
Checkpoint 1

p7zip

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Overview of the Target

p7zip is a fully compliant linux port of the open source *7zip* tool for Windows. It is a utility used to archive and extract various compression formats. It is primarily used in Windows GUI tools as an underlying utility to support their file compression features.

p7zip provides the following features:

1. Several compression algorithms (*lz4*, *zstd*, *Lizard*, etc...)
2. CLI frontend
3. Cryptographic algorithms for archive encryption (*SHA256*, *AES*, *RAR5*, etc...)

Debug Environment

How to build the target

Step 1:

```
1 git clone git@github.com:jinkeihan57/p7zip.git
```

We clone [jinkeihan57's repo](#), which is a *Linux port* for the 7zip Windows utility. The port is *fully compliant* with the Windows equivalent, and supports all the same formats.

Step 2:

```
1 cp 7zip_gcc_dbg.mak p7zip/CPP/7zip/7zip_gcc.mak
```

We created a custom [Makefile](#) that patches the original build script to include debug flags. We copy the patch into the correct directory.

Step 3:

```
1 cd p7zip/CPP/7zip/Bundles/Alone2 && make -f makefile.gcc && cd -
```

We build the 7zz tool, which is the primary binary from the project, which supports archiving and extracting the most number of formats.

Step 4:

```
1 PATH=$PATH:$PWD/p7zip/CPP/7zip/Bundles/Alone2/_o/bin
```

For development purposes, we update the current terminal session's [PATH](#) to include the path to the 7zz binary.

Experiment with the Target

```
→ 1-checkpoint git:(main) X 7zz -h

7-Zip (z) 22.00 ZS v1.5.2 (x64) : Copyright (c) 1999-2022 Igor Pavlov : 2022-06-15
64-bit locale=en_US.UTF-8 Threads:16

Usage: 7zz <command> [<switches>...] <archive_name> [<file_names>...] [@listfile]

<Commands>
a : Add files to archive
b : Benchmark
d : Delete files from archive
e : Extract files from archive (without using directory names)
h : Calculate hash values for files
i : Show information about supported formats
l : List contents of archive
rn : Rename files in archive
t : Test integrity of archive
u : Update files to archive
x : eXtract files with full paths
```

Figure 1: List of commands

Simple tests

In the `playground` directory, we have some sample files setup for basic tests.

```
1 cd playground
2 7zz a files.zip file1.txt file2.txt
3 7zz e files.zip -ofiles_extracted
```

Target analysis

```
→ bin git:(master) X file 7zz
7zz: ELF 64-bit LSB executable, x86-64, version 1 (SYSV),
dynamically linked, interpreter /lib64/ld-linux-x86-64.so.
2, BuildID[sha1]=02bfdb94fd86cb3d5e02ceaff225f37714a05ad3,
for GNU/Linux 3.2.0, with debug_info, not stripped
→ bin git:(master) X
```

Figure 2: File format

```

+ 390r-debugging-setup git:(main) pwn checksec p7zip/CPP/7zip/Bundles/Alone2/_o/bin/7zz

[*] '/home/lifewhiz/projects/revEng/390r-debugging-setup/p7zip/CPP/7zip/Bundles/Alone2/_o/bin/7zz'
Arch:      amd64-64-little
RELRO:     Partial RELRO
Stack:     No canary found
NX:        NX enabled
PIE:       No PIE (0x400000)
RUNPATH:   b'$ORIGIN/../lib/7z_addon_codec'
+ 390r-debugging-setup git:(main)

```

Figure 3: checksec mitigations

```

+ 390r-debugging-setup git:(main) x ROPgadget --binary p7zip/CPP/7zip/Bundles/Alone2/_o/bin/7zz
+ 390r-debugging-setup git:(main) x wc -l rop_out.txt
151080 rop_out.txt
+ 390r-debugging-setup git:(main) x cat rop_out.txt | head
Gadgets information
=====
0x000000000043f068 : adc ah, bh ; add byte ptr [rax], al ; add byte ptr [rax], al ; jmp 0x43ef74
0x0000000000440250 : adc ah, bh ; add byte ptr [rax], al ; add byte ptr [rax], al ; jmp 0x440154
0x00000000004a902a : adc ah, bh ; cmc ; jmp qword ptr [rsi - 0x70]
0x00000000004a902a : adc ah, bh ; cmc ; jmp qword ptr [rsi - 0x70] ; pop rbx ; ret
0x000000000059626d : adc ah, bh ; dec dword ptr [rax - 0x77] ; ret
0x000000000041f48d : adc ah, bh ; jmp 0x41f35c
0x0000000000485c5d : adc ah, bh ; jmp 0x485ab0
0x0000000000595d1a : adc ah, bh ; jmp 0x594d4a
+ 390r-debugging-setup git:(main) x

