Secure Coding in C and C++

Exercise #4: Using Valgrind to Find Memory Errors

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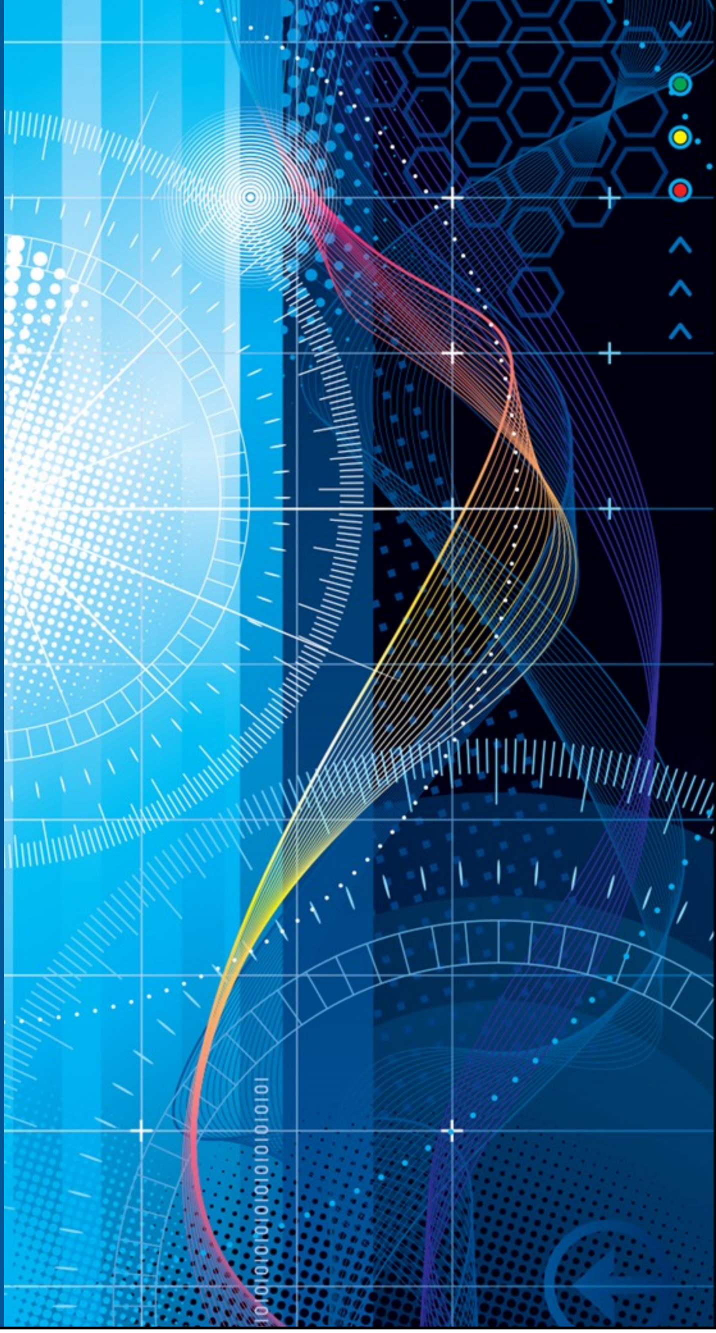

Notices

Sample Program

Caesar cipher decryption program

- Implements simple rotation cipher
- Takes input from files

In a real usage scenario, the decrypted file and the keys file must be kept secret from unauthorized users.

- Should only be usable by intended user
- The secret file can be used by anyone; it’s protected by encryption!

Usage

The program accepts a command line argument:

```
Usage: %s secret_file keys_file [output_file]
```

The `secret_file` argument specifies the name of the file containing the encrypted text.

The `keys_file` argument specifies the name of the file containing the corresponding “keys” to decrypt each line of the encrypted text.

- `keys_file` must live in home directory, or a subdirectory.
- `keys_file` can only be read with `root` privileges

The program also accepts an optional `output_file` argument.

- If `output_file` is not specified, the program prints the output to `stdout`.
- Otherwise `output_file` must be placed in home directory, or a subdirectory.

