Real World Kernel Pool Exploitation

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Agenda

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- Introduction
- The Kernel Pool and its structures
- Allocation and Free algorithm
- Exploiting a Kernel Pool overflow
- MS08-001: IGMPv3 Kernel Pool overflow
- Conclusion

Introduction

Introduction

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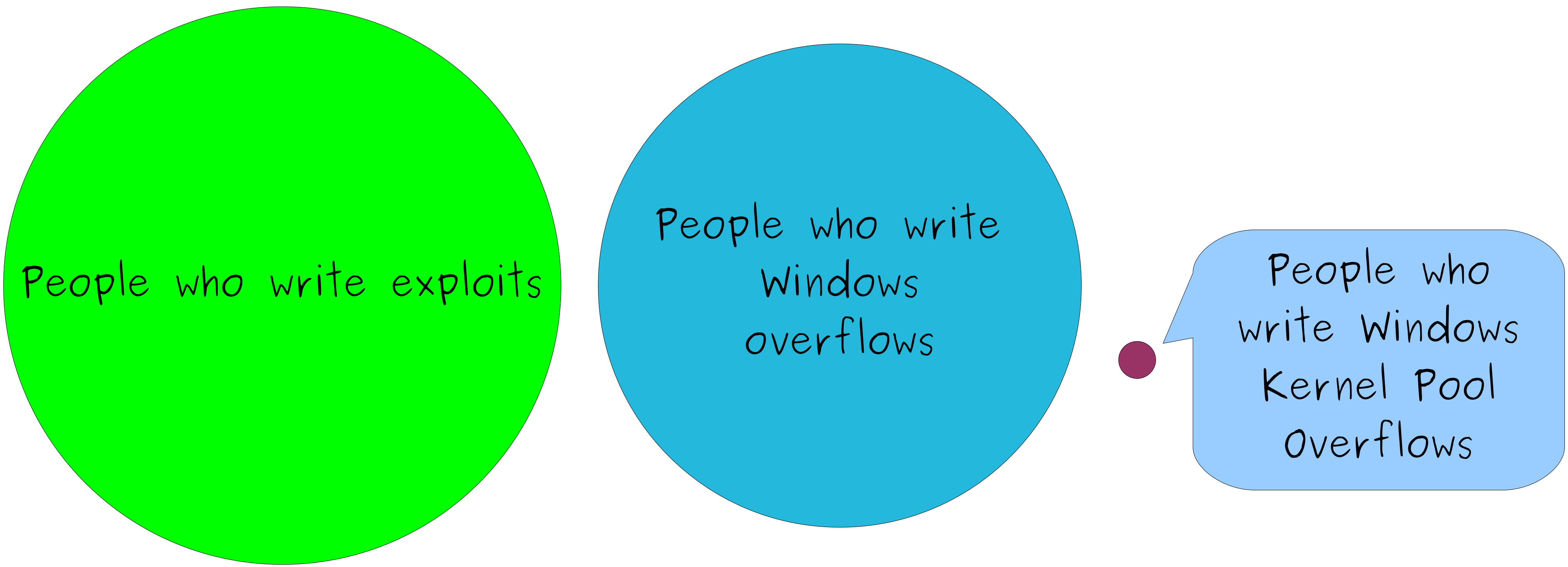
- Kernel vulnerabilities are more popular
  - Less protections than in userland
    - Kernel allocations are highly performance optimized
    - Less room for heap cookies and other roadblocks
  - Code has had less attention than userland services
- Several kernel pool overflows to exploit
  - Our example: MS08-001 (IGMPv3 Overflow)

Population



People who write exploits
People who write Windows overflows
People who write Windows Kernel Pool Overflows

Other considerations

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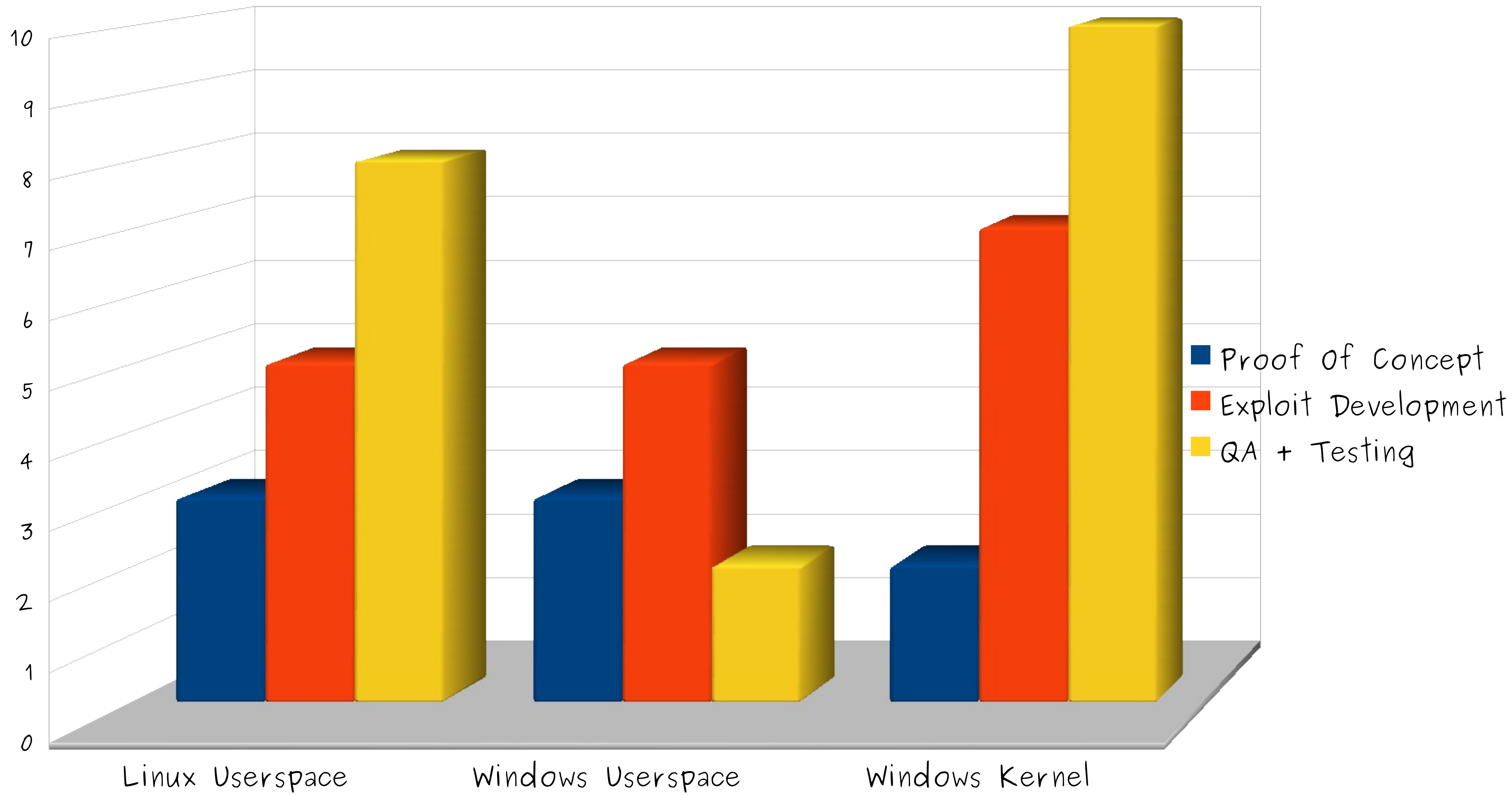
- Because few people know how to write them, Windows Kernel Heap overflows are often mis-characterized as “Denial of Service”
- Huge investment in exploit development before it is known if a reliable exploit can be created for any bug
  - If it costs 100K dollars to even know if you have a risk from any particular vulnerability, can you afford to find out?

