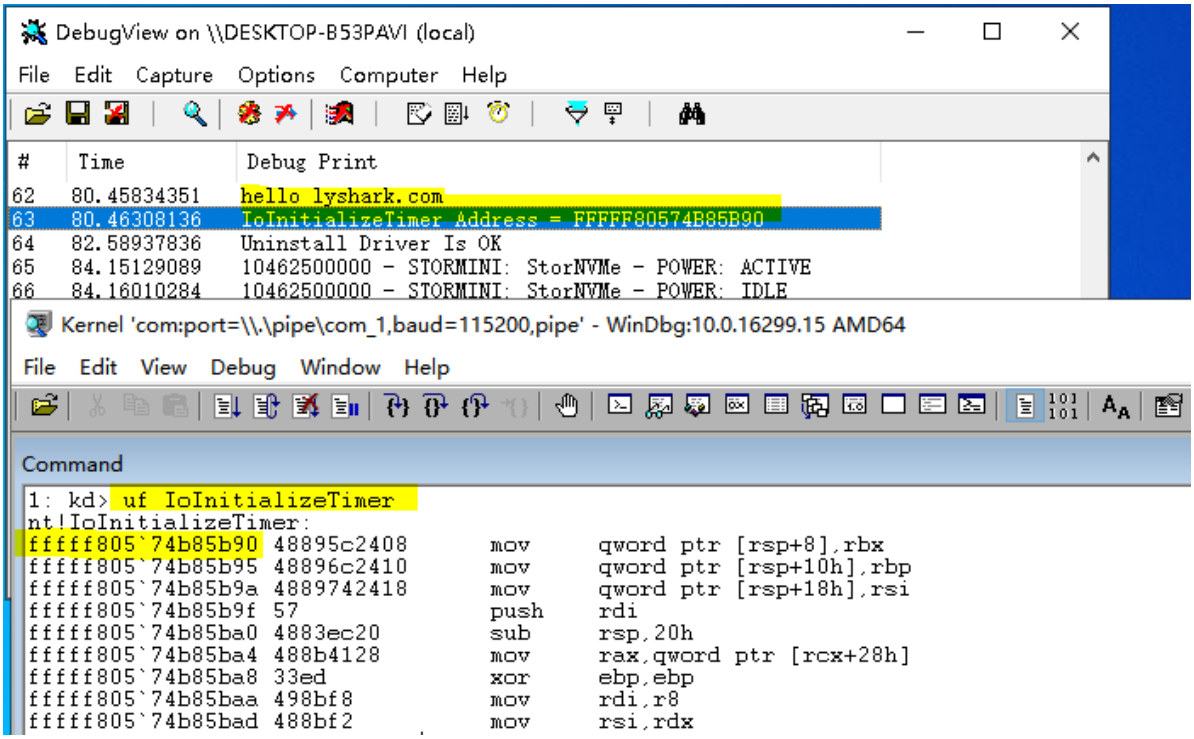
```
lyshark.com: kd> dt _IO_TIMER
ntdll!_IO_TIMER
   +0x000 Type             : Int2B
   +0x002 TimerFlag        : Int2B
   +0x008 TimerList        : _LIST_ENTRY
   +0x018 TimerRoutine     : Ptr64     void
   +0x020 Context          : Ptr64 Void
   +0x028 DeviceObject     : Ptr64 _DEVICE_OBJECT
```



如上方的基础知识有了也就够了，接着就是实际开发部分，首先我们需要编写一个`GetIoInitializeTimerAddress()`函数，让该函数可以定位到`IoInitializeTimer`所在内核中的基地址上面，具体实现调用代码如下所示。

```
#include <ntifs.h>

// 得到IoInitializeTimer基址
// By: LyShark 内核开发系列教程
PVOID GetIoInitializeTimerAddress()
{
    PVOID VariableAddress = 0;
    UNICODE_STRING uioiTime = { 0 };

    RtlInitUnicodeString(&uioiTime, L"IoInitializeTimer");
    VariableAddress = (PVOID)MmGetSystemRoutineAddress(&uioiTime);
    if (VariableAddress != 0)
    {
        return VariableAddress;
    }
    return 0;
}

VOID UnDriver(PDRIVER_OBJECT driver)
{
    DbgPrint(("Uninstall Driver Is OK \n"));
}

NTSTATUS DriverEntry(IN PDRIVER_OBJECT Driver, PUNICODE_STRING RegistryPath)
{
    DbgPrint(("hello lyshark.com \n"));

    // 得到基址
    PUCHAR IoInitializeTimer = GetIoInitializeTimerAddress();
    DbgPrint("IoInitializeTimer Address = %p \n", IoInitializeTimer);

    Driver->DriverUnload = UnDriver;
    return STATUS_SUCCESS;
}
```

