Windows Heap Overflows

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Introduction

This presentation will examine how to exploit heap based buffer overflows on the Windows platform. Heap overflows have been well documented on *nix platforms, for example Matt Connover's paper – w00w00 on heap overflows, but they've not been well documented on Windows, though Halvar Flake's Third Generation Exploits paper covered the key concepts.

Heap based buffers are safe…. ?????

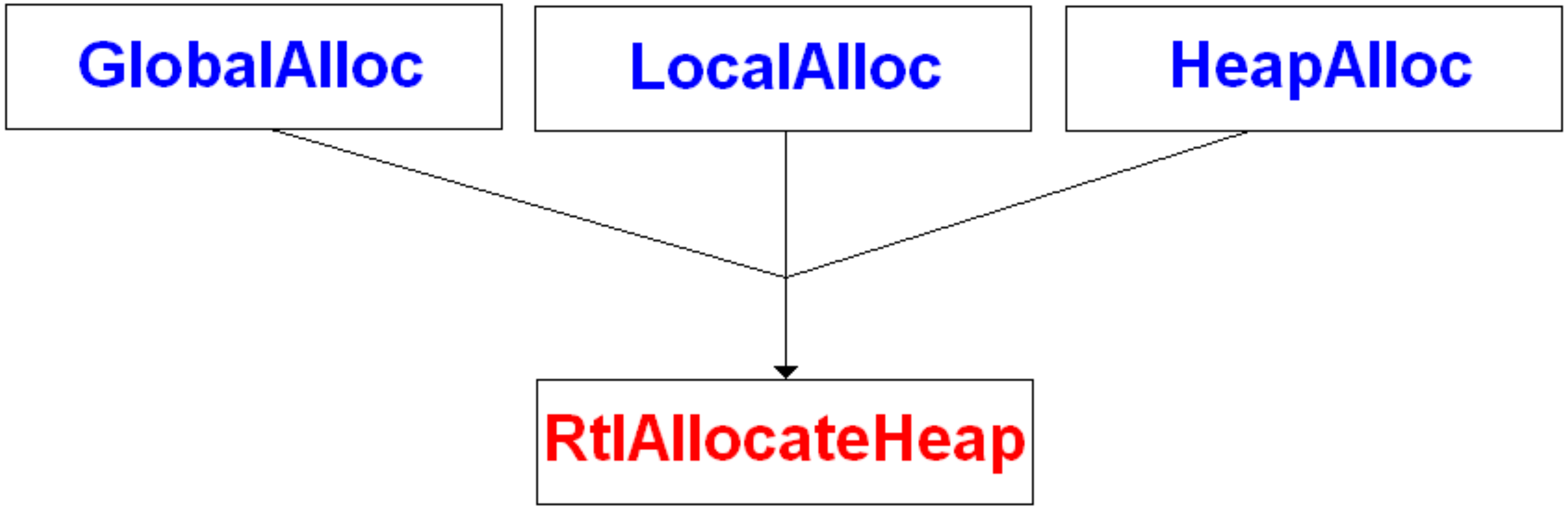
Most developers are aware of the dangers of stack based buffer overflows but too many still believe that if a heap based buffer is overflowed it's not too much of a problem.

One paper on secure coding suggested that to solve the problem of stack based overflows was to move the buffer to the heap!

What is a heap?

The heap is an area of memory used for storage of dynamic data. Every process has a default process heap but a developer can create their own private heaps. Space is allocated from the heap and freed when finished with.

Heap functions



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Heap Design

Each heap starts with a structure. This structure, amongst other data, contains an array of 128 LIST_ENTRY structures. Each LIST_ENTRY structure contains two pointers – see winnt.h. This array can be found at 0x178 bytes into the heap structure – call it the FreeList array.

Heap Design

When a heap is first created there are two pointers that point to the first free block set in FreeList[0]. Assuming the heap base address is 0x00350000 then first available block can be found at 0x00350688.

Heap Design

0x00350178 (FreeList[0].Flink) = 0x00350688 (First Free Block)
0x0035017C (FreeList[0].Blink) = 0x00350688 (First Free Block)

0x00350688 (First Free Block) = 0x00350178 (FreeList[0])
0x0035068C (First Free Block+4) = 0x00350178 (FreeList[0])

When an allocation occurs these pointers are updated accordingly. As more allocations and frees occur these pointers are continually updated and in this fashion allocated blocks are tracked in a doubly linked list.

So where's the problem?

When a heap based buffer is overflowed the control information is overwritten so when the buffer (allocated block) is freed and it comes to updating the pointers in the FreeList array there's going to be an access violation.