Diversity increases QA costs dramatically



Addresses May Vary

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- The following slides assume:
  - Structures, constants and offsets are from ntkrnlpa.exe 5.1.2600.2180
  - nt!KeNumberNodes is 1 (non NUMA architecture)
- *Reminder*: Windows XP SP2 has 4 kernels
  - ntoskrnl.exe
  - ntkrnlpa.exe: PAE
  - ntkrnlmp.exe: MP
  - ntkrpamp.exe: PAE+MP (NUMA aware)

The Kernel Pool and its structures

Kernel Pool vs. Userland Heap

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- Quite similar
- Only a few pools for all the kernel allocations
  - Think LsaSs default heap
- Kernel pool is designed to be fast
  - As few checks as possible
    - No kernel pool cookie
    - No kernel pool safe unlink

Kernel Pool

- Used by Windows for dynamic memory allocations within kernel land by functions:
  - nt!ExAllocatePool, nt!ExAllocatePoolWithTag, ...
  - nt!ExFreePool, nt!ExFreePoolWithTag, ...
- There are several kernel pools, default being:
  - One *non-paged* pool
  - Two *paged* pools
  - One *session paged* pool
- Pools are defined thanks to structure nt!_POOL_DESCRIPTOR, and stored in nt!PoolVector

Non Paged Pool

- *Non pageable* system memory
- Can be accessed from any IRQL
- Scarce resource
- Descriptor for non paged pool is static:
  - nt!NonPagedPoolDescriptor in .data section
- It is initialized in nt!InitializePool
- Pointer to the descriptor is stored in entry 0 of nt!PoolVector

Paged Pool

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- *Pageable* system memory
- Number of paged pools defined by nt!ExpNumberOfPagedPools (default is **2**)
- An array of pool descriptors is dynamically allocated and initialized in nt!InitializePool
  - NonPagedPool allocation
  - One more descriptor than number of paged pools
- Pointer to array stored in entry 1 of nt!PoolVector and in nt!ExpPagedPoolDescriptor

Session Paged Pool

- *Pageable* system memory
- Descriptor for the session paged pool is located in the session space
  - PagedPool member of nt!MmSessionSpace structure
    - Usually 0xbf7f0000+0x244
- Initialized in nt!MiInitializeSessionPool
  - used for session space allocations
  - do not use lookaside lists
- Pointer to the descriptor stored in nt!ExpSessionPoolDescriptor

nt!_POOL_DESCRIPTOR

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```
kd> dt nt!_POOL_DESCRIPTOR
   +0x000 PoolType          : _POOL_TYPE
   +0x004 PoolIndex         : Uint4B
   +0x008 RunningAllocs     : Uint4B
   +0x00c RunningDeAllocs   : Uint4B
   +0x010 TotalPages        : Uint4B
   +0x014 TotalBigPages     : Uint4B
   +0x018 Threshold         : Uint4B
   +0x01c LockAddress       : Ptr32 Void
   +0x020 PendingFrees      : Ptr32 Void
   +0x024 PendingFreeDepth  : Int4B
   +0x028 ListHeads         : [512] _LIST_ENTRY
```

Pool Descriptor

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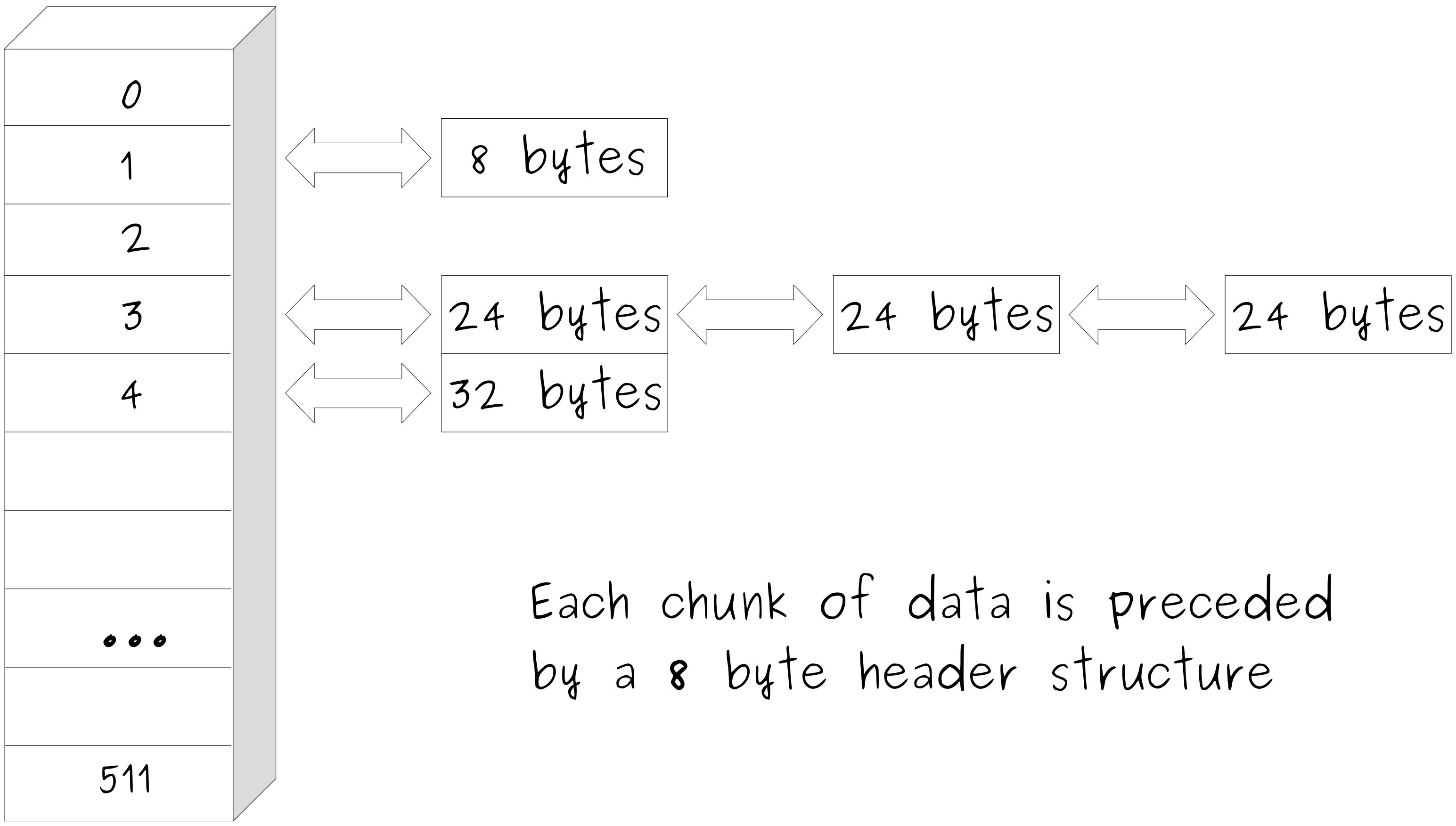
- Some of the members:
  - *PoolType*: NonPagedPool=0, PagedPool=1, ...
  - *PoolIndex*: 0 for non-paged pool and paged session pool, index of the pool descriptor in nt!ExpPagedPoolDescriptor for paged pools
  - *ListHeads*: 512 double-linked lists of free memory chunks of the same size (8 byte granularity)
    - List number for a requested allocation size is calculated by `BlockSize=(NumberOfBytes+0xf)>>3`
    - Thus can be used for allocations up to 0xff0 (4080) bytes

ListHeads



Each chunk of data is preceded by a 8 byte header structure

nt!_POOL_HEADER

```
kd> dt nt!_POOL_HEADER
   +0x000 PreviousSize       : Pos 0, 9 Bits
   +0x000 PoolIndex          : Pos 9, 7 Bits
   +0x002 BlockSize          : Pos 0, 9 Bits
   +0x002 PoolType           : Pos 9, 7 Bits
   +0x000 Ulong1             : Uint4B
   +0x004 ProcessBilled      : Ptr32 _EPROCESS
   +0x004 PoolTag            : Uint4B
   +0x004 AllocatorBackTraceIndex : Uint2B
   +0x006 PoolTagHash        : Uint2B
```

Chunk Header

- Explanations on some of the members:
  - *PreviousSize*: *BlockSize* of the preceding chunk
    - 0 if chunk is located at the beginning of a page
  - *BlockSize*: Number of bytes requested plus header size rounded up to a multiple of 8, divided by 8
    - or `(NumberOfBytes+0xf)>>3`
  - *PoolIndex*: same definition as for the descriptor
  - *PoolType*: 0 if free, (PoolType+1)|4 if allocated
  - *PoolTag*: Usually 4 printable characters identifying the code responsible for the allocation

Free Chunk Header

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- When *PoolType*=0, the chunk header is followed by a nt!_LIST_ENTRY structure
  - This is the entry pointed to by the ListHeads double linked list
- Chunks freed to the lookaside lists remain the same, their *PoolType* is non 0