```

Figure 4: List of ROP Gadgets

```

+ 390r-debugging-setup git:(main) x readelf -d p7zip/CPP/7zip/Bundles/Alone2/_o/bin/7zz | grep 'NEEDED'
0x0000000000000001 (NEEDED) Shared library: [libzstd.so.1]
0x0000000000000001 (NEEDED) Shared library: [liblz4.so.1]
0x0000000000000001 (NEEDED) Shared library: [libbrotlienc.so.1]
0x0000000000000001 (NEEDED) Shared library: [libbrotlidec.so.1]
0x0000000000000001 (NEEDED) Shared library: [libbrotlicommon.so.1]
0x0000000000000001 (NEEDED) Shared library: [liblzirad.so.1]
0x0000000000000001 (NEEDED) Shared library: [liblz5.so.1]
0x0000000000000001 (NEEDED) Shared library: [libfast-lzma2.so.1]
0x0000000000000001 (NEEDED) Shared library: [liblzhamcomp.so]
0x0000000000000001 (NEEDED) Shared library: [liblzhamdecomp.so]
0x0000000000000001 (NEEDED) Shared library: [liblzhamdll.so]
0x0000000000000001 (NEEDED) Shared library: [libstdc++.so.6]
0x0000000000000001 (NEEDED) Shared library: [libm.so.6]
0x0000000000000001 (NEEDED) Shared library: [libgcc_s.so.1]
0x0000000000000001 (NEEDED) Shared library: [libc.so.6]

```

Figure 5: List of Shared Libraries

```

➔ 390r-debugging-setup git:(main) x one_gadget /usr/lib64/libc.so.6
0x4d170 posix_spawn(rsp+0xc, "/bin/sh", 0, rbx, rsp+0x50, environ)
constraints:
    rsp & 0xf == 0
    rcx == NULL
    rbx == NULL || (u16)[rbx] == NULL

0xf5552 posix_spawn(rsp+0x64, "/bin/sh", [rsp+0x40], 0, rsp+0x70, [rsp+0xf0])
constraints:
    [rsp+0x70] == NULL
    [[rsp+0xf0]] == NULL || [rsp+0xf0] == NULL
    [rsp+0x40] == NULL || (s32)[rsp+0x40+0x4] <= 0

0xf555a posix_spawn(rsp+0x64, "/bin/sh", [rsp+0x40], 0, rsp+0x70, r9)
constraints:
    [rsp+0x70] == NULL
    [r9] == NULL || r9 == NULL
    [rsp+0x40] == NULL || (s32)[rsp+0x40+0x4] <= 0

0xf555f posix_spawn(rsp+0x64, "/bin/sh", rdx, 0, rsp+0x70, r9)
constraints:
    [rsp+0x70] == NULL
    [r9] == NULL || r9 == NULL
    rdx == NULL || (s32)[rdx+0x4] <= 0
➔ 390r-debugging-setup git:(main) x

```

Figure 6: List of One Gadgets

Function call graph

The following can be used to analyze execution of the target and produce graphs. It requires `valgrind` and `kcachegrind` to be installed.

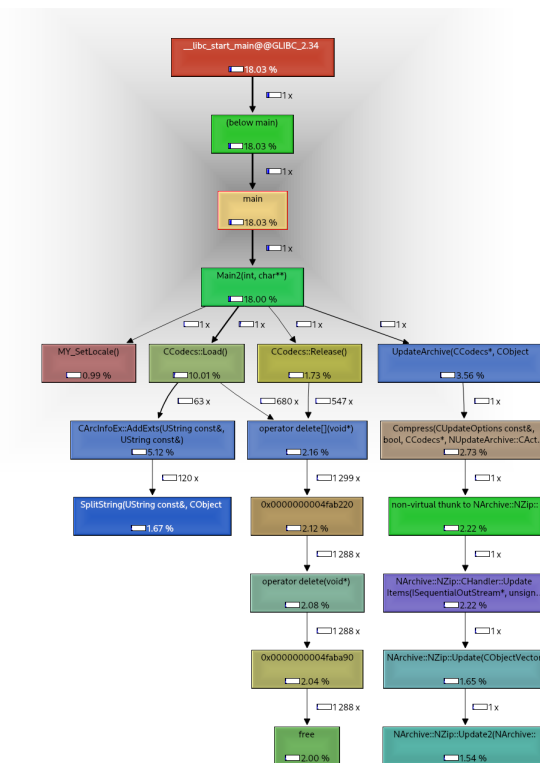
```
1 valgrind --callgrind-out-file=callgrind_vis2 --tool=callgrind 7zz e
  files.zip -ofiles_extracted
```

