«Insecure Coding»

Insecure Coding

- *(Buffer Overflows)*
- String handling mischief
- Integer overflows / underflows
- Information disclosure (unitialized memory, buffer overread)

Secure Coding: Insecure Functions

Secure Coding: Insecure Functions

http://stackoverflow.com/questions/2565727/what-are-the-c-functions-from-the-standard-library-that-must-should-be-avoided

Functions which can create a buffer overflow:

- gets(char *s)
- scanf(const char *format, ...)
- sprintf(char *str, const char *format, ...)
- strcat(char *dest, const char *src)
- strcpy(char *dest, const char *src)

Secure Coding: Insecure Functions

Recap:

- Don’t use functions which do not respect size of destination buffer

C Strings

And string function strangeness

C Strings

Strings in C:

```
Byte 0 to (n-1): String
Byte n         : \0
```

Strings in Pascal:

```
Byte 0         : Length of string (n)
Byte 1 to (n+1): String
```

C Strings

Thererefore :

```
char str[8];
strcpy(str, "1234567"); // str[7] = '\0'
strlen(str);            // 7 (8 bytes)

strcpy(str, "12345678");  // str[7] = '8'
                          // str[8] = '\0'
strlen(str);              // 8 (9 bytes)

strcpy(str, "123456789");   // str[7] = '8'
                            // str[8] = '9'
                            // str[9] = '\0'
strlen(str);                // 9 (10 bytes)
```

C Strings

Therererefore:

```
char str[8];

strncpy(str, "1234567", 8); // str[7] = '\0'

strncpy(str, "12345678", 8); // str[7] = '8'
                             // (No overflow)

strncpy(str, "123456789", 8); // str[7] = '8'
                              // (No overflow)
```

C Strings

Using standard C string functions on strings with missing \0 terminator is bad

```
char str1[8];
char str2[8];

strncpy(str1, "XXXXYYY", 8);
strncpy(str2, "AAAABBBB", 8);

Len str1: 7
Len str2: 15
str1: XXXXYYY
str2: AAAABBBBXXXXYYY
```

C Strings

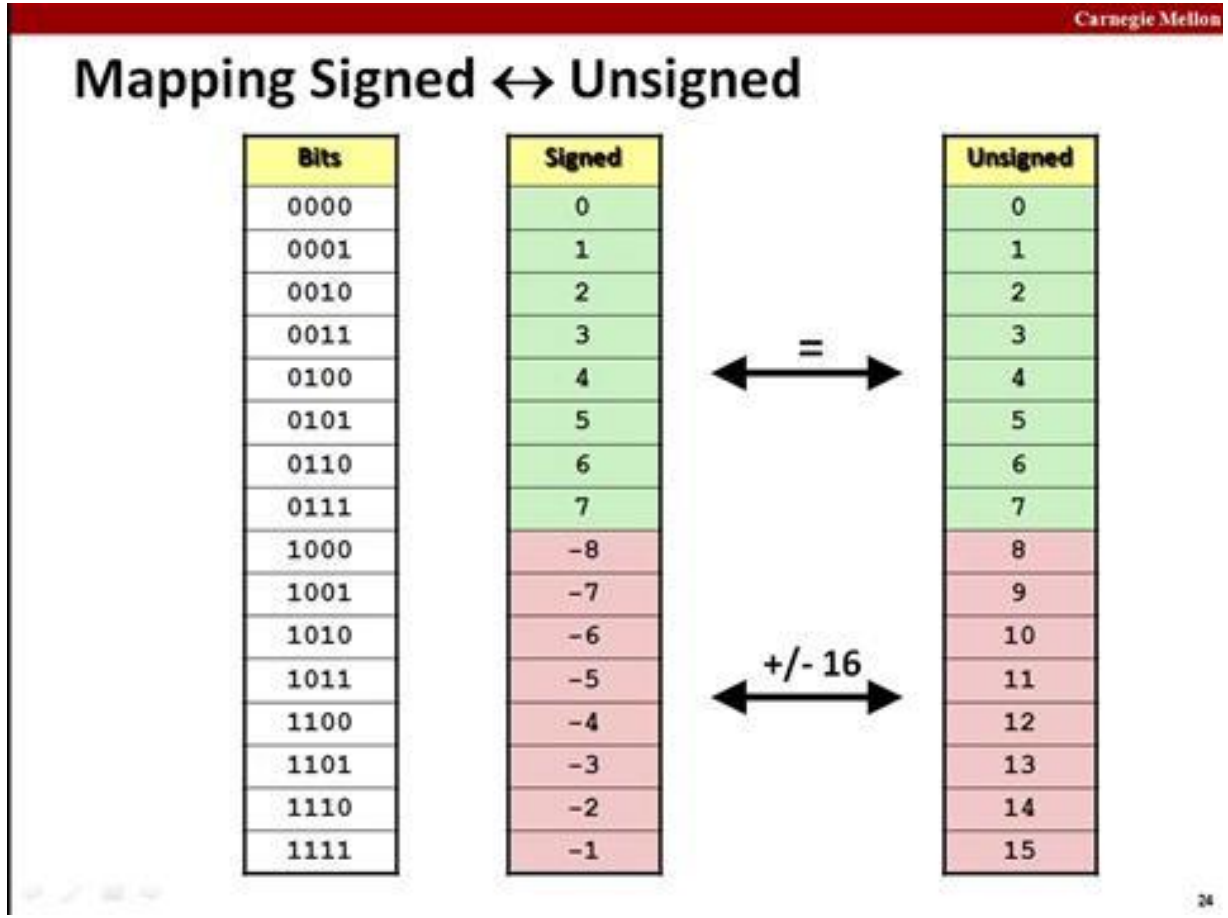
How to do it correctly

```
#def BUF_SIZE 8
char str1[BUF_SIZE];
char str2[BUF_SIZE];

strncpy(str1, "XXXXYYYY", BUF_SIZE);
str1[BUF_SIZE-1] = "\0";

strncpy(str2, "AAAABBBB", BUF_SIZE);
str2[BUF_SIZE-1] = "\0";

Len str1: 7
Len str2: 7
str1: XXXXYYY
str2: AAAABBB
```