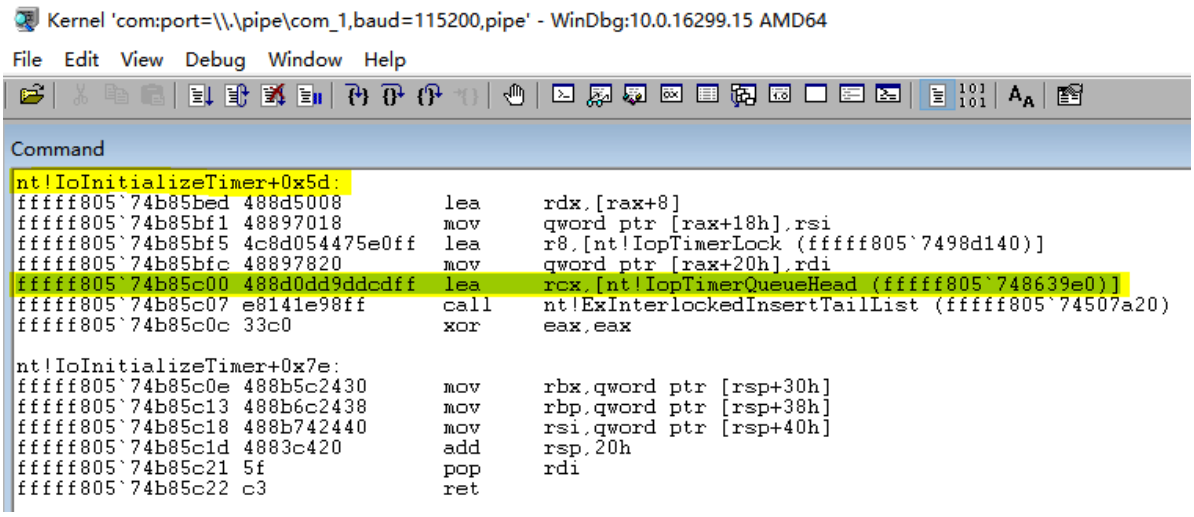
运行这个驱动程序，然后对比下是否一致:



接着我们在反汇编代码中寻找 `IoTimerQueueHead`，此处在LyShark系统内这个偏移位置是 `nt!IoInitializeTimer+0x5d` 具体输出位置如下。

```
lyshark.com: kd> uf IoInitializeTimer

nt!IoInitializeTimer+0x5d:
fffff805`74b85bed 488d5008        lea     rdx,[rax+8]
fffff805`74b85bf1 48897018        mov     qword ptr [rax+18h],rsi
fffff805`74b85bf5 4c8d054475e0ff  lea     r8,[nt!IopTimerLock
(fffff805`7498d140)]
fffff805`74b85bfc 48897820        mov     qword ptr [rax+20h],rdi
fffff805`74b85c00 488d0dd9ddcdff  lea     rcx,[nt!IopTimerQueueHead
(fffff805`748639e0)]
fffff805`74b85c07 e8141e98ff      call    nt!ExInterlockedInsertTailList
(fffff805`74507a20)
fffff805`74b85c0c 33c0            xor     eax,eax
```

