Riding the Overflow – Then and Now

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tl;dr


I USED TO BE GOOD
AT BUFFER OVERFLOWS
UNTIL THEY STARTED
TO PROTECT
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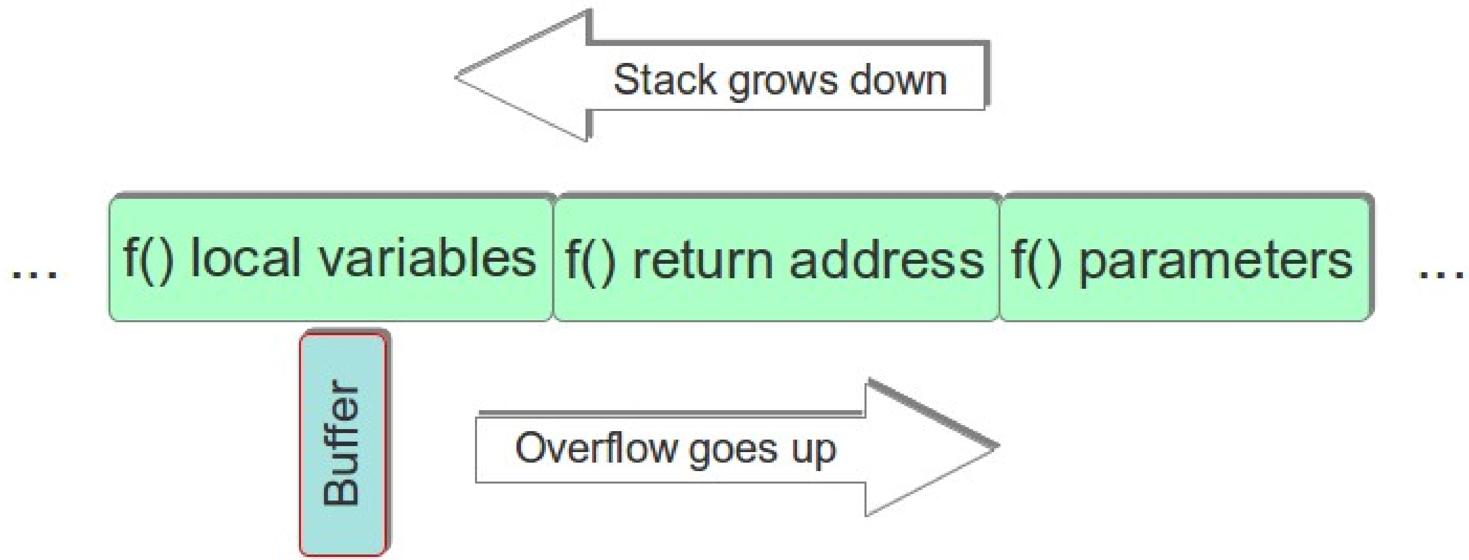
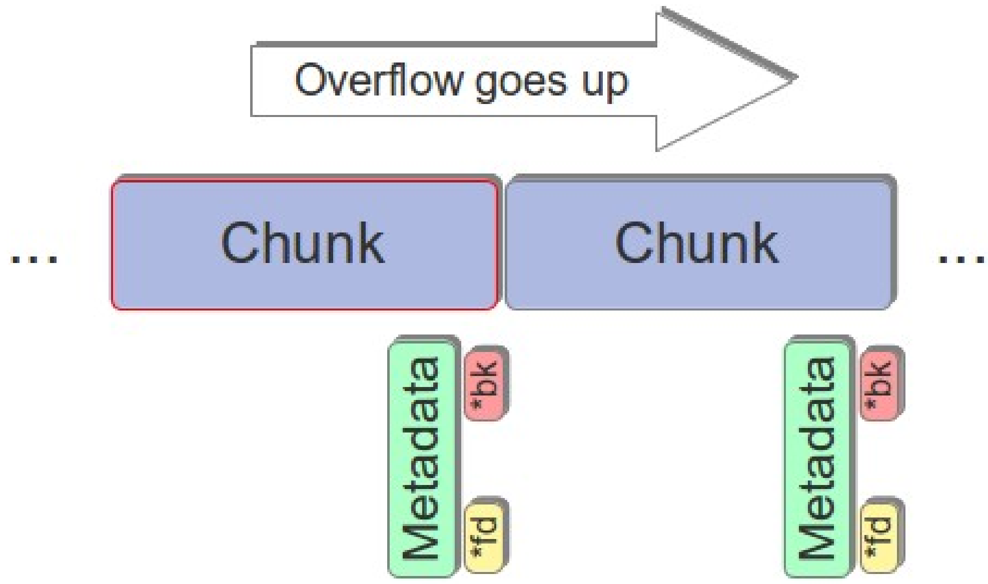
Buffer overflow