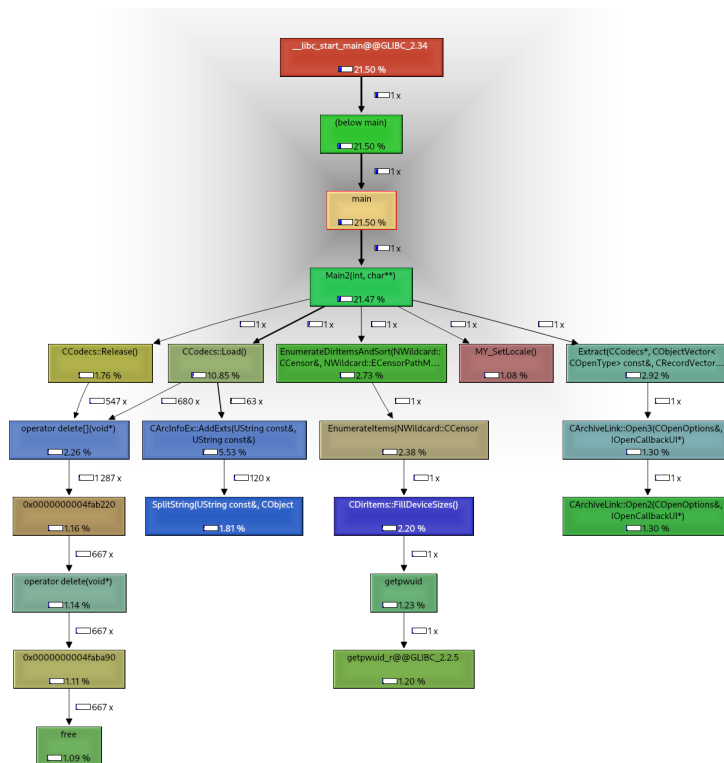
Use the `valgrind` command above to generate a `callgrind_vis2` file.

```
1 kcachegrind callgrind_vis2
```

Use the `kcachegrind` command to visualize the `callgrind_vis2`.

In the next two pages, we find two function call graphs for the `archive` and `extract` subcommands.

Archive Command:**Figure 7:** a subcommand

Extract Command:**Figure 8:** e subcommand

Mapping out the Target Code-Base

DOC/readme.txt has some useful high level overviews of the codebase:

DOC	Documentation
7zFormat.txt	- 7z format description
copying.txt	- GNU LGPL license
unRARLicense.txt	- License for unRAR part of source code
src-history.txt	- Sources history
Methods.txt	- Compression method IDs
readme.txt	- Readme file
lzma.txt	- LZMA compression description
7zip.nsi	- installer script for NSIS
7zip.wix	- installer script for WIX
Asm	- Source code in Assembler : optimized code for CRC, SHA, AES, LZMA decoding.
C	- Source code in C
CPP	- Source code in C++
Common	common files for C++ projects
Windows	common files for Windows related code
7zip	
Common	Common modules for 7-zip
Archive	files related to archiving
Bundle	Modules that are bundles of other modules (files)
Alone	7za.exe: Standalone version of 7-Zip console that supports only 7z/xz/cab/zip/gzip/bzip2/tar.
Alone2	7zz.exe: Standalone version of 7-Zip console that supports all formats.
Alone7z	7zr.exe: Standalone version of 7-Zip console that supports only 7z (reduced version)
Fm	Standalone version of 7-Zip File Manager
Format7z	7za.dll: .7z support
Format7zExtract	7zxa.dll: .7z support, extracting only
Format7zR	7zr.dll: .7z support, reduced version
Format7zExtractR	7zxr.dll: .7z support, reduced version, extracting only
Format7zF	7z.dll: all formats
LzmaCon	lzma.exe: LZMA compression/decompression
SFXCon	7zCon.sfx: Console 7z SFX module
SFXWin	7z.sfx: Windows 7z SFX module
SFXSetup	7zS.sfx: Windows 7z SFX module for Installers
Compress	files for compression/decompression
Crypto	files for encryption / decompression
UI	
Agent	Intermediary modules for FAR plugin and Explorer plugin
Client7z	Test application for 7za.dll
Common	Common UI files
Console	7z.exe : Console version
Explorer	7-zip.dll: 7-Zip Shell extension
Far	plugin for Far Manager
FileManager	7zFM.exe: 7-Zip File Manager
GUI	7zG.exe: 7-Zip GUI version