```
kd> dt nt!_LIST_ENTRY
   +0x000 Flink            : Ptr32 _LIST_ENTRY
   +0x004 Blink            : Ptr32 _LIST_ENTRY
```

Lookaside Lists

- Like for userland heaps, kernel uses lookaside lists for faster allocating and freeing of small chunks of data
  - Maximum *BlockSize* being 32 (or 256 bytes)
- They are defined in the processor control block
  - 32 entry PPPagedLookasideList
  - 32 entry PPNPagedLookasideList
- Each entry holds **2** single chained lists of nt!_GENERAL_LOOKASIDE structures: one “per processor” *P*, one “system wide” *L*

nt!_GENERAL_LOOKASIDE

```
kd> dt nt!_GENERAL_LOOKASIDE
   +0x000 ListHead          : _SLIST_HEADER
   +0x008 Depth             : Uint2B
   +0x00a MaximumDepth      : Uint2B
   +0x00c TotalAllocates    : Uint4B
   +0x010 AllocateMisses    : Uint4B
   +0x010 AllocateHits      : Uint4B
   +0x014 TotalFrees        : Uint4B
   +0x018 FreeMisses        : Uint4B
   +0x018 FreeHits          : Uint4B
   +0x01c Type              : _POOL_TYPE
   +0x020 Tag               : Uint4B
   +0x024 Size              : Uint4B
   +0x028 Allocate          : Ptr32     void*
   +0x02c Free              : Ptr32     void
   +0x030 ListEntry         : _LIST_ENTRY
   +0x038 LastTotalAllocates : Uint4B
   +0x03c LastAllocateMisses : Uint4B
   +0x03c LastAllocateHits : Uint4B
   +0x040 Future            : [2] Uint4B
```

nt!MmNonPagedPoolFreeListHead

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- Static array of 4 double linked lists for non-paged free chunks bigger than a page
  - Index in the array is (SizeOfChunkInPages-1)
    - Last entry also has everything bigger than 4 pages
- Structure used is nt!_MMFREE_POOL_ENTRY