在WinDBG中标注出颜色 `lea rcx,[nt!IopTimerQueueHead (fffff805748639e0)]` 更容易看到。



接着就是通过代码实现对此处的定位，定位我们就采用特征码搜索的方式，如下代码是特征搜索部分。

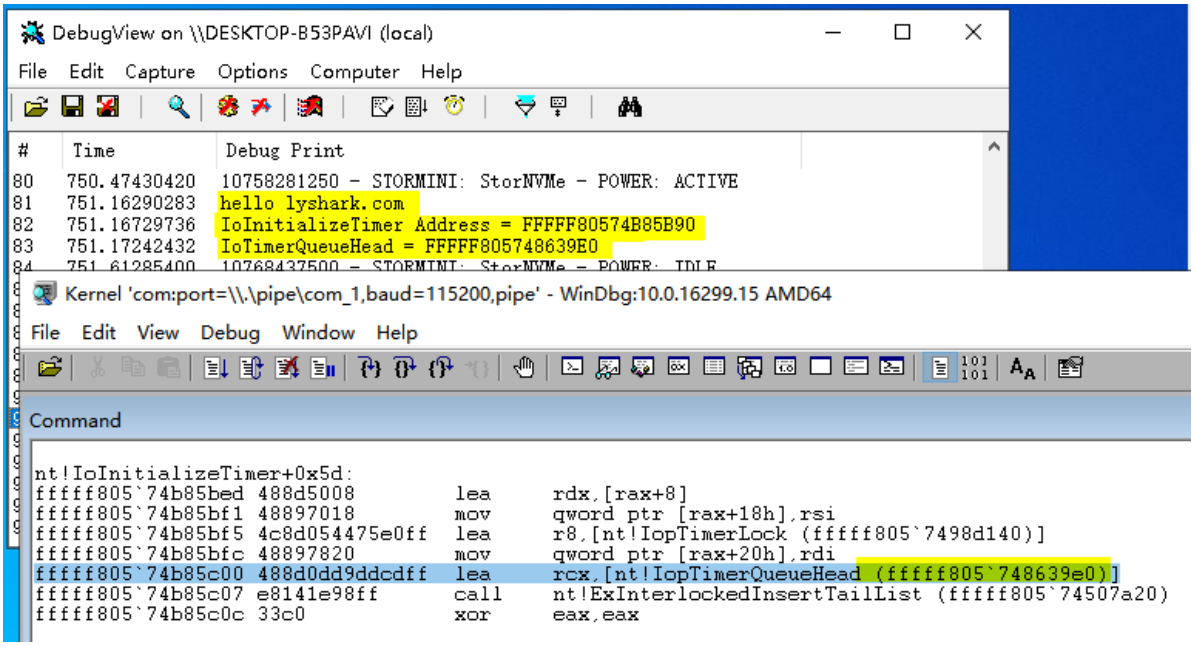
- StartSearchAddress 代表开始位置
- EndSearchAddress 代表结束位置，粗略计算0xff就可以定位到了。

```
#include <ntifs.h>

// 得到IoInitializeTimer基址
// By: LyShark 内核开发系列教程
PVOID GetIoInitializeTimerAddress()
{
    PVOID VariableAddress = 0;
    UNICODE_STRING uioiTime = { 0 };

    RtlInitUnicodeString(&uioiTime, L"IoInitializeTimer");
    VariableAddress = (PVOID)MmGetSystemRoutineAddress(&uioiTime);
    if (VariableAddress != 0)
    {
        return VariableAddress;
    }
    return 0;
}

VOID UnDriver(PDRIVER_OBJECT driver)
{
    DbgPrint(("Uninstall Driver Is OK \n"));
}

NTSTATUS DriverEntry(IN PDRIVER_OBJECT Driver, PUNICODE_STRING RegistryPath)
{
    DbgPrint(("hello lyshark.com \n"));

    // 得到基址
    PUCHAR IoInitializeTimer = GetIoInitializeTimerAddress();
    DbgPrint("IoInitializeTimer Address = %p \n", IoInitializeTimer);

    INT32 iOffset = 0;
    PLIST_ENTRY IoTimerQueueHead = NULL;

    PUCHAR StartSearchAddress = IoInitializeTimer;
    PUCHAR EndSearchAddress = IoInitializeTimer + 0xFF;
    UCHAR v1 = 0, v2 = 0, v3 = 0;

    for (PUCHAR i = StartSearchAddress; i < EndSearchAddress; i++)
    {
        if (MmIsAddressValid(i) && MmIsAddressValid(i + 1) && MmIsAddressValid(i
+ 2))
        {
            v1 = *i;
            v2 = *(i + 1);
            v3 = *(i + 2);

            // 三个特征码
            if (v1 == 0x48 && v2 == 0x8d && v3 == 0x0d)
            {
                memcpy(&iOffset, i + 3, 4);
                IoTimerQueueHead = (PLIST_ENTRY)(iOffset + (ULONG64)i + 7);
```

```
                DbgPrint("IoTimerQueueHead = %p \n", IoTimerQueueHead);
                break;
            }
        }
    }

    Driver->DriverUnload = UnDriver;
    return STATUS_SUCCESS;
}
```