Figure 9: Code Base Overview

The functionality of the console version of this application is straightforward. The binary accepts command line arguments (`main` defined in *MainAr.cpp*), then attempts to pass them to `main2()` in *Main.cpp* (wrapped in try block).

`main2()` handles the bulk of all functionality.

It parses command line arguments beginning at line 733. Argument length is checked, arguments are converted to Unicode and pushed to a string vector.

Arguments are first parsed into the following struct using `parse1()` defined in the *ArchiveCommandLine.cpp*.

```
1 struct CArcCmdLineOptions
2 {
3     bool HelpMode;
4
5     // bool LargePages;
6     bool CaseSensitive_Change;
7     bool CaseSensitive;
8
9     bool IsInTerminal;
10    bool IsStdOutTerminal;
11    bool IsStdErrTerminal;
12    bool StdInMode;
13    bool StdOutMode;
14    bool EnableHeaders;
15
16    bool YesToAll;
17    bool ShowDialog;
18    bool TechMode;
19    bool ShowTime;
20
21    AString ListFields;
22
23    int ConsoleCodePage;
24
25    NWildcard::CCensor Censor;
26
27    CArcCommand Command;
28    UString ArchiveName;
```

First arguments checked are related to showing *help/copyright*, and calls the `ShowCopyrightAndHealth()` function.

Then `parse2()` is called on the options struct.

ArchiveCommandLine.cpp handles a bunch of flags that can be passed, ie. SLP mode (large pages), core affinity, etc. Also contains several other methods for parsing.

Importantly, it defines the formats of arguments. Beginning on line 341, `isFromExtractGroup()`

is defined. We see there are `extract`, and `extractFull` flags.

A scanner is defined in *ExtractCallbackConsole.cpp*, and this is presumably used to enumerate files in an archive.

Line 1196 in `main2()` defines an if statement that executes the following block if the user runs the “extract” command.

If the user doesn’t use the `extract` command, it executes an else block at 1358.

There is a `NO_CRYPT0` flag that is set, if the archive is password protected.

On line 1402, an if block is executed if the user intends to update the archive. It checks whether the parsed command is part of the update group of commands: `add`, `delete`, `rename`, etc.

There are a bunch of callbacks used for operating on archives. One such interface for the update callback is defined in `update.h`.

`Update.cpp` contains several methods for archiving and updating and archive, it’s called from line 1142 in `CPP/7Zip/UI/Console/Main.cpp`, and itself contains a method called `Compress`, defined at 502 and called at 1630.

