Unlink – Exercise 1

The exercise is inside unlink/exercise1/. Move to this directory in order to start the challenge.

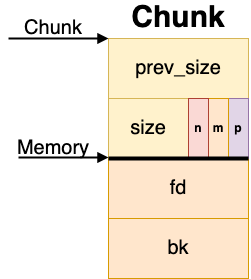
There are a several files in here but only four of them matter:

Figure : Malloc chunk

* unlink.c: The source code for the exploitable challenge.
* unlink: The compiled binary for the challenge.
* start.py: The starting point for the challenge with part of the solution already written.
* solution.py: The solution for the challenge with comments.

The goal of the challenge is to use the recently learned **unlink** exploit technique in order to solve the challenge. We will use the *unlink* technique in order to overwrite a function pointer to jump to our custom shellcode. By the end of this exercise*,* you should have a better understanding of how the *unlink* exploit technique works.

Challenge Setup

In order to understand this challenge, we are going to look through the source code in unlink.c. The VM has *vim* and *Visual Studio Code* installed; use one of these to follow along with the source code.

Graphical user interface, text

Description automatically generatedAt the beginning of the program, three calls to malloc are made; all of which return chunks of size **0x90**. The names are intentional and are used as they are named.

Figure : Allocating the chunks

Text

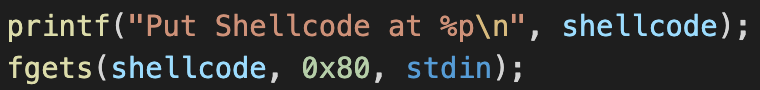
Description automatically generatedThe variable shellcode is controllable by the user. This is where you can store the shellcode for the challenge. Although the *heap* is normally non-executable (NX), the heap was made executable for this exercise with a call to *mprotect*. The purpose of the *unlink* technique is to gain a *WRITE-WHAT-WHERE* primitive but only to writeable locations. Because of this, the best place to write to is a *function pointer* and point this to shellcode.

Figure : Writing the shellcode

Text

Description automatically generatedThe next section of code *frees* the chunk unlink\_chunk. Then, after the chunk has been *freed*, we write to the chunk. If a *freed* chunk is being written to, that indicates a *use after free* vulnerability! The code for this can be seen in *Figure 3*.

Figure : Free unlink\_chunk and write to this chunk

Figure : Free the victim and print

To end the program, the third chunk (free\_victim) is also freed. Then, a call to *puts* is made in order to print out a string.

Besides what is shown in the binary, there are a few environment setups that are important to note.

* This challenge uses GLibC 2.23. The most notable thing about this is that the TCache is not in GLibC 2.23.
* The security checks for the *unlink* macro have been removed. Everything else is the standard configuration for LibC.
* The heap was made *executable* for this exercise.
* The function *winner()* can be called in order to pop a shell.

Vulnerability

In *Figure 3* a call to free is made. Then, directly after this call, this chunk is written to. Because the chunk has been *freed* and is now being *used*, we have a classic *use after free* vulnerability on unlink\_chunk.

Text

Description automatically generatedIn order to see this in GDB, we can put a breakpoint on *fgets*. This can be done with the command b fgets.

Figure : Demonstrating use after free via two GDB commands

Once the breakpoint has been hit, run two commands: bt and unsortedbin. The first command (*backtrace*) shows us the function call stack. This is useful because it allows us to see the *parameters* of each function that was called recursively. Entry #0 of the *bracktrace* command shows a call to [fgets](https://linux.die.net/man/3/fgets) where the parameter *buf* is the address being written to. The address shown for this buffer (in GDB) is 0x4050c0, which can be seen in *Figure 6* shown above.

The second command (*unsortedbin*) shows the contents of the unsorted bin within Malloc. At this point, there is only a single heap chunk in the bin: 0x4050b0. Although the two addresses differ by 0x10, these are the same pieces of memory! The *buf* is the *memory* pointer address of the chunk, while the reference in the *unsorted bin* is the *chunk* pointer. The difference of the reference for this can be seen in *Figure 1*. All in all, the user program interacts 0x10 bytes after the actual chunk, while the allocator uses the beginning of the chunk throughout.

Unlink Exploit Triggering

Text

Description automatically generatedThere is a *use after free* vulnerability in this binary, as described above. Now, it is time to exploit it using the *unlink* technique.