搜索三个特征码 `v1 == 0x48 && v2 == 0x8d && v3 == 0x0d` 从而得到内存位置，运行驱动对比下。

- 运行代码会取出 `lea` 指令后面的操作数，而不是取出lea指令的内存地址。



最后一步就是枚举部分，我们需要前面提到的 `IO_TIMER` 结构体定义。

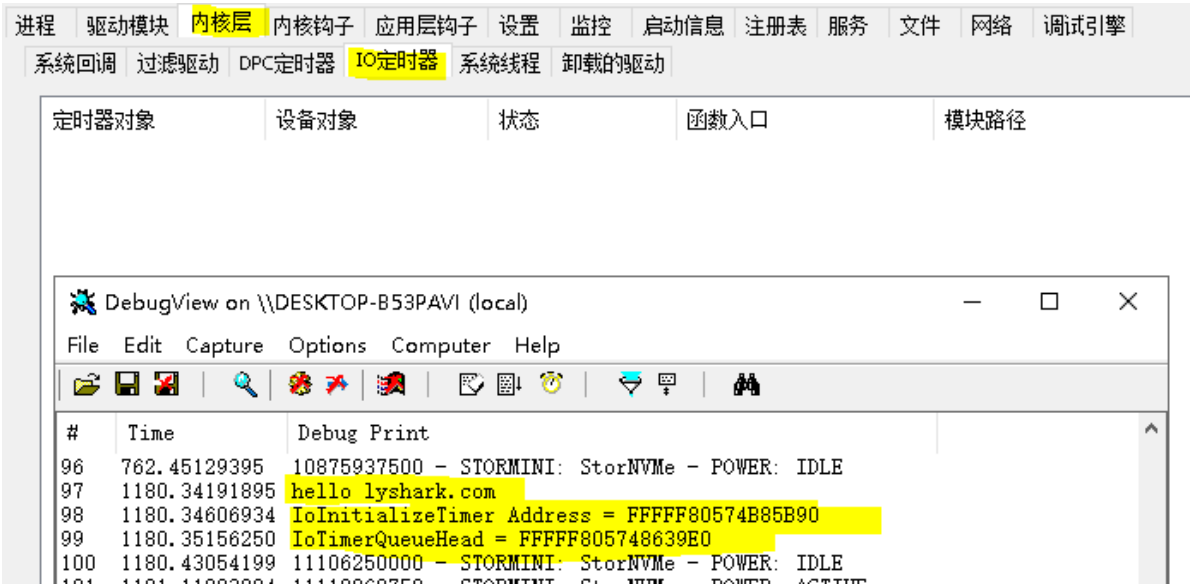
- PIO_TIMER Timer = CONTAINING_RECORD(NextEntry, IO_TIMER, TimerList) 得到结构体，循环输出即可。

```
// By: LyShark 内核开发系列教程
// https://www.cnblogs.com/LyShark/articles/16784393.html
#include <ntddk.h>
#include <ntstrsafe.h>

typedef struct _IO_TIMER
{
  INT16         Type;
  INT16         TimerFlag;
  LONG32        Unknown;
  LIST_ENTRY    TimerList;
  PVOID         TimerRoutine;
  PVOID         Context;
  PVOID         DeviceObject;
}IO_TIMER, *PIO_TIMER;


// 得到IoInitializeTimer基址
PVOID GetIoInitializeTimerAddress()
```

```
{
  PVOID VariableAddress = 0;
  UNICODE_STRING uioiTime = { 0 };

  RtlInitUnicodeString(&uioiTime, L"IoInitializeTimer");
  VariableAddress = (PVOID)MmGetSystemRoutineAddress(&uioiTime);
  if (VariableAddress != 0)
  {
    return VariableAddress;
  }
  return 0;
}

VOID UnDriver(PDRIVER_OBJECT driver)
{
  DbgPrint("卸载完成... \n");
}

NTSTATUS DriverEntry(IN PDRIVER_OBJECT Driver, PUNICODE_STRING RegistryPath)
{
  DbgPrint(("hello lyshark.com \n"));

  // 得到基址
  PUCHAR IoInitializeTimer = GetIoInitializeTimerAddress();
  DbgPrint("IoInitializeTimer Address = %p \n", IoInitializeTimer);

  // 搜索IoTimerQueueHead地址
  /*
    nt!IoInitializeTimer+0x5d:
    fffff806`349963cd 488d5008        lea     rdx,[rax+8]
    fffff806`349963d1 48897018        mov     qword ptr [rax+18h],rsi
    fffff806`349963d5 4c8d05648de0ff  lea     r8,[nt!IopTimerLock
(fffff806`3479f140)]
    fffff806`349963dc 48897820        mov     qword ptr [rax+20h],rdi
    fffff806`349963e0 488d0d99f6cdff  lea     rcx,[nt!IopTimerQueueHead