Future Plans

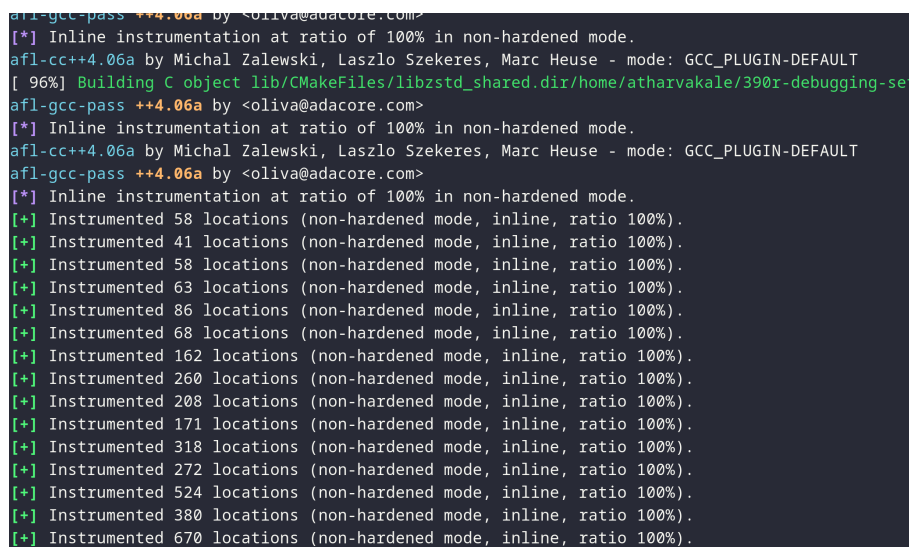
Fuzzing

We plan to use fuzzing as an approach to find bugs in **p7zip**. In specific, mutational fuzzing would be a good fit, where we would use a corpus of ZIP and regular files to test the archiving/extracting features of the binary. Given that p7zip is designed to handle many file formats, it is likely we can find bugs since parsing correctly and safely is quite difficult.

To start with, we used the **AFL++** docker container setup:

```
1 docker pull aflplusplus/aflplusplus
2 docker run -ti -v ./src aflplusplus/aflplusplus
```

Then, we re-compiled the binary with AFL instrumentation enabled.



```
afl-gcc-pass ++4.06a by <oliva@adacore.com>
[*] Inline instrumentation at ratio of 100% in non-hardened mode.
afl-cc++4.06a by Michal Zalewski, Laszlo Szekeres, Marc Heuse - mode: GCC_PLUGIN-DEFAULT
[ 96%] Building C object lib/CMakeFiles/libzstd_shared.dir/home/atharvakale/390r-debugging-se
afl-gcc-pass ++4.06a by <oliva@adacore.com>
[*] Inline instrumentation at ratio of 100% in non-hardened mode.
afl-cc++4.06a by Michal Zalewski, Laszlo Szekeres, Marc Heuse - mode: GCC_PLUGIN-DEFAULT
afl-gcc-pass ++4.06a by <oliva@adacore.com>
[*] Inline instrumentation at ratio of 100% in non-hardened mode.
[+] Instrumented 58 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 41 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 58 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 63 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 86 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 68 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 162 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 260 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 208 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 171 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 318 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 272 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 524 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 380 locations (non-hardened mode, inline, ratio 100%).
[+] Instrumented 670 locations (non-hardened mode, inline, ratio 100%).
```

Figure 10: Compiling with AFL Source Code Instrumentation

We also started a dummy test for archive to see how fuzzing the binary works. Of course, this does not crash the binary, but we got a working template. We need to figure out ways to smarten the input and find coverage through symbolic execution.

```

american fuzzy lop ++4.06a {default} (...dles/Alone2/_o/bin/7zz_fuzz) [fast]
├─ process timing ─┬─ overall results
│   run time : 0 days, 0 hrs, 1 min, 59 sec      cycles done : 0
│   last new find : 0 days, 0 hrs, 0 min, 0 sec  corpus count : 286
│   last saved crash : none seen yet             saved crashes : 0
│   last saved hang : none seen yet              saved hangs : 0
├─ cycle progress ─┬─ map coverage
│   now processing : 55.30 (19.2%)              map density : 6.97% / 7.47%
│   runs timed out : 0 (0.00%)                 count coverage : 3.63 bits/tuple
├─ stage progress ─┬─ findings in depth
│   now trying : havoc                          favored items : 13 (4.55%)
│   stage execs : 39/114 (34.21%)               new edges on : 29 (10.14%)
│   total execs : 85.5k                        total crashes : 0 (0 saved)
│   exec speed : 655.4/sec                     total tmouts : 0 (0 saved)
├─ fuzzing strategy yields ─┬─ item geometry
│   bit flips : disabled (default, enable with -D) levels : 6
│   byte flips : disabled (default, enable with -D) pending : 263
│   arithmetics : disabled (default, enable with -D) pend fav : 0
│   known ints : disabled (default, enable with -D) own finds : 285
│   dictionary : n/a                          imported : 0
│   havoc/splice : 196/62.5k, 89/20.0k         stability : 66.58%
│   py/custom/rq : unused, unused, unused, unused
│   trim/eff : 0.00%/912, disabled
└─ [cpu000: 12%]

```

Figure 11: Attempt to Fuzz