Secure Coding: Integer Overflow

Signed integer

Signed int: can be negative
Halves the amount of numbers it can store



Integer Overflows

“Adding a positive number to an integer might make it smaller”

Unsigned:

If you add a positive integer to another positive integer, the result is truncated. Technically, if you add two 32-bit numbers, the result has 33 bits.

On the CPU level, if you add two 32-bit integers, the lower 32 bits of the result are written to the destination, and the 33rd bit is signalled out in some other way, usually in the form of a "carry flag".

Integer overflows

Consists of different weaknesses:

- Unsigned Integer Wraparound
- Signed Integer Overflow
- Numeric Truncation Error

Secure Programming Practices in C++ - NDC Security 2018 (Patricia Aas)

- https://www.youtube.com/watch?v=Jh0G_A7iRac

Integer Overflow: Example 1

signed int

Integer Overflow: example 1 - signed int

NAME

memcpy - copy memory area

SYNOPSIS

#include <string.h>

void *memcpy(void *dest, const void *src, **size_t n**);

DESCRIPTION

The memcpy() function copies n bytes from memory area src to memory area dest. The memory areas must not overlap. Use memmove(3) if the memory areas do overlap.

According to the 1999 ISO C standard (C99), ***size_t is an unsigned integer*** *type of at least 16 bit (see sections 7.17 and 7.18.3)*

Integer Overflow: example 1 - signed int

```
void test(int inputLen, char *input) {
        char arr[1024];
        printf("Input len : %i / 0x%x\n", inputLen, inputLen);

        if (inputLen > 1024) {
                printf("Not enough space\n");
                return;
        }
        printf("Ok, copying %u\n", inputLen);
        memcpy(arr, input, inputLen);
        …
}
```

Integer Overflow: example 1 - signed int

```
void test3(int inputLen) {
        char arr[1024];
        printf("Input len : %i / %u / 0x%x\n",
                inputLen, inputLen, inputLen);
        if (inputLen > 1024) {
```

```
test3(0x7fffffff);
    Input len : 2147483647 / 2147483647
    Not enough space

test3(0x80000000);
    Input len : -2147483648 / 2147483648
    Ok, copying: 2147483648
```

Integer Overflow: example 1

Integer overflow problem:

Programs:

- Usually use “signed int” (can be smaller than 0, half the space)
- Indexes should be “unsigned int” (always positive)
- But: malloc() takes a size_t (unsigned int)!