The Input Files

All of the files involved are just character files.

Each line contains the ciphertext and corresponding "key" (number of chars to rotate). For example:

Ciphertext	Key	Plaintext
`Lzak ak s lwkl`	8	`This is a test`

The lines are delimited by EOL.

A working set of example files is included.

Using Valgrind

Compile application with debugging symbols and low optimization if possible (`-g3` and `-O0`)

- allows Valgrind to produce more informative output, just as with a debugger

Invocation:

```
$ valgrind --leak-check=full myprog \
arg1 arg2...
```

The `--leak-check=full` option enables memory leak checking

Exercise

Review and repair the code.

- compile and test with the supplied valid input files
- quick manual code reading and identification of potential problem areas
- construct various invalid inputs, rerun under Valgrind using those inputs, and record the errors produced

Use reference material.

- Valgrind documentation (`/usr/share/doc/valgrind`, man page)
- C standard
- man / help pages
- CERT Secure Coding standards
- *Secure Coding in C and C++*

Exercise

Find memory errors
using Valgrind
(30 minutes)

Double-Free in `usage()` 1

What if we supply no arguments?

```
$ valgrind ./caesar
[...]
sorry, user
Usage: caesar secret_file keys_file [output_file]
==19557== Invalid free() / delete / delete[]
==19557==    at 0x401D240: free (vg_replace_malloc.c:233)
==19557==    by 0x8048706: main (caesar.c:27)
==19557==  Address 0x4160028 is 0 bytes inside a block of size 80 free'd
==19557==    at 0x401D240: free (vg_replace_malloc.c:233)
==19557==    by 0x8048A3D: usage (caesar.c:78)
==19557==    by 0x80486FB: main (caesar.c:26)
==19557==
==19557== ERROR SUMMARY: 1 errors from 1 contexts (suppressed: 11 from 1)
```

Double-Free in `usage()` 2

Once in `usage()`:

```
fprintf(stderr, errmsg);
free(errmsg);
```

And once again in `main()`:

```
usage(errmsg);
free(errmsg);
```

Note: Modern versions of the GNU libc will detect this as well:

```
*** glibc detected *** double free or corruption (top): 0x0804a008 ***
Aborted
```

Long Username Buffer Overflow

What if we supply a long username?

```
$ USER=`perl -e 'print "A" x 256;'` valgrind ./caesar
[...lots of invalid read/write messages...]
==19577== Invalid read of size 1
==19577==    at 0x406B0E7: vfprintf (in /lib/tls/i686/cmov/libc-2.3.6.so)
==19577==    by 0x406AD7B: buffered_vfprintf (in /lib/tls/i686/cmov/libc-…
==19577==    by 0x406AFBA: vfprintf (in /lib/tls/i686/cmov/libc-2.3.6.so)
==19577==    by 0x40736AE: fprintf (in /lib/tls/i686/cmov/libc-2.3.6.so)
==19577==    by 0x8048A32: usage (caesar.c:77)
==19577==    by 0x80486FB: main (caesar.c:26)
==19577==  Address 0x4160162 is not stack'd, malloc'd or (recently) free'd
sorry, [AA...]
Usage: caesar secret_file keys_file [output_file]
[...]
==19577== ERROR SUMMARY: 940 errors from 9 contexts (suppressed: 11 from 1)
```

The `getenv()` Function

The contents of the **`USER`** environment variable are supplied to the usage error message without any bounds checking:

```
errmsg = (char *)malloc(LINELENGTH);
sprintf(errmsg, "...", getenv("USER"));
```

No length check

Input Line Buffer Overflows 1

Spot the problem:

```
#define LINELENGTH 80
[...]
if (!(inbuf = malloc(LINELENGTH)))
  errx(1, "Couldn't allocate memory.");
while (fgets(inbuf, 100, infile) ...
```