```
kd> dt nt!_MMFREE_POOL_ENTRY
   +0x000 List             : _LIST_ENTRY
   +0x008 Size             : Uint4B
   +0x00c Signature        : Uint4B
   +0x010 Owner            : Ptr32 _MMFREE_POOL_ENTRY
```

- Thus free non-paged “big” chunks are linked through the pages themselves

Allocation and Free algorithms

Allocation Summary

- Windows kernel pool allocates in small chunks:
  - 8 byte granularity up to 4080 bytes (included)
    - Used to be 32 for Windows 2000
  - Page granularity above
- Makes extensive use of optimized lists:
  - Single linked Lookaside lists up to 256 bytes
  - Double linked ListHeads lists up to 4080 bytes
- Splits an entry if a chunk of the exact size cannot be found
- Expands the pool if needed

Simplified Allocation Algorithm

nt!ExAllocatePoolWithTag (1/2)

- If NumberOfBytes>0xff0:
  - Call nt!MiAllocatePoolPages
- If PagedPool requested:
  - If BlockSize≤0x20:
    - Try the “per processor” paged lookaside list
    - If failed, try the “system wide” paged lookaside list
    - Return on success
  - Try and lock a paged pool descriptor
- Else:
  - If BlockSize≤0x20:
    - Try the “per processor” non-paged lookaside list

Simplified Allocation Algorithm

nt!ExAllocatePoolWithTag (2/2)

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    - If failed, try the "system wide" non-paged lookaside list
    - Return on success
  - Try and lock the non-paged pool descriptor
- Use ListHeads of currently locked pool:
  - Use 1st non empty ListHeads[n]
    - With BlockSize≤n<512
    - Split entry if bigger than needed
    - Return on success
  - If failed, expand the pool by adding a page
    - Try again!

Free Chunk Splitting

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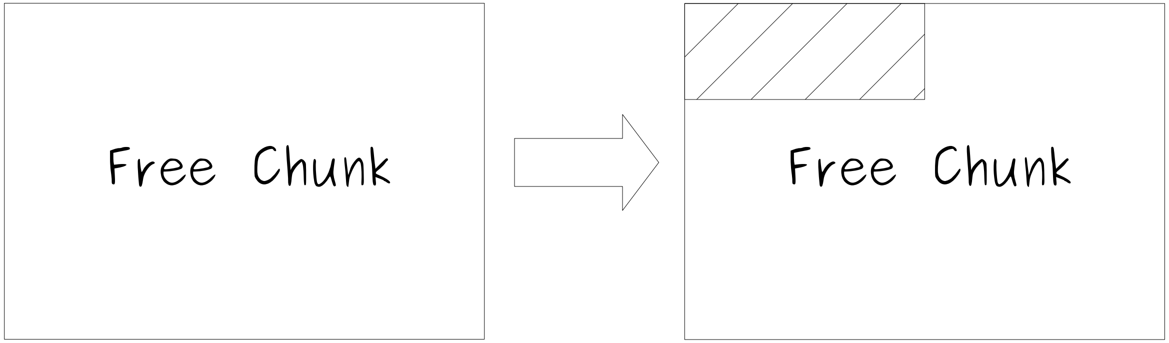
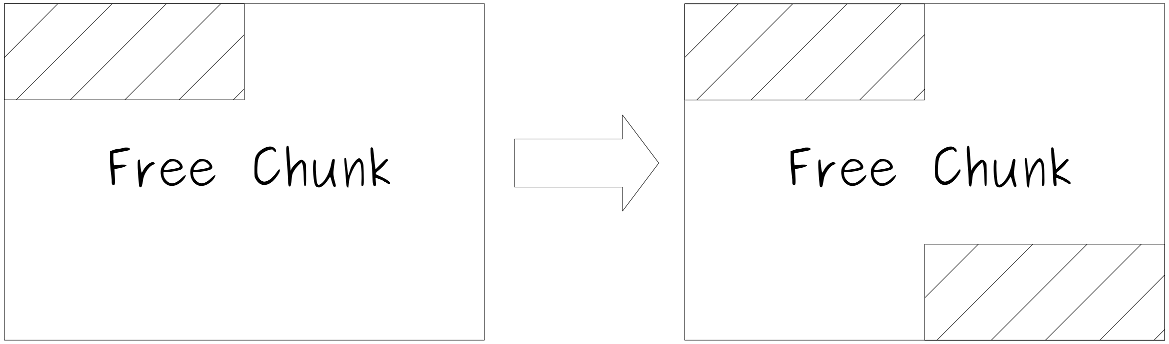
- If the algorithm has selected a chunk larger than the requested NumberOfBytes, <u>it is split</u>
  - If the chunk is at the start of a page:
    - Take the allocation from the *front* of the chunk
  - Otherwise:
    - Take the allocation from the *end* of the chunk
- The remaining part is inserted in the correct list

Splitting Schema

Free chunk at the beginning of a page, allocated chunk goes at the front



Otherwise, allocated chunk goes at the end



Free Summary

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- Free algorithm works pretty much as expected:
  - It will use Lookaside lists for chunks up to 256 bytes
    - If they are not full already
  - It will use ListHeads for chunks up to 4080 bytes
- Merges contiguous free chunks to lower fragmentation
- Releases pages if necessary

Simplified Free Algorithm

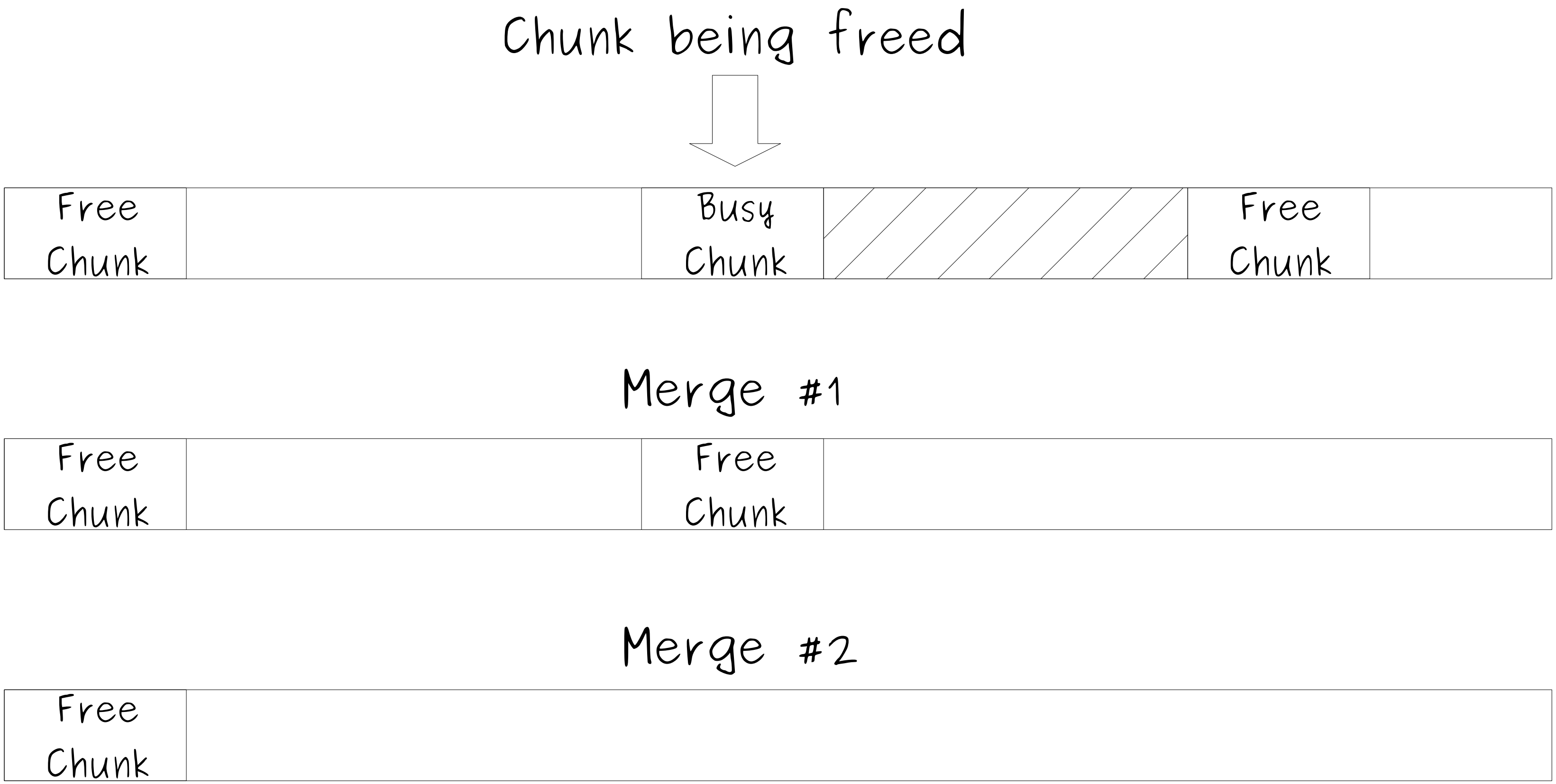
nt!ExFreePoolWithTag (1/2)

- If P is page aligned:
  - Call nt!MiFreePoolPages
- If BlockSize≤0x20:
  - If PoolType=PagedPool:
    - Put in “per processor” paged lookaside list
    - If failed, put in “system wide” paged lookaside list
    - Return on success
  - Else:
    - Put in “per processor” non-paged lookaside list
    - If failed, put in “system wide” non-paged lookaside list
    - Return on success

Simplified Free Algorithm
nt!ExFreePoolWithTag (2/2)

- If next chunk is free and not page aligned:
  - Merge with current chunk
- If previous chunk is free:
  - Merge with current chunk
- If resulting chunk is a full page:
  - Call nt!MiFreePoolPages
- Else:
  - Add chunk to the tail of the correct ListHeads
    - Based on PoolType, PoolIndex and BlockSize of chunk

Merging Schema



Exploiting a Kernel Pool overflow

Pool BugChecks

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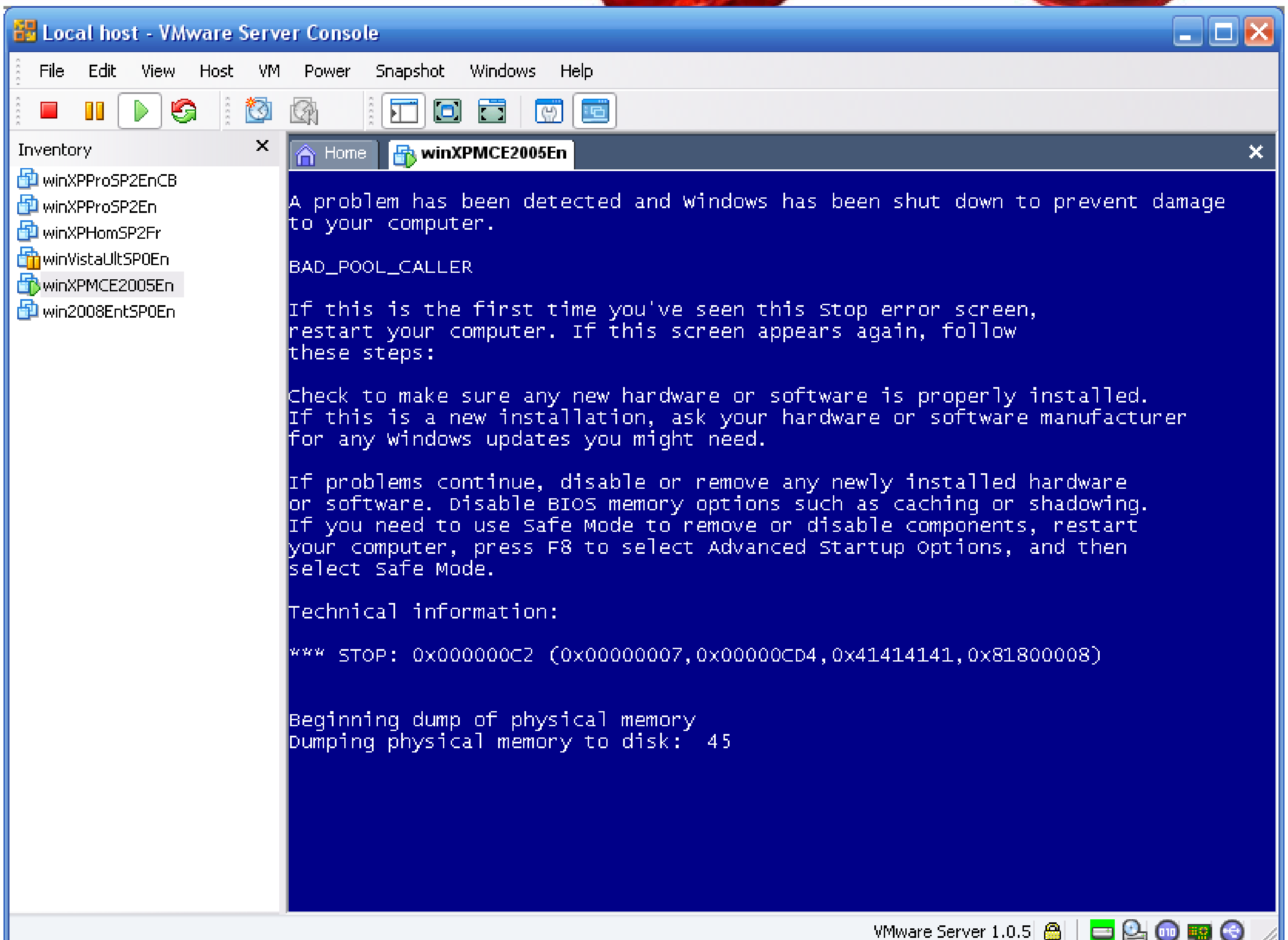
- Discrepancies in the kernel pool will most likely result in a BugCheck (Blue Screen)