- (a.k.a.) Buffer overrun
- An anomaly where a program, while writing data to the buffer, overruns its boundary, thus overwriting adjacent memory
- Commonly associated with programming languages C and C++ (no bounds checking)
- Stack-based (e.g. statically allocated built-in array at compile time) – overwriting stack elements
- Heap-based (e.g. dynamically allocated *malloc()* array at run time) – overwriting heap internal structures (e.g. linked list pointers)

Stack-based overflow



Heap-based overflow



Vulnerable code (stack-based)

```
#include <stdio.h>
#include <string.h>

int main(int argc, char* argv[])
{
    char buff[100];

    if (argc >= 2)
    {
        strcpy(buf, argv[1]);
    }

    return 0;
}
```

Vulnerable code (heap-based)

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>

int main(int argc, char *argv[])
{
        char *p, *q;

        p = malloc(1024);
        q = malloc(1024);

        if (argc >= 2)
        {
                strcpy(p, argv[1]);
        }

        free(q);
        free(p);

        return 0;
}
```

History

- 1961 - Burroughs 5000 (executable space protection)
- 1972 - Computer Security Technology Planning Study (buffer overflow as an idea)
- 1988 - Morris worm (earliest exploitation – *gets()* in fingerd)
- 1995 - Buffer overflow rediscovered (Bugtraq)
- 1996 - “Smashing the Stack for Fun and Profit” (Aleph One)
- 1997 - “Return-into-lib(c) exploits” (Solar Designer)
- 2000 - The Linux PaX project
- 2001 - Code Red (IIS 5.0); Heap spraying (MS01-033 – Index Server ISAPI Extension)
- 2003 - SQL Slammer (MsSQL 2000); Microsoft VS 2003 flag */GS*
- 2004 - NX on Linux (kernel 2.6.8); DEP on Windows (XP SP2); Egg hunting (skape)
- 2005 - ASLR on Linux (kernel 2.6.12); GCC flag *-fstack-protector*
- 2007 - ASLR on Windows (Vista); ROP (Sebastian Krahmer)

DEP/NX

- Data Execution Prevention/No eXecute
- (a.k.a.) Non-executable stack, Execute Disable, Exec Shield (Linux), W^X (FreeBSD)
- Set of hardware and software technologies that perform additional checks on memory
- Provides protection for all memory pages that are not specifically marked as executable
- Processor must support hardware-enforced mechanism (NX/EVP/XD)
- Executables and libraries have to be specifically linked (problems with older software)

ASLR

- Address Space Layout Randomization
- Introduces the randomness into the address space of process
- Positions of key data areas are randomly scattered (i.e. dynamic/shared libraries, heap and stack)
- Its strength is based upon the low chance of an attacker guessing the locations of randomly placed areas
- Executables and dynamic/shared libraries have to be specifically linked (problems with older software)

Stack canaries

- (a.k.a.) Stack cookies, Stack-Smashing Protector (SSP)
- Named for analogy to a canary in a coal mine
- Implemented by the compiler
- Placing a small (e.g. random) integer value to stack just before the return pointer
- In order to overwrite the return pointer (and thus take control of the process) the canary value would also be overwritten
- This value is checked to make sure it has not changed before a routine uses the return pointer from the stack

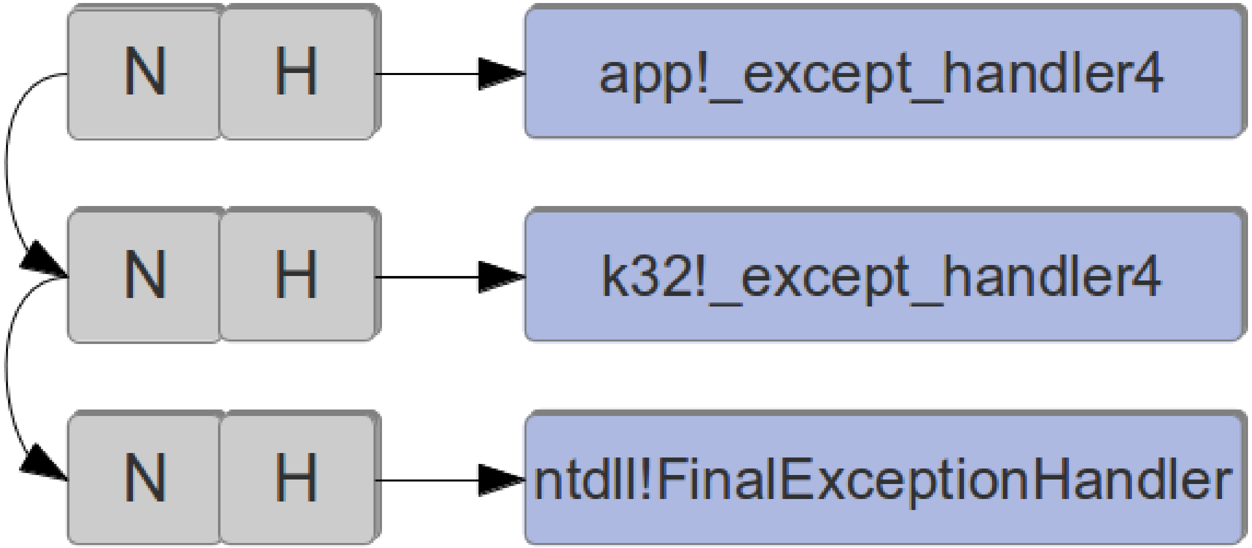
ASCII armor

- Generally maps important library addresses (e.g. libc) to a memory range containing a NULL byte (e.g. `0x00******` - `0x0100******`)
- Makes it hard to construct address or pass arguments by exploiting string functions (e.g. *strcpy()*)
- Not effective when NULL byte is not an issue
- Easily bypassable by using PLT (Procedure Language Table) entries in case of position independent binary