Input Line Buffer Overflows 2

What if we supply an encrypted file with long lines?

```
$ valgrind ./caesar bad_encrypted.txt keys.txt
[...lots of invalid read/write messages...]
==22501== Invalid write of size 1
==22501==    at 0x401EB42: memcpy (mc_replace_strmem.c:406)
==22501==    by 0x4085102: _IO_getline_info (in /lib/tls/…
==22501==    by 0x4084FEE: _IO_getline (in /lib/tls/…
==22501==    by 0x4083F18: fgets (in /lib/tls/i686/cmov/libc-2.3.6.so)
==22501==    by 0x804888D: main (caesar.c:46)
==22501==  Address 0x41603A7 is 15 bytes after a block of size 80 alloc'd
==22501==    at 0x401C621: malloc (vg_replace_malloc.c:149)
==22501==    by 0x80487CA: main (caesar.c:43)
[...]
==22501== ERROR SUMMARY: 52 errors from 7 contexts (suppressed: 11 from 1)
==22501== malloc/free: in use at exit: 2,032 bytes in 27 blocks.
==22501== malloc/free: 27 allocs, 0 frees, 2,032 bytes allocated.
```

Uninitialized Variable

What happens when an invalid key is supplied?

```
$ valgrind ./caesar encrypted.txt bad_keys.txt
[...]
caesar: bad rotation value
==20338== Syscall param exit_group(exit_code) contains uninitialised byte(s)
==20338==    at 0x40BC4F4: _Exit (in /lib/tls/i686/cmov/libc-2.3.6.so)
==20338==    by 0x40F8092: errx (in /lib/tls/i686/cmov/libc-2.3.6.so)
==20338==    by 0x80488CC: decrypt (caesar.c:62)
==20338==    by 0x8048848: main (caesar.c:51)
==20338==
==20338== ERROR SUMMARY: 1 errors from 1 contexts (suppressed: 11 from 1)
```

In `decrypt()`:

```
int i;
[...]
if ((rot < 0)   | ( rot >= 26))
        errx(i, "bad rotation value");
```

Perhaps the programmer meant 1 instead of i?

Valgrind Diagnostic

```
==4928== Conditional jump or move depends on uninitialized value(s)
==4928==    at 0x40239E7: strlen (mc_replace_strmem.c"242
==4928==    by 0x4089127: fputs (in /lib/tls/i686/cmov/libc-2.7.so
==4928==    by 0x804888F: main (caesar.c:52)
```

```
outbuf = decrypt(inbuf, atoi(keystr));
fputs(outbuf, (oflag ? outfile : stdout));
```

`outbuf` is initialized, but not null-terminated!

Null-termination

```
if (!(outbuf = malloc(LINELENGTH)))
   err(1, NULL);
 i = 0;
 while (ch = msg[i]) {
    outbuf[i] = /* . . . */ ch;
    ++i;
  }
 outbuf[i] = '\0';
 return outbuf;
```

Failed to null-terminate the NTBS `outbuf`

Memory Leaks

There are also lots of memory leaks in this code:

```
$ valgrind --leak-check=full ./caesar bad_encrypted.txt keys.txt
[...]
==6436== 1,300 bytes in 13 blocks are definitely lost in loss record 4 of 4
==6436==    at 0x4022AB8: malloc (vg_replace_malloc.c:207)
==6436==    by 0x80488FB: decrypt (caesar.c:64)
==6436==    by 0x8048863: main (caesar.c:51)
==6436==
==6436== LEAK SUMMARY:
==6436==    definitely lost: 1,432 bytes in 27 blocks.
==6436==      possibly lost: 0 bytes in 0 blocks.
==6436==    still reachable: 704 bytes in 2 blocks.
==6436==         suppressed: 0 bytes in 0 blocks.
```

Leaks such as these can allow an attacker to cause a denial of service on an affected program.

Bonus: Format String Vulnerability

In `usage()`:

Recall that `errmsg` is constructed from `getenv("USER”)`

```
fprintf(stderr, errmsg);
```

Missing format specifier

Valgrind doesn’t really detect this error but provides some helpful output over **gdb**:

```
$ USER="user%n%n%n%n" valgrind ./caesar
==19584== Process terminating with default action of signal 11 (SIGSEGV)
==19584==  Bad permissions for mapped region at address 0x80486FC
[...]
==19601== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 11 from 1)
```

Questions