Developers:

- Usually use "int" = "signed int"
- Don’t want to type “unsigned…”
- Don’t understand size_t
- Want to communicate error: if(result < 0) { }

Integer Overflow: Example 2

unsigned int overflow / truncate

Integer Overflow: example 2 - unsigned int overflow / truncate

```
#define BUF_SIZE 256

int catvars(char *buf1, char *buf2,
  unsigned int len1, unsigned int len2)
{
  char mybuf[BUF_SIZE];

  if((len1 + len2) > BUF_SIZE){    // Truncate if (len1 + len2) > 2^32
      return -1;
  }

  memcpy(mybuf, buf1, len1);
  memcpy(mybuf + len1, buf2, len2); // buffer overflow

  do_some_stuff(mybuf);
```

len1: 260 / 260 / 0x104
len2: -4 / 4294967292 / 0xfffffffc

len1 + len2: 256 / 256 / 0x100

```
if((len1 + len2) > 256){
    return -1;
}

// We arrive here
memcpy(mybuf, buf1, len1);
memcpy(mybuf + len1, buf2, len2); // len2 = 0xfffffffc

do_some_stuff(mybuf);
```

Integer Overflow: example 2 - unsigned int overflow / truncate

Adding two unsigned int can produce an overflow
Overflow bit is just "forgotten"

```
   0x   FFFFFFFF
+  0x   FFFFFFFF
=  0x  1FFFFFFFE
=  0x   FFFFFFFE
```

Integer Overflow: Example 3

signed array index

Example 3 - signed array index

```
int table[500];

int insert_in_table(int val, int pos) {
    if(pos > 500) {
        return -1;
    }

    table[pos] = val; // pos = -1?
    return 0;
}
```

Integer Overflow: Example 5

Integer Overflow – Example 5

Multiplication overflow:

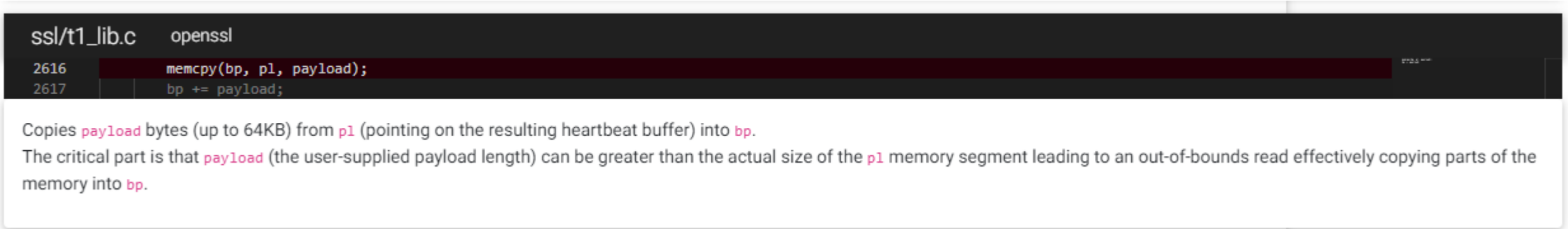
```
int* function(int *array, int len){
    int *myarray, i;

    myarray = malloc(len * sizeof(int));    // len < 0? len = 0?
    if(myarray == NULL){
        return -1;
    }

    for(i = 0; i < len; i++){
        myarray[i] = array[i];
    }

    return myarray
}
```