SEH

- Structured Exception Handler
- Implemented by the compiler
- Pointer to the exception handler is added to the stack in the form of the “Exception Registration Record” (SEH) and “Next Exception Registration Record” (nSEH)
- If the buffer is overflown and (junk) data is written to the SEH (located eight bytes after ESP), invalid handler is called due to the inherently raised exception (i.e. STATUS_ACCESS_VIOLATION), thus preventing us from successful execution of our payload

SEH (chain)



N
H
app!_except_handler4
N
H
k32!_except_handler4
N
H
ntdll!FinalExceptionHandler

SEHOP

- Structured Exception Handler Overwrite Protection
- Blocks exploits that use (highly popular) SEH overwrite method
- Enabled by default on Windows Server 2008, disabled on Windows Vista SP1 and Windows 7
- Symbolic exception registration record appended to the end of exception handler list
- Integrity of exception handler chain is broken if symbolic record can't be reached and/or if it's found to be invalid

SafeSEH

- Safe Structured Exception Handling
- (a.k.a.) Software-enforced DEP
- All exception handlers' entry points collected to a designated read-only table collected at the compilation time
- Safe Exception Handler Table
- Attempt to execute any unregistered exception handler will result in the immediate program termination

Safe functions

- Well-written functions that automatically perform buffer management (including bounds checking), reducing the occurrence and impact of buffer overflows
- Usually by introducing explicit parameter *size*

Unsafe	Safe
sprintf	snprintf, asprintf
strncat	strlcat
gets	fgets
strcat	strlcat
vsprintf	vsnprintf, vasprintf
strcpy	strlcpy
strncpy	strlcpy

NOP sled

- (a.k.a.) NOP slide, NOP ramp
- oldest and most widely known method for stack buffer overflow exploitation
- large sequence of NOP (no-operation) instructions meant to "slide" the CPU's execution flow
- used when jump location has to be given (payload), while it's impossible to be exactly predicted
- `|buffer| = |NOP sled| + |payload| + |guessed address from inside NOP sled (EIP)|`

ret2libc

- (a.k.a.) ret2system, arc injection
- Overwriting the return address with location of a function that is already loaded in the binary or via shared library
- Also, providing required arguments through stack overwrite
- Shared library *libc* is always linked to executables on UNIX style systems and provides useful calls (e.g. *system()*)
- `|buffer| = |junk| + |address of function system() (EIP)| + |address of function exit()| + |address of string "/bin/sh"|`

ret2reg

- Return-to-register (e.g. ESP, EAX, etc.)
- (a.k.a.) Trampolining
- Also, variants like ret2pop, ret2ret, etc.
- We overwrite the EIP with the address of an existing instruction that would jump to the location of a register
- Preferred choice is the register pointing to the location inside our buffer (usually ESP)
- Much more reliable method than NOP sled
- `|buffer| = |junk| + |address of JMP ESP or CALL ESP instruction (EIP)| + |compensating NOPs| + |payload|`

Egg hunting

- Used in reduced buffer space situations
- Allows usage of a small payload (“egg hunter”) to find the actual (bigger) payload
- The final payload must be somewhere in memory (stack, heap or secondary buffer)
- Final payload must be prepended with the unique marking string (2x4 bytes) called “egg”
- Egg hunter types: *SEH, IsBadReadPtr, NtDisplayString, NtAccessCheckAndAuditAlarm*
- `|buffer| = |junk| + |egg hunter| + |address of JMP ESP or CALL ESP instruction (EIP)| + |JMP to egg hunter| + |junk| + |egg| + |egg| + |payload|`

Egg hunter (NtDisplayString)