Figure : Consolidate chunks backwards source code

The *unlink* process takes place whenever a chunk within a *doubly linked list* (unsorted bin, smallbin, largebin) is being removed from the middle of a linked list. This normally occurs when two chunks need to be *consolidated* (combined) in order to make one larger chunk; this is done to prevent fragmentation within the allocator. In the case of this exercise, unlink\_chunk and free\_victim are directly adjacent to one another. Additionally, since unlink\_chunk is already free when free\_victim is *freed*, the chunk unlink\_chunk is removed or **unlinked** from the unsorted bin in order to be combined with free\_victim.

A screenshot of a cell phone

Description automatically generatedText

Description automatically generatedIn order to see the backwards consolidation being triggered (*Figure 7*), put a breakpoint at the *unlink* macro. This can be done using the command ﻿  
b unlink. If we run the program with this breakpoint set, you will notice that the breakpoint is hit when freeing free\_victim. Additionally, if you print *fwd* and *bck* (print fwd and print bck) you will notice that the pointer is the same value that is written into unlink\_chunk with the UAF; this can be seen in *Figure 8*. This confirms that the consolidation is happening as expected.

Figure : Showing the pointer addresses

With the *unlink* macro being triggered and we control the pointers for the fwd and *bck*, this is the perfect candidate for using the *unlink* attack! Using control over the *fd* and the *bk* pointers in our chunk (see *Figure 1*), we can construct a *WRITE-WHAT-WHERE* primitive.

Figure : Unlink macro

In the *unlink* macro in *Figure 9* the address of *P* is the pointer being freed. The value of FD is the fd pointer of P. Then, the value of BK is the bk pointer of P. We control both P->fd and P->bk because the *use after free* takes place on *P.* Since FD=P->fd and BK=P->bk, we control FD and BK as well.

The third line (FD->bk=BK) is writing to the address of FD (plus some offset) with the value of BK. Additionally, the fourth line is writing to the address of BK with the value of FD. The important thing to note is that we control BOTH FD and BK. This means that we control the *address* being written to and the *value* being written. The control over both the *address* and the *value* means that we have a *WRITE-WHAT-WHERE* primitive!

Where and What to Write

Now that we have a *WRITE-WHAT-WHERE* primitive, what can we do with it? Ideally, we want to get code execution. So, for the *where,* we want to overwrite a function pointer directly. In this challenge, either the RIP on the stack or the *Global Offset Table* (GOT) can be used. For the rest of this write up, we will use the *GOT*, as it is easier and more consistent to use than RIP on the stack.

Diagram

Description automatically generatedIn Linux, binaries can either be *dynamically* or *statically* linked. When a binary is

Figure : Symbol resolution in LibC

*dynamically* linked, the libraries are not included within the binary. Although it looks like magic, they are figured out at run time and the usage in the *binary* itself is not overly complicated. When a library function is called, the *resolution* process finds the *address* of this symbol within LibC and writes the address of the symbol back to the *Global Offset Table* *(GOT)*. Because this symbol is effectively a function pointer, we can overwrite the GOT entries in order to get code execution. For more on information on how the *GOT* works, read [this](https://systemoverlord.com/2017/03/19/got-and-plt-for-pwning.html) article.

Table

Description automatically generatedAt the very end of the program (shown in *Figure 5*), there is a call to *puts*. By overwriting the GOT entry for *puts*, we can control the flow of execution! Now that we have the *where* taken care of, we can talk about the *what.*

Figure : Chunk setup for exploit

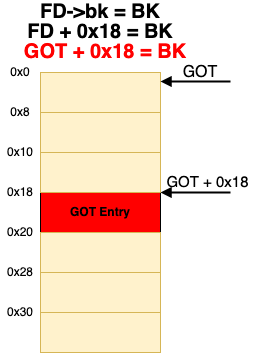
Because we are overwriting a function pointer, we need to overwrite the GOT entry with an executable section of code. Additionally, since *two* writes occur, we cannot simply write the value of *winner()*. Instead, we need to write to a location that is *writable* and *executable*. Luckily for us, the *heap* has been made executable for this exercise. As denoted by the variable name shellcode, it is the perfect place to find a *writable* and *executable* section of memory.