Information Disclosure

Heartbleed

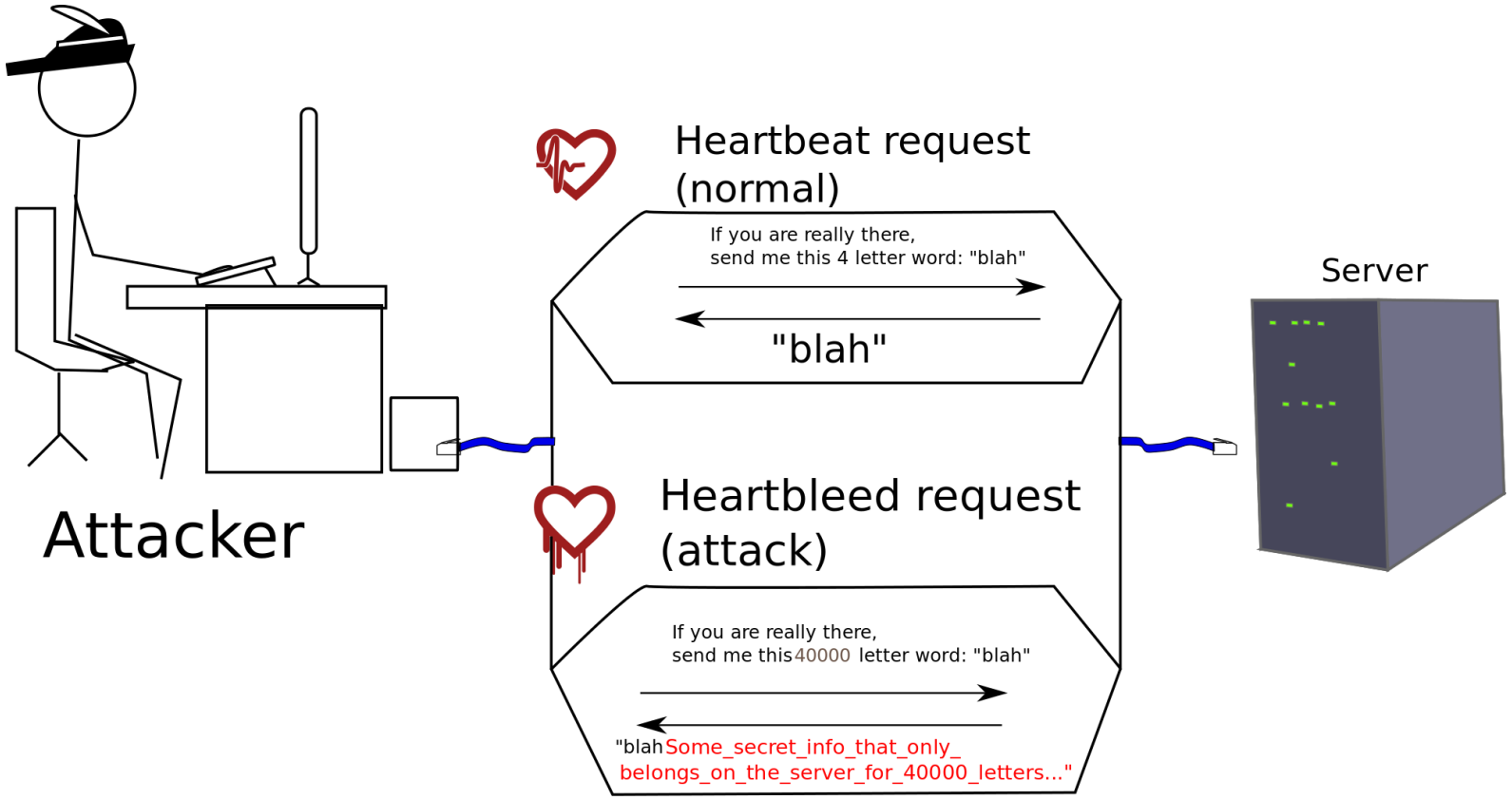
https://www.vulncode-db.com/CVE-2014-0160

“The Heartbleed bug is an issue with the Heartbeat protocol that is used for […]. It allows an attacker to exfiltrate up to 16 KB memory data from a target running a vulnerable OpenSSL version.”



Heartbleed

```
char buffer[1024];
write(socket, buffer, len_attacker);  // e.g. 40'000
```



Some Buffer Overflow Bugs

Some Bugs: Mongoose MQTT

```
MG_INTERNAL int parse_mqtt(struct mbuf *io, struct mg_mqtt_message *mm) {
     const char *p = &io->buf[1], *end;
[...]
    /* decode mqtt variable length */
    // In Fixed header
    do {
      len += (*p & 127) << 7 * (p - &io->buf[1]);
    } while ((*p++ & 128) != 0 && ((size_t)(p - io->buf) <= io->len));

    // end = p for (attacker controlled) len = 0
    end = p + len;
    if (end > io->buf + io->len + 1) {
      return -1;
    }
```