```
0x19: BAD_POOL_HEADER
0x41: MUST_SUCCEED_POOL_EMPTY
0xc1: SPECIAL_POOL_DETECTED_MEMORY_CORRUPTION
0xc2: BAD_POOL_CALLER
```

- Some are only present in Checked Build
- Avoid those when exploiting a pool overflow!

BugCheck Example



Some BugCheck Conditions

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- nt!ExFreePoolWithTag:
  - BugCheck 0xc2, 7 if *PoolType*&4=0
    - The chunk attempted to be freed is already free
  - BugCheck 0x19, 0x20 if *PreviousSize* of next chunk is ≠ *BlockSize* of current chunk
- Checked Build:
  - BugCheck 0x19, 3 if (Entry→Flink)→Blink!≠Entry or (Entry→Blink)→Flink≠Entry
    - It didn't make it to retail build, thanks Microsoft!

Exploitable Overflows?

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Yes!

- Unlike in userland heaps, there is no such thing as a kernel pool *cookie*
- There is no safe unlinking in retail build

Kernel Pool Unlink

- Removing an entry '*e*' from a double linked list:

```
PLIST_ENTRY b,f;
f=e→Flink;
b=e→Blink;
b→Flink=f;
f→Blink=b;
```

- This leads to a usual write4 primitive:

```
*(where)=what
*(what+4)=where
```

- Locating the unlinks:
  - nt!ExFreePoolWithTag: when merging chunks
  - nt!MiAllocatePoolPages, nt!MiFreePoolPages, ...

Notations

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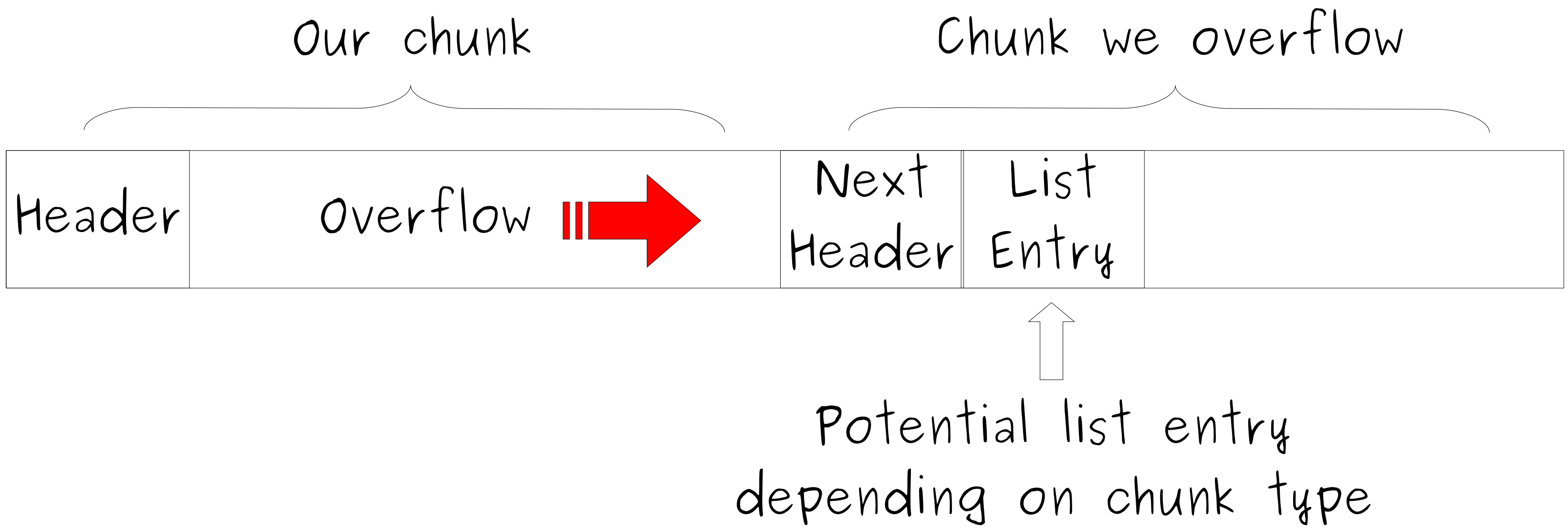
Kernel Pool Overflow



Different Write4

- Summary list of write4 techniques:
  - Write4 on Merge with Next
    - When freeing our chunk
  - Write4 on Merge with Previous
    - When freeing the chunk we overflowed
  - Write4 on *ListHeads* Unlink
    - If we overflowed an entry in a *ListHeads* list
  - Write4 on MmNonPagedPoolFreeListHead Unlink
    - If we overflowed an entry in a MmNonPagedPoolFreeListHead list

Write4 on Merge with Next

Case #1

- When our chunk is freed:
  - If *PreviousSize* of next chunk is = *BlockSize* of current chunk
    - To avoid BugCheck 0x19
  - If *BlockSize*>0x20 (or lookaside lists are full)
    - To avoid a free to lookaside
  - If *PoolType* of next chunk is 0
  - If *BlockSize* of next chunk is >1
    - Otherwise it means there is no list entry
  - Then merge with next chunk:
    - And **unlink** happens on list entry of next chunk

Exploit Case #1

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- Allocate a chunk of size 256-4080 bytes
  - Works with smaller chunks if lookaside lists are full
- Craft a free header after our chunk with:
  - Correct *PreviousSize*
  - *PoolType*=0
  - Wanted *Flink* and *Blink*
  - Requires a minimum overflow of about 16 bytes
- Write4 happens when <u>our allocated chunk is freed</u>

Write4 on Merge with Previous

Case #2

- When the chunk we overflowed is freed:
  - If *PreviousSize* of next chunk is = *BlockSize* of current chunk
    - To avoid BugCheck 0x19
  - If *BlockSize*>0x20 (or lookaside lists are full)
    - To avoid a free to lookaside
  - If *PoolType* of previous chunk is 0
  - If *BlockSize* of previous chunk is >1
    - Otherwise it means there is no list entry
  - Then merge with previous chunk:
    - And **unlink** happens on list entry of previous chunk

Exploit Case #2 (1/2)

- Allocate a chunk
- Next chunk **must** be allocated and of size 256-4080 bytes (not as easy as it looks)
  - Works with smaller chunks if lookaside lists are full
- Craft a fake <u>free</u> header and list entry at the end of our chunk (with realistic sizes)
- Overflow *PreviousSize* of next chunk to make it point to our fake header
  - Requires a <u>~1 byte overflow</u>!
    - 0x00 can work if *PreviousSize*>0x100

Exploit Case #2 (2/2)

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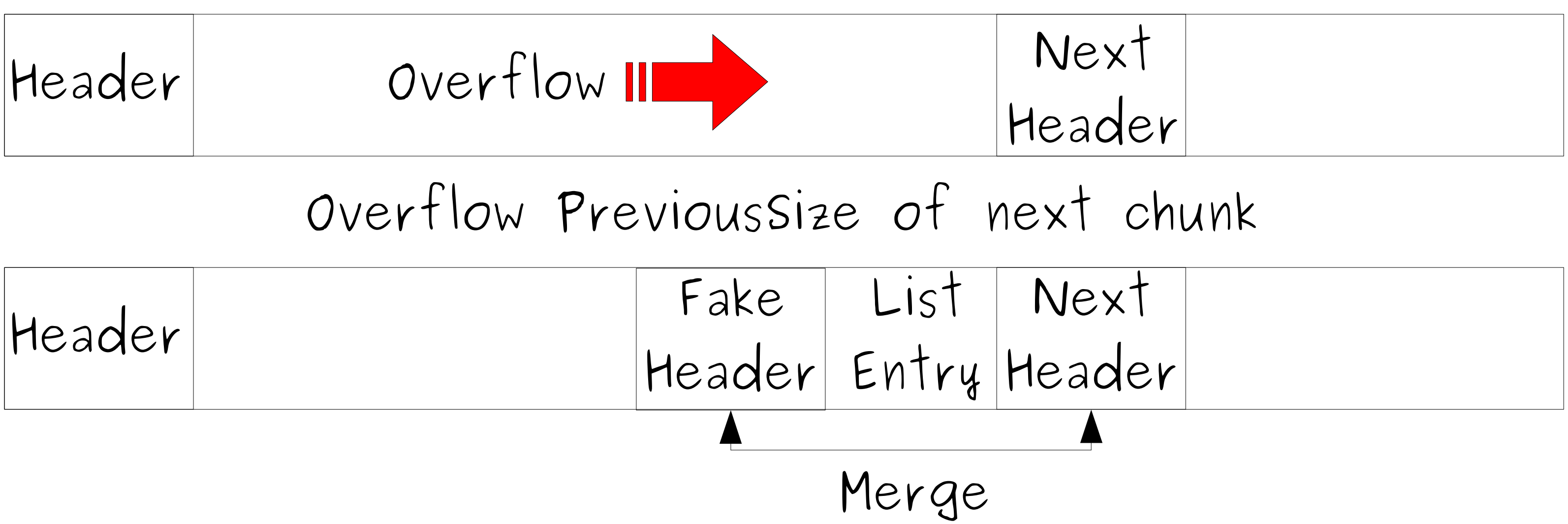
- A bigger overflow would require knowledge of *BlockSize* of next chunk to avoid BugCheck
  - Or enough bytes to craft another header after (~257)
- Write4 happens when <u>next chunk is freed</u>
  - Also works with page aligned chunks!



ListHeads Write4

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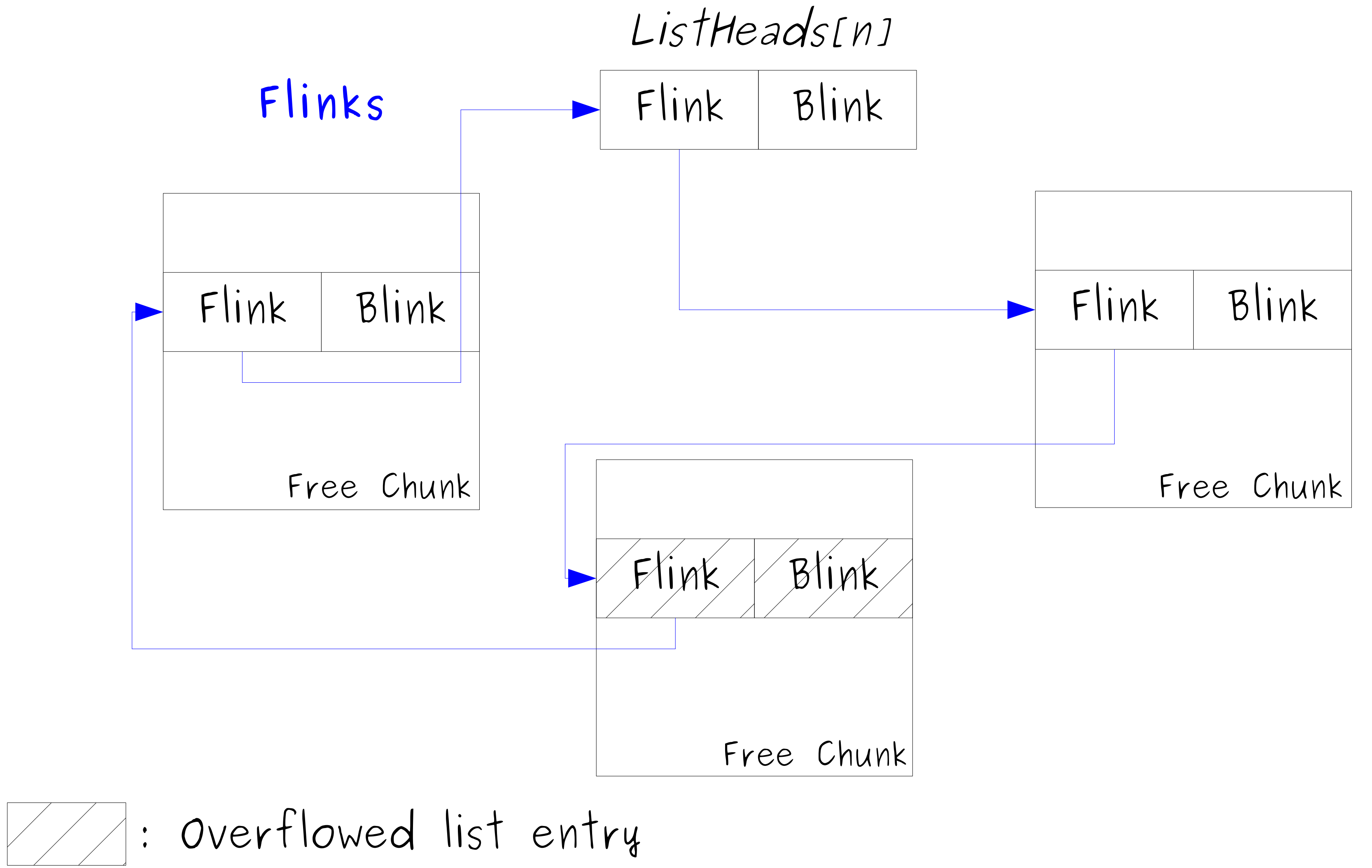
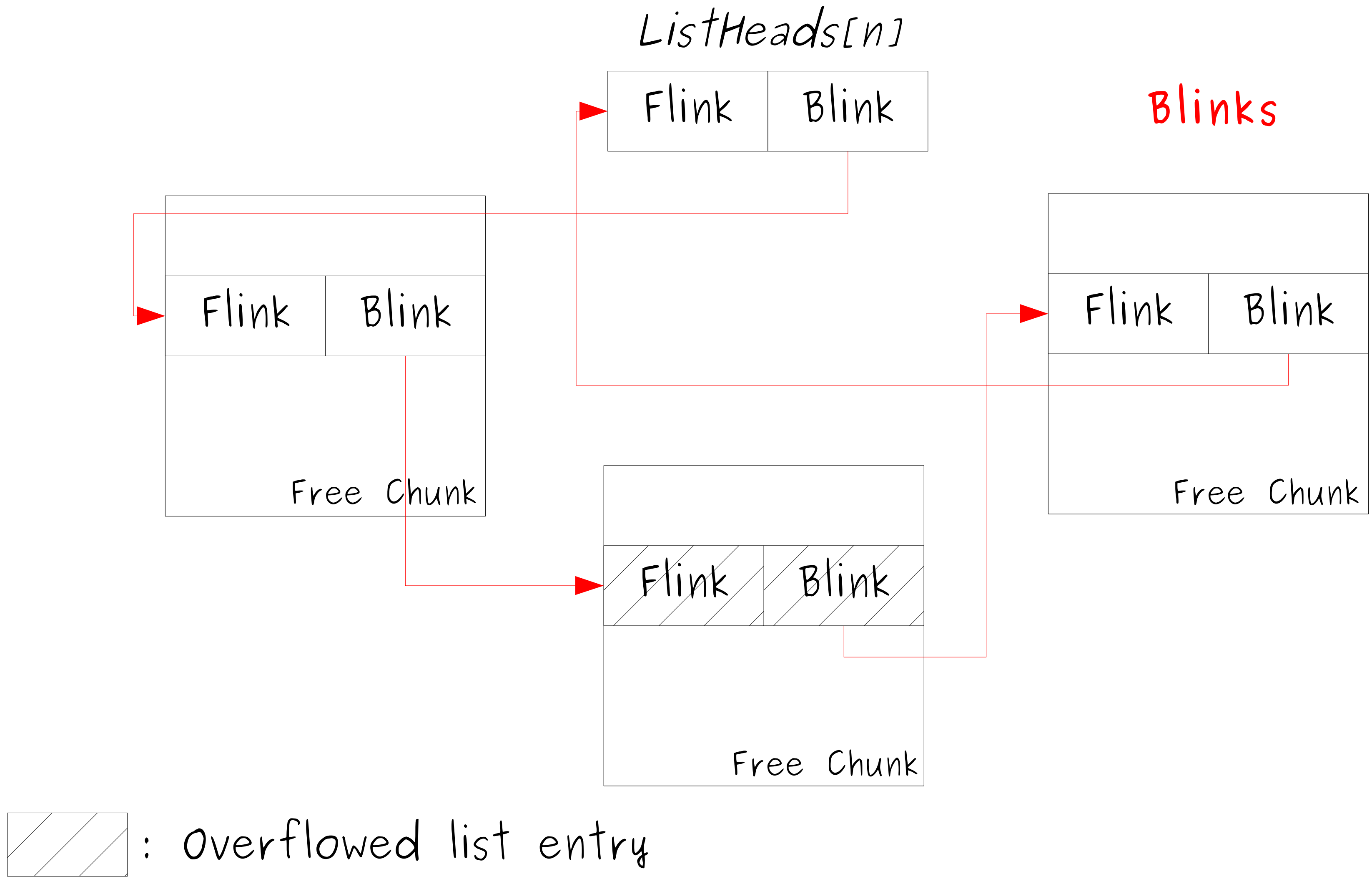
- When the chunk we overflowed is allocated:
  - If the chunk was requested through ListHeads list
    - No other constraint on *BlockSize*, *PreviousSize*, ...
  - Then the overflowed list entry is removed from the ListHeads list:
    - We overwrite of ListHeads[*BlockSize*]→*Flink* with a pointer we control
- Next time a chunk of *BlockSize* is requested, our pointer will be returned
- **Variations** of the write4 exist based on operations done on the neighboring entries

ListHeads Illustrated (1/3)

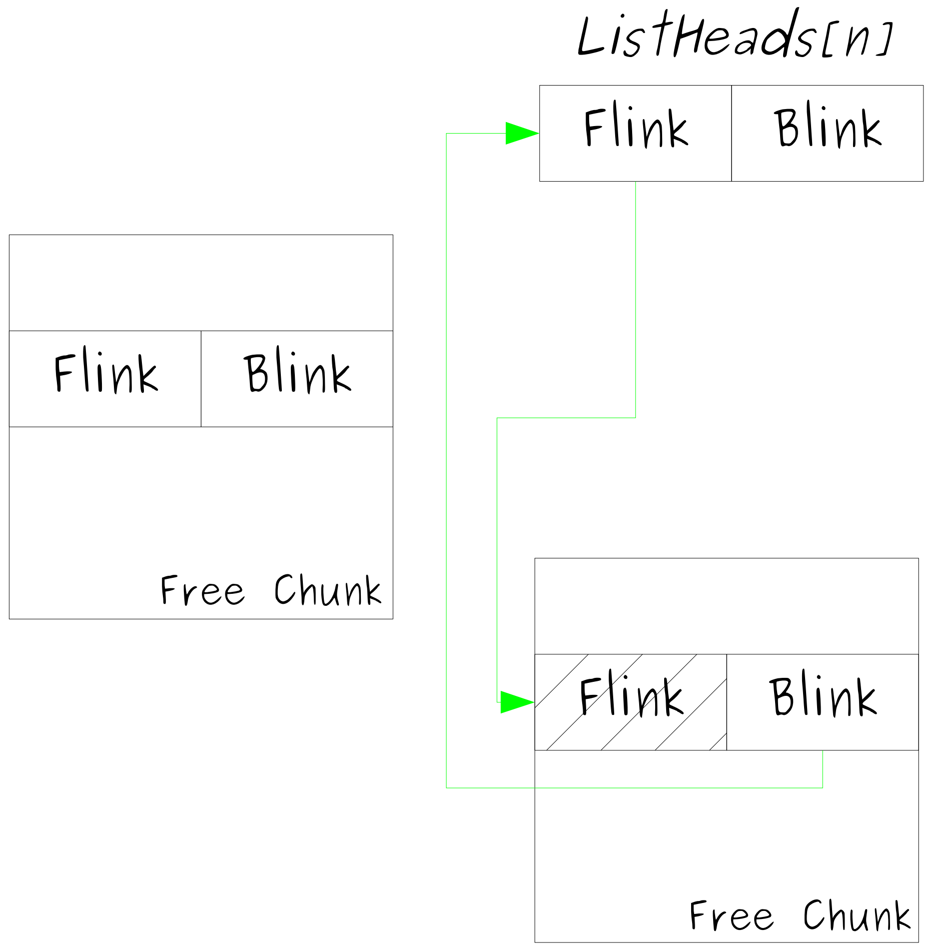


ListHeads Illustrated (1/3)

KNOWING YOU'RE SECURE



ListHeads Illustrated (2/3)



Allocation of size n unlinks ListHeads[n]→Flink