(fffff806`34675a80)]
    fffff806`349963e7 e8c43598ff      call    nt!ExInterlockedInsertTailList
(fffff806`343199b0)
    fffff806`349963ec 33c0            xor     eax,eax
  */
  INT32 iOffset = 0;
  PLIST_ENTRY IoTimerQueueHead = NULL;

  PUCHAR StartSearchAddress = IoInitializeTimer;
  PUCHAR EndSearchAddress = IoInitializeTimer + 0xFF;
  UCHAR v1 = 0, v2 = 0, v3 = 0;

  for (PUCHAR i = StartSearchAddress; i < EndSearchAddress; i++)
  {
    if (MmIsAddressValid(i) && MmIsAddressValid(i + 1) && MmIsAddressValid(i +
2))
    {
      v1 = *i;
      v2 = *(i + 1);
      v3 = *(i + 2);
```

```
      // fffff806`349963e0 48 8d 0d 99 f6 cd ff  lea rcx,[nt!IopTimerQueueHead
(fffff806`34675a80)]
      if (v1 == 0x48 && v2 == 0x8d && v3 == 0x0d)
      {
        memcpy(&iOffset, i + 3, 4);
        IoTimerQueueHead = (PLIST_ENTRY)(iOffset + (ULONG64)i + 7);
        DbgPrint("IoTimerQueueHead = %p \n", IoTimerQueueHead);
        break;
      }
    }
  }

  // 枚举列表
  KIRQL OldIrql;

  // 获得特权级
  OldIrql = KeRaiseIrqlToDpcLevel();

  if (IoTimerQueueHead && MmIsAddressValid((PVOID)IoTimerQueueHead))
  {
    PLIST_ENTRY NextEntry = IoTimerQueueHead->Flink;
    while (MmIsAddressValid(NextEntry) && NextEntry !=
(PLIST_ENTRY)IoTimerQueueHead)
    {
      PIO_TIMER Timer = CONTAINING_RECORD(NextEntry, IO_TIMER, TimerList);

      if (Timer && MmIsAddressValid(Timer))
      {
        DbgPrint("IO对象地址: %p \n", Timer);
      }
      NextEntry = NextEntry->Flink;
    }
  }

  // 恢复特权级
  KeLowerIrql(OldIrql);

  Driver->DriverUnload = UnDriver;
  return STATUS_SUCCESS;
}
```

运行这段源代码，并可得到以下输出，由于没有IO定时器所以输出结果是空的：



至此IO定时器的枚举就介绍完了，在教程中你已经学会了使用特征码定位这门技术，相信你完全可以输出内核中想要得到的任何结构体。

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