So where's the problem?

Example: See code listing A – heap.c

So where’s the problem?

Access violation

```
77F6256F mov dword ptr [ecx],eax
77F62571 mov dword ptr [eax+4],ecx
```

```
EAX = 0x42424242
ECX = 0x42424242
```

If we own both EAX and ECX we have an arbitrary DWORD overwrite. We can overwrite the data at any 32bit address with a 32bit value of our choosing.

Exploiting Heap Overflows

Repairing the Heap

Unhandled Exception Filter

PEB function Pointer

Vectored Exception Handling

Thread Environment Block

Repairing the heap

After the overflow the heap is corrupt so you'll need to repair the heap.

Many of the Windows API calls use the default process heap and if this is corrupt the exploit will access violate.

Repairing the heap

Could repair on a per vulnerability/exploit basis. Time consuming and could run into problems.

Need a generic way to repair the heap which is effective for all exploits. Write it once and reuse it.

Repairing the heap

The best method for repairing the heap is to reset the heap making it “appear” as if it is a fresh new heap. This will keep other heap data intact but allow fresh allocations.

Repairing the heap

We reset our overflow heap control structure with heap.TotalFreeSize and set the flags to 0x14 then set heap.FreeLists[0].Flink and heap.FreeLists[0].Blink to the start of the fake control structure.

See code listing B – asm-repair-heap.

Exploit: Using the Unhandled Exception Filter

The Unhandled Exception Filter method is the most common method used. The UEF is the “last ditch effort” exception handler.

Exploit: Using the Unhandled Exception Filter

Location varies from OS to OS and SP to SP. Disassemble the SetUnhandledExceptionFilter function.

```
77E7E5A1          mov ecx,dword ptr [esp+4]
77E7E5A5          mov eax,[77ED73B4]
77E7E5AA          mov dword ptr ds:[77ED73B4h],ecx
77E7E5B0          ret 4
```

UEF = 0x77ED73B4

Exploit: Using the Unhandled Exception Filter

When an unhandled exception occurs the following block of code is executed:

```
77E93114mov eax,[77ED73B4]
77E93119cmp eax,esi
77E9311B                je 77E93132
77E9311D                push edi ***
77E9311E                call eax
```

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Exploit: Using the Unhandled Exception Filter

Essence of the method is to set our own Unhandled Exception Filter.

EDI was pushed onto the stack. 0x78 bytes past EDI is a pointer to the end of the buffer – just before the heap management control stuff.

Exploit: Using the Unhandled Exception Filter

Set the UEF to an address that points to a

CALL DWORD PTR [EDI + 0x78]

Many can be found in netapi32.dll, user32.dll, rpcrt4.dll for example.

Exploit: Using the Unhandled Exception Filter

Notes: Other OSes may not use EDI. Windows 2000 for example has a pointer at ESI+0x4C and EBP+0x74.

Using this method you need to know the target system – i.e. what OS and what SP level.

Exploit: Using the Unhandled Exception Filter

Example: See code listing C – heap-uef.c and code listing D - exploit-uef.c

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Exploit: Using Vectored Exception Handling

Vectored Exception Handling is new as of Windows XP.

Unlike traditional frame based exception handling where EXCEPTION_REGISTRATION structures are stored on the stack information about VEH is stored on the heap.

Exploit: Using Vectored Exception Handling

A pointer to the first Vectored Exception Handler is stored at 0x77FC3210. Points to a _VECTORED_EXCEPTION_NODE.

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Exploit: Using Vectored Exception Handling

```
struct _VECTORED_EXCEPTION_NODE
{
   DWORD   m_pNextNode;
   DWORD   m_pPreviousNode;
   PVOID   m_pfnVectoredHandler;
}
```

Exploit: Using Vectored Exception Handling

Vectored handlers are called before any frame based handlers! Technique involves overwriting the pointer to the first _VECTORED_EXCEPTION_NODE @ 0x77FC3210 with a pointer to a fake VE node.

Exploit: Using Vectored Exception Handling

```
77F7F49E        mov     esi,dword ptr ds:[77FC3210h]
77F7F4A4        jmp     77F7F4B4
77F7F4A6        lea     eax,[ebp-8]
77F7F4A9        push    eax
77F7F4AA        call    dword ptr [esi+8]
77F7F4AD        cmp     eax,0FFh
77F7F4B0        je      77F7F4CC
77F7F4B2        mov     esi,dword ptr [esi]
77F7F4B4        cmp     esi,edi
77F7F4B6        jne     77F7F4A6
```

The code behind calling the vectored exception handler.