Figure : Unlink offset on the address

The outcome of the *where* and *what* can be seen in *Figure 11*. One concept that is not obvious is the *where* that we want to write to. The *unlink* macro, shown in *Figure 7*, contains the code FD->bk=BK. This is writing to the address of *FD* with the struct accessor *bk*. When accessing a struct in C, the accessor is only a small *offset* on the memory that depends on the content in the struct. FD->bk is functionality equivalent to FD + 0x18. Because of this, if we simply try to write to the address of the GOT entry (the target of the write) then we would write to GOT entry + 0x18, which is 0x18 bytes too far. In order to compensate for this, we need to **subtract** 0x18 from the address that we are attempting to write to. This way, the struct accessor is neutralized since FD + 0x18 – 0x18 is the same as FD. This concept can be seen visually in *Figure 12*.

Finally, we are onto the payload for the *unlink*. In order to line up the attack, we need to setup the pointers properly on the chunk with the *use after free* on it. The *fd (WHERE)* pointer needs to have the address of the *GOT* minus the offset of 0x18. Then, the *bk* (*WHAT*) needs to have the address of the *shellcode*. The code for this can be seen below.

fake\_chunk = p64(puts\_GOT - 0x18)

fake\_chunk += p64(shellcode\_address)

It should be noted that although we choose the FD as the *what* and the BK as the *where* this attack can be done in either direction. For the sake of simplicity, we just chose one and went with it. Additionally, *two* writes occur with *unlink* operation; one at FD + 0x18 and one at BK + 0x10. So, the content of the location being written to (in this case, the *shellcode*) could become corrupted if you are not careful.

The code changes above are the *only* TODO’s in the program! So, this should be enough to solve the exercise. Damn, we have popped a shell!

Shellcode

The shellcode was written for you but not explained; let’s change that. This shellcode is shown below:

0: 68 f6 11 40 00 push 0x401236

5: c3 ret

The goal of the shellcode is to jump to the *winner* function that pops a shell; the address 0x401236 is the address of the *winner* function. Within x86\_64 assembler, there is no *jmp* or *call* function that accepts an absolute address (only relative). For instance, the assembler call 0x401236 using an absolute address would be quite nice, if it existed. Additionally, there is no instruction for moving a value directly into RIP. Because of these downsides, we must be creative!

In order to emulate an assembler instruction that *jmps* directly to the code, we are *pushing* the address of the *winner* function onto the stack. Then, the ret instruction takes this address off the stack and sets the RIP (instruction pointer) to this address. Now, the next instruction will be the *winner* function, popping the shell, which demonstrates major pwnage.

If you are trying to debug shellcode on x86\_64, the best instruction is int3 or 0xcc. This instruction will *pause* execution of the *shellcode* and wait for a debugger to continue execution. If trying to simply get to the point of shellcode, this instruction is extremely helpful.

A final note on the shellcode for the *unlink* challenge is to be careful that the shellcode does not get corrupted. A write occurs at FD + 0x18 and BK + 0x10. These writes will BOTH happen, corrupting the shellcode on one side. In order to get around this, write small shellcode (like the one use in this example) or *jmp* over the top of the expected to be corrupted values.

Welcome to the Now

The *unlink* technique is a relic of the past. From the original *unlink* post in 2001, titled [*Once Upon a Free*](http://phrack.org/issues/57/9.html)*,* security protections have been put in place in order to prevent this exact attack from happening.

Figure : Unlink doubly linked list protection - [Source](https://elixir.bootlin.com/glibc/glibc-2.23/source/malloc/malloc.c#L1414)

The [protection](https://elixir.bootlin.com/glibc/glibc-2.23/source/malloc/malloc.c#L1414) aims to prevent the arbitrary setting of the *fd* and *bk* pointers on the check. In order to do this, the check validates that the chain for the linked list is valid from *both* directions. This is done by ensuring that P->fd->bk == P and P->bk->fd == P. By adding this protection, the classic *unlink* vulnerability has been patched in modern versions of GLibC.

You may be wondering: “*was everything I just did a waste of time?”* However, this could not be further from the truth! In order to run, we first then to crawl, then walk then run. From this module, you now have practical experience with exploiting the *fd* and *bk* pointers, understanding how the allocator works , *pwndbg* commands and many other important things. Additionally, the ***unsafe unlink*** builds off the *classic unlink* technique. Understanding this technique is crucial for the firm grasp of the *unsafe unlink* technique and other techniques, such as the unsorted bin attack.

In the demo/unsafe\_unlink directory, there is a proof of concept for the ***unsafe unlink*** technique that is well worth the time to go through.