```
loop_inc_page:
or    dx, 0x0fff       // Add PAGE_SIZE-1 to edx
loop_inc_one:
inc   edx              // Increment our pointer by one
loop_check:
push  edx              // Save edx
push  0x43             // Push NtDisplayString
pop   eax              // Pop into eax
int   0x2e             // Perform the syscall
cmp   al, 0x05         // Did we get 0xc0000005 (ACCESS_VIOLATION) ?
pop   edx              // Restore edx
loop_check_8_valid:
je    loop_inc_page    // Yes, invalid ptr, go to the next page
is_egg:
mov   eax, 0x50905090  // Throw our egg in eax
mov   edi, edx         // Set edi to the pointer we validated
scasd                  // Compare the dword in edi to eax
jnz   loop_inc_one     // No match? Increment the pointer by one
scasd                  // Compare the dword in edi to eax again (which is now
edx + 4)
jnz   loop_inc         // No match? Increment the pointer by one
matched:
jmp   edi              // Found the egg. Jump 8 bytes past it into our code.
```

SEH bypass

- SEH is highly flawed against buffer overflows
- Overwrite (last in chain) SEH with address of "POP; POP; RET" sequence of instructions and nSEH with explicit relative "JMP" to payload
- Deliberate exception has to be caused (inherently by sending malformed buffer)
- “POP; POP; RET” passes the execution flow to the nSEH's JMP, which afterwards jumps to the payload at the end of the buffer
- `|buffer| = |junk| + |JMP to payload (nSEH)| + |address of “POP; POP; RET” sequence of instructions (SEH)| + |compensating NOPs| + |payload|`