Exploit: Using Vectored Exception Handling

Need to find a pointer on the stack to our buffer. Assume it can be found at 0x0012FF50. This becomes our m_pfnVectoredHandler making the address of our pseudo _VECTORED_EXCEPTION_NODE 0x0012FF48.

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Exploit: Using Vectored Exception Handling

Remember on the free we get an arbitrary DWORD overwrite:

```
77F6256F mov dword ptr [ecx],eax
77F62571 mov dword ptr [eax+4],ecx
```

We set EAX to 0x77FC320C and ECX to 0x0012FF48.

Exploit: Using Vectored Exception Handling

0x77FC320C is moved into 0x0012FF48 then 0x0012FF48 is moved into 0x77FC3210 – thus our pointer is set. When an exception occurs 0x0012FF48 (our pseudo VEN) is moved into ESI and DWORD PTR[ESI+8] is called. ESI+8 is a pointer to our buffer.

Exploit: Using Vectored Exception Handling

Notes: If the location of the stack (and thus the pointer to the buffer) moves this method can be unreliable.

Example: See code listing E – heap-vector.c and F – exploit-vector.c

Exploit: RtlEnterCriticalSection pointer in the PEB

Each process contains a structure known as the PROCESS ENVIRONMENT BLOCK or PEB. The PEB can be referenced from the Thread Information/Environment Block TIB/TEB. FS:[0] points to the TEB.

```
mov eax, dword ptr fs:[0x30]
mov eax, dword ptr fs:[eax+0x18]
```

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Exploit: RtlEnterCriticalSection pointer in the PEB

As well as containing other process specific data the PEB contains some pointers to RtlEnterCriticalSection and RtlLeaveCriticalSection. These pointers are referenced from RtlAccquirePebLock and RtlReleasePebLock. RtlAccquirePebLock is called from ExitProcess for example.

Exploit: RtlEnterCriticalSection pointer in the PEB

The location of the PEB is stable across Windows NT 4 / 2000 / XP and thus the pointer to RtlEnterCriticalSection can be found at 0x7FFDF020. Whilst the PEB can be found at the same address in Windows 2003 the function pointers are no longer present so this method won’t work with 2003.

Exploit: RtlEnterCriticalSection pointer in the PEB

The method simply involves overwriting the pointer to RtlEnterCriticalSection in the PEB with the address of an instruction that will return to the buffer.

Example: See code listing G – heap-peb.c and H – exploit-peb.c

Exploit: TEB Exception Handler Pointer

Each Thread Environment Block contains a pointer to the first frame based exception handler. The first thread's TEB has a base address of 0x7FFDE000 and each new thread's TEB is assigned an address growing towards 0x00000000. If a thread exits and a new thread is created then it will get the address of the previous thread's TEB.

Exploit: TEB Exception Handler Pointer

This can lead to a “messy” TEB table and can make this method uncertain.

However, if the address of the vulnerable thread’s TEB is stable then this method can be used quite effectively.

Exploit: TEB Exception Handler Pointer

The method involves overwriting the pointer to the first exception handler in the TEB with an address that points to an instruction that will get path of execution back to the buffer.

Exploit: Getting Creative!

There are other ways to exploit heap based buffer overflows to execute arbitrary code to defeat mechanisms such as marking the heap as non-executable.

Exploit: Getting Creative!

Assume we have a process with the heap marked as non-executable. This can be defeated with pointer subversion.

An example of this can be found in the fault reporting functionality of the UnhandledExceptionFilter() function.

Exploit: Getting Creative!

The fault reporting code calls GetSystemDirectoryW() to which "faultrep.dll" is concatenated. This library is the loaded and the ReportFault() function is called.

Exploit: Getting Creative!

GetSystemDirectoryW() references a pointer in the .data section of kernel32.dll that points to where the wide character string of the Windows system directory can be found. This pointer can be found at 0x77ED73BC. On overflow we can set this pointer to our own system directory.

Exploit: Getting Creative!

Thus when GetSystemDirectoryW() is called the "system" directory is a directory owned by the attacker – this can even be a UNC path. The attacker would create their own faultrep.dll which exports a ReportFault() function and so when the UnhandledExceptionFilter() function is called arbitrary code can be executed.

Exploit: Getting Creative!

Whilst code paths are finite I'd argue that the possibilities of what can be done is limited more by the imagination.

Conclusion

Hopefully this presentation has demonstrated the dangers of heap based buffer overflows and that developers not treat them as benign.

Any questions?

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Thanks for coming!

Thanks for coming and enjoy the rest of the conference!

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