```
PLIST_ENTRY b,f;
f=ListHeads[n]->Flink->Flink;
b=ListHeads[n]->Flink->Blink;
b->Flink=f;
f->Blink=b;
```

ListHeads Illustrated (3/3)

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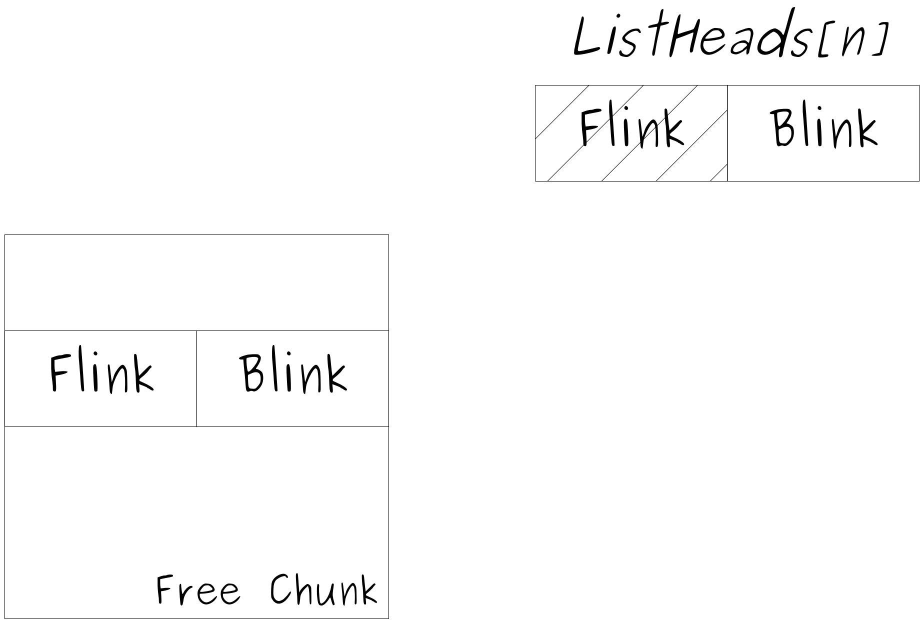

Allocation of size n unlinks ListHeads[n]→Flink

```
PLIST_ENTRY b,f;
f=ListHeads[n]→Flink→Flink;
b=ListHeads[n]→Flink→Blink;
b→Flink=f;
f→Blink=b;        ⇦ might AV
```

ListHeads[n]→Flink is now under our control!

MMFREE_POOL_ENTRY Write4

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- When the chunk we overflowed is allocated:
  - If the chunk was requested through nt!MmNonPagedPoolFreeListHead list
    - Overflowed chunk is obviously page aligned
  - Then the write4 happens when the MMFREE_POOL_ENTRY structure is removed from the double linked list
- Variants of the write4 exist based on operations done on the neighboring list entries

What? Where?

- Most complicated with Kernel Pool overflows:
  - Only a few pools for **all** kernel allocations
    - Lot of allocation and free
  - 4 different kernels based on architecture:
    - Single processor: *ntoskrnl.exe*, *ntkrnlpa.exe*
    - Multi processors: *ntkrnlmp.exe*, *ntkrpamp.exe*
  - A lot of kernel patches for every service pack
  - ⇨ Addresses tend to change, <u>a lot</u>
- Any access violation will most likely end up in a BugCheck ☹

Some Ideas

Non Exhaustive

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- nt!KiDebugRoutine function pointer
  - Called by nt!KiDispatchException if not NULL
  - Should be kept as last resort
- Context specific function pointers
  - tcpip!tcpxsum_routine is called right after the overflow in the case of MS08-001
- Function pointers arrays
  - nt!HalDispatchTable
  - Interrupt Dispatch Table (IDT)
- Kernel instructions – page is RWE!

Write4 into the Kernel

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- Before

Edx points to something we control

```
    mov eax, [edx+8]
    mov ebx, [edx+0Ch]
    mov [ebx], eax
    mov [eax+4], ebx
loc_80543F0B: ; CODE XREF: ExFreePoolWithTag(x,x)+518j
    movzx edx, word ptr [edx+2]
```

- After

Jmp edx being 2 bytes long, we can pick the upper 2 so that the write4 doesn't trigger an access violation