ROP

- Return-Oriented Programming
- Attacker executes carefully chosen machine instruction sequences called “gadgets”
- Each gadget ends with an instruction RET (e.g. “INC EAX; RET”)
- ROP “chain” consists of gadget memory locations
- Provides a fully functional language that can be used to perform any operation desired (usually to disable DEP)
- `|buffer| = |junk| + |ROP chain to disable DEP| + |compensating NOPs| + |payload|`

ROP (disable DEP)

API / OS	XP SP2	XP SP3	Vista SP0	Vista SP1	Windows 7	Windows 2003 SP1	Windows 2008
VirtualAlloc	yes	yes	yes	yes	yes	yes	yes
HeapCreate	yes	yes	yes	yes	yes	yes	yes
SetProcessDEPPolicy	no (1)	yes	no (1)	yes	no (2)	no (1)	yes
NtSetInformationProcess	yes	yes	yes	no (2)	no (2)	yes	no (2)
VirtualProtect	yes	yes	yes	yes	yes	yes	yes
WriteProcessMemory	yes	yes	yes	yes	yes	yes	yes

(1) = doesn't exist

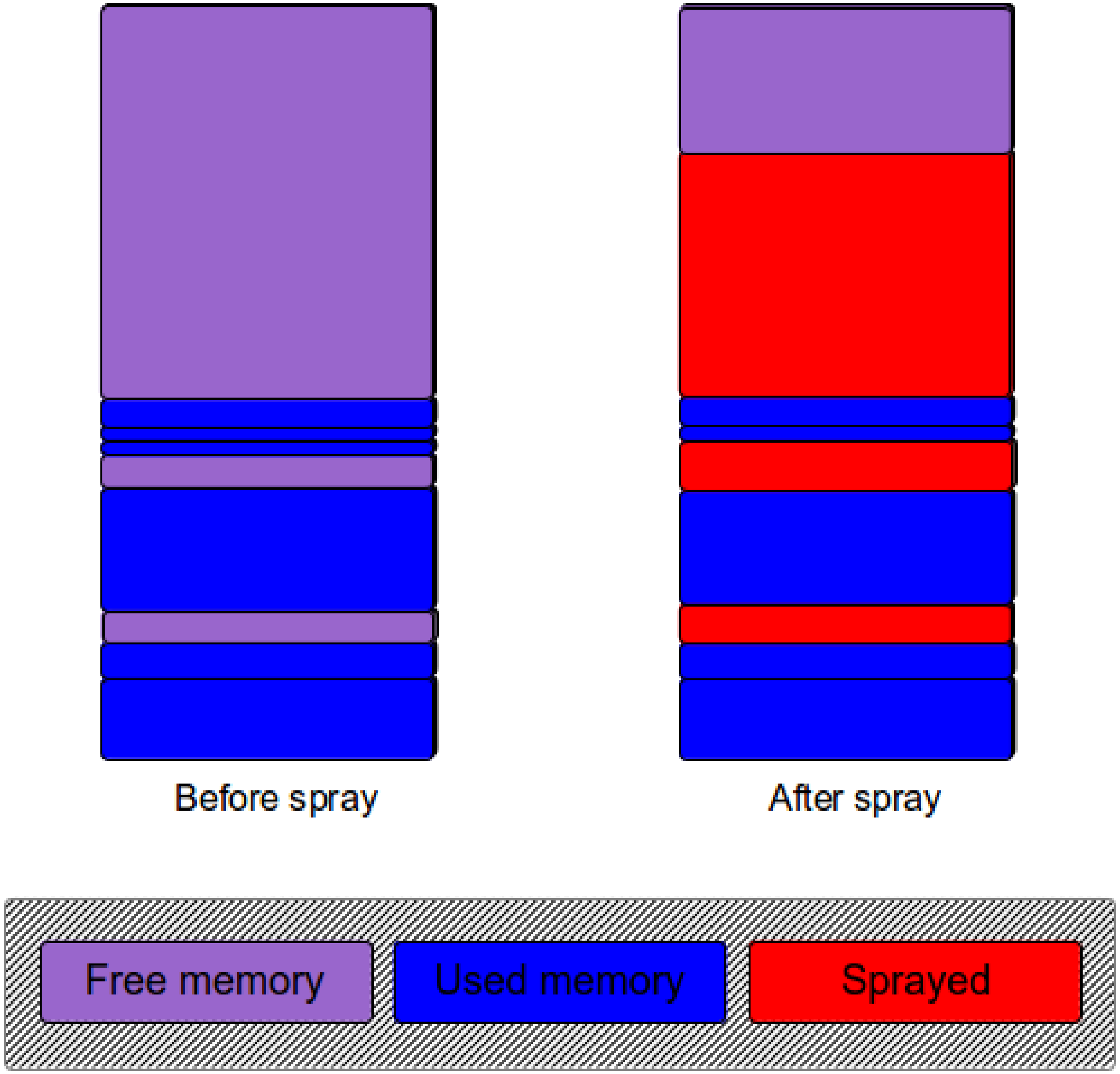
(2) = will fail because of default DEP Policy settings

Taken from: https://www.corelan.be

Heap spray

- Top payload delivery method used in browser exploits (and recent high profile attacks)
- Takes advantage of the fact that the heap management is deterministic
- Attacker needs to be able to deliver the payload in the right location in memory before triggering the bug that leads to EIP control
- A good heap spray (if done right) will end up allocating a chunk of memory at a predictable location, after a certain amount of allocations
- At the end (predictable) heap address needs to be put into EIP

Heap spray (memory)



Demo time

Questions?