Some Bugs: Mongoose MQTT

```
case MG_MQTT_CMD_SUBSCRIBE:
     mm->message_id = getu16(p); // Variable header
     p += 2; // p > end for len = 0
     /*
      * topic expressions are left in the payload and can be parsed with
      * `mg_mqtt_next_subscribe_topic`
      */
     mm->payload.p = p;
     mm->payload.len = end - p; // mm->payload.len < 0 for len = 0
     printf("MQTT Subscribe 1: p: %p   len: %lx\n",
       mm->payload.p, mm->payload.len);
     break;
```

Some Bugs: Mongoose MQTT

```
static void mg_mqtt_broker_handle_subscribe(struct mg_connection *nc,
                                            struct mg_mqtt_message *msg) {
  struct mg_mqtt_session *ss = (struct mg_mqtt_session *) nc->user_data;
  uint8_t qoss[512]; // static size, will be overflowed
  size_t qoss_len = 0;
  struct mg_str topic;
  uint8_t qos;
  int pos;
  struct mg_mqtt_topic_expression *te;

for (pos = 0;
       (pos=mg_mqtt_next_subscribe_topic(msg, &topic, &qos, pos)) != -1;)
   {
    qoss[qoss_len++] = qos; // Stack based buffer overflow here
   }
  [...]
}
```

Some Bugs: Exim Off By One buffer overflow

https://devco.re/blog/2018/03/06/exim-off-by-one-RCE-exploiting-CVE-2018-6789-en/

```
b64decode(const uschar *code, uschar **ptr)
{
int x, y;
uschar *result = store_get(3*(Ustrlen(code)/4) + 1);

*ptr = result;
// perform decoding
}
```

As shown above, exim allocates a buffer of `3*(len/4)+1` bytes to store decoded base64 data. However, when the input is not a valid base64 string and the length is `4n+3`, exim allocates `3n+1` but consumes `3n+2` bytes while decoding. This causes one byte heap overflow (aka off-by-one).

Some Bugs: Netkit-telnetd buffer overflow

```
static void
encrypt_keyid(struct key_info *kp, unsigned char *keyid, int len)
{
    ...
    if (!(ep = (*kp->getcrypt)(*kp->modep))) {
        ...
    } else if ((len != kp->keylen)
                || (memcmp(keyid,kp->keyid,len) != 0)) {
        /* Length or contents are different */
        kp->keylen = len;
        memcpy(kp->keyid, keyid, len);
```

Some Bugs: iOS 11 Multipath TCP

Let's first take a quick look at the offending code in `mptcp_usr_connect()`, which is the handler for the `connectx` syscall for the `AP_MULTIPATH` socket family:

```
if (src) {
    // verify sa_len for AF_INET
                if (src->sa_family == AF_INET &&
                    src->sa_len != sizeof(mpte->__mpte_src_v4)) {
                        mptcplog((LOG_ERR, "%s IPv4 src len %u\n", __func__,
                                  src->sa_len),
                                 MPTCP_SOCKET_DBG, MPTCP_LOGLVL_ERR);
                        error = EINVAL;
                        goto out;
                }

    // verify sa_len for AF_INET6
                if (src->sa_family == AF_INET6 &&
                    src->sa_len != sizeof(mpte->__mpte_src_v6)) {
                        mptcplog((LOG_ERR, "%s IPv6 src len %u\n", __func__,
                                  src->sa_len),
                                 MPTCP_SOCKET_DBG, MPTCP_LOGLVL_ERR);
                        error = EINVAL;
                        goto out;
                }

    // code doesn't bail if sa_family is neither AF_INET nor AF_INET6
                if ((mp_so->so_state & (SS_ISCONNECTED|SS_ISCONNECTING)) == 0) {
                        memcpy(&mpte->mpte_src, src, src->sa_len);
                }
        }
```

The code does not validate the `sa_len` field if `src→sa_family` is neither `AF_INET` nor `AF_INET6` so the function directly falls through to `memcpy` with a user specified `sa_len` value up to 255 bytes.

Assembly

C

C++

References

References:

- Catching Integer Overflows in C
  - https://www.fefe.de/intof.html