```
    mov eax, [edx+8]
    mov ebx, [edx+0Ch]
    mov [ebx], eax
    mov [eax+4], ebx
loc_80543F0B: ; CODE XREF: ExFreePoolWithTag(x,x)+518j
    jmp edx
```

Fixing the Kernel Pool

- Check for inconsistencies and fix them:
  - Lookaside lists, both “per processor” and systemwide
    - Zero out *Sequence*, *Depth* and *Next* of *ListHead* member of the given nt!_GENERAL_LOOKASIDE entry
      - In fact the first 8 bytes
  - ListHeads lists for involved pool descriptor(s)
    - Set ListHeads[*BlockSize*]→*Flink* and ListHeads[*BlockSize*]→B*link* to &ListHeads[*BlockSize*]
  - nt!MmNonPagedPoolFreeListHead array

MS08-001: IGMPv3 Kernel Pool overflow

History

- Remote default kernel pool overflow in Windows XP when parsing IGMPv3 packets
  - Even bypasses default firewall rules!
- Released January, 8th 2008 in MS08-001
  - Along with MLDv2 vulnerability for Vista
- Reported by Alex Wheeler and Ryan Smith of IBM – Internet Security Systems
- Considered by Microsoft SWI as “unlikely” exploitable

IGMPv3 Membership Queries

RFC 3376

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Type = 0x11  | Max Resp Code |           Checksum            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Group Address                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Resv  |S| QRV |     QQIC      |     Number of Sources (N)     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address [1]                      |
+-                                                             -+
|                       Source Address [2]                      |
+-                              .                              -+
.                               .                               .
.                               .                               .
+-                                                             -+
|                       Source Address [N]                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Vulnerability

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1. Walk a single linked list to count the number of entries (using a 32 bit counter)
2. Allocate some memory:

```
loc_44197:    ; CODE XREF: GetGSIsInRecord(x,x)+18j
    push 10h ; Priority
    movzx eax, dx          ⇦ Failed!
    push 'qICT' ; Tag
    lea eax, ds:8[eax*4]
    push eax ; NumberOfBytes
    push ebx ; PoolType
    call ds:__imp__ExAllocatePoolWithTagPriority@16
```

3. Copy the list entries in the allocated array by walking the list ⇨ Overflow

Trigger

- Send multiple IGMPv3 membership queries
  - Group address has to be valid
  - Can be sent to:
    - Unicast IP address (ie. 10.10.10.42)
    - Broadcast IP address (ie. 10.10.10.255)
    - Multicast IP address (ie. 224.0.0.1)
  - Total number of **unique** source addresses must be 65536 or greater
    - IP addresses in the 224-239 range are ignored
- Wait for the IGMPv3 report to be triggered

Issues (1/2)

- Sending a lot of IGMPv3 membership queries induces *high CPU utilization*
  - Each new source address triggers the allocation of a **20 (0x14) byte** structure
  - The linked list of structures is walked before adding a new element to check for uniqueness of IP ($O(n^2)$)
- High CPU usage leads to potential <u>packets dropping</u>
  - Final buffer will not be as expected

Issues (2/2)

- IGMPv3 reports are on a *random* timer
  - Can be triggered before all the queries are sent
  - Buffer will not be filled as intended
- 16 bit wrap *usually* means **huge** overflow
  - 65536 entries are put in a 0 byte buffer

Solutions

KNOWING YOU'RE SECURE

- Exponential delay between packets sending
  - Still fast enough to avoid a random report trigger
- Report trigger can be forced if *QQIC=0*
  - Empty the list before the attack
  - Trigger the overflow when all the packets are sent
- Index for the copy is on 16 bit register
  - Overflow size is actually (for n>0xffff):

$$(0x10000-(n\%0x10000))*4$$

  - For *n=0x1fffe*, allocation size if **0x40000** (page aligned allocation), overflow size is **8**

Dirty Way

256<(n%0x10000)*4+8<4080

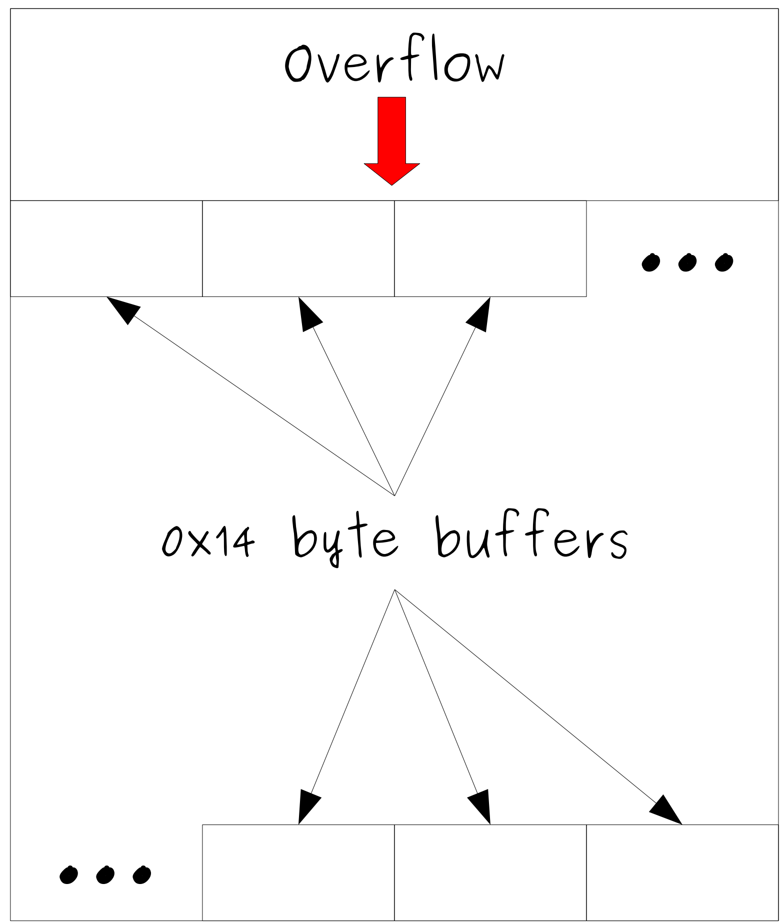
- Pros
  - Relatively small number of packets (~180)
  - Since the allocated buffer is freed after the overflow, "Write4 on Merge with Next" will always happen
    - Next chunk is easily craftable
  - We control *BlockSize* to some extent, which is interesting for the "Write4 into Kernel" technique
- Cons
  - Overflow is huge! (>0x3f000 bytes)
    - A large chunk of the kernel pool will be trashed ☹
    - Lot of pool fixing to do

Why would it work?

KNOWING YOU'RE SECURE

Kernel Pool is filled with n 0x14 byte buffers

Our buffer will be allocated before those (we pretty much exhausted all the free chunks)



Buffer closest to our allocated buffer is the 1st one to be copied and freed

Requires a "carpet" of ~13000 contiguous 0x14 byte buffers (not too hard)

Clean Way

(0x10000-(n%0x10000))*4=8

KNOWING YOU'RE SECURE

- Pros
  - 8 byte overflow only
    - The kernel pool remains pretty clean
- Cons
  - Next chunk can be:
    - A nt!_MMFREE_POOL_ENTRY: we overflow a list entry
    - A busy nt!_POOL_HEADER
      - “Write4 on Merge with Previous” will happen on free
    - Etc

    ⇨ Headaches
  - Higher number of packets (~300)

Conclusion

Conclusion

- Kernel still offers a nice playground for exploitation even in latest Windows versions
- Exploitation costs have increased dramatically
  - We're still working on MS08-001!

NUMA

- More memory allocations are NUMA aware:
  - Up to 16 non-paged pool descriptors
    - Initial non-paged pool has separate address ranges for each node
  - Up to 16 paged pool descriptors
- This makes kernel pool overflows more complex

Literature

- How to exploit Windows kernel memory pool
  - SoBeIt, Xcon 2005
- Reliable Windows Heap Exploits
  - M. Conover, O. Horovitz, CanSecWest 2004
- Owning NonPaged pool using stealth hooking
  - mxatone, Phrack 65

Thank you!

Questions?