Secure Coding

«Insecure Coding»

Insecure Coding

- *(Buffer Overflows)*
- String handling mischief
- Integer overflows / underflows
- Information disclosure (unitialized memory, buffer overread)
- *(Heap related; Use After Free etc.)*
- Format String Vulnerabilities

Off by one

```
int i;

void vuln(char *foobar) {
  char buffer[512];

  for (i=0;i<=512;i++)
    buffer[i]=foobar[i];
}
```

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

Threrefore:

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

strcpy(str, "12345678");  // str[7] = ‘8’
                          // str[8] = ‘\0’
strlen(str);              // 8

strcpy(str, "123456789");   // str[7] = ‘8’
                            // str[8] = ‘9’
                            // str[8] = ‘\0’
strlen(str);                // 9
```

Overflow for input strings which are too large

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

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

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

C Strings

Thererefore:

```
char str[8];
strcpy(str, "1234567"); // str[7] = ‘\0’



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)
```

No null terminator if input string is too large (>=dest_len)

```
strcpy(str, "1234567"); // str[7] = ‘\0’



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);
```

- Result: (strlen, printf)

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

C Strings

How to do it correctly:

```
strncpy(str2, "AAAABBBB", 8);
str2[7] = “\0”;
```

Or strlcpy() (non-standard)

Secure Coding: Integer Overflow

Integer Overflows

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

Signed:

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

Integer Overflow: example 1

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

        if (inputLen > 1024) {
                printf("Not enough space\n");
                return;
        }
        printf("Ok, copying...\n");
        …
}
```

Integer Overflow: example 1

```
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...
```

Integer Overflow: example 1

Integer overflow problem:

Programs:

- Usually use “unsigned int”
- Indexes should be “unsigned int” (cannot be <0)
- malloc() takes a size_t (unsigned int)

Developers:

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

Integer Overflow: Example 2

Integer Overflow: example 2

```
#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){    /* [3] */
      return -1;
  }

  memcpy(mybuf, buf1, len1);      /* [4] */
  memcpy(mybuf + len1, buf2, len2);

  do_some_stuff(mybuf);
```

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

len1 + len2: 256 / 256 / 0x100
```

```
if((len1 + len2) > 256){    /* [3] */
      return -1;
  }

  memcpy(mybuf, buf1, len1);      /* [4] */
  memcpy(mybuf + len1, buf2, len2);

  do_some_stuff(mybuf);
```

Integer Overflow: Example 3

Example 3

```
int table[500];

int insert_in_table(int val, int pos) {
    if(pos > (sizeof(table) / sizeof(int)) ) {
        return -1;
    }

    table[pos] = val;

    return 0;
}
```

Integer Overflow: Example 4

Example 4

```
#define BUF_SIZE 32
void concat_print(
    char *first, unsigned int *first_len,
    char *second, unsigned int *second_len)
{
    char buf[BUF_SIZE];

    if (*first_len + *second_len > BUF_SIZE) {
        return;
    }

    for(unsigned int n=0; n<*first_len; n++) {
        buf[n] = first[n];
    }

    for(unsigned int n=0; n<*second_len; n++) {
         buf[*first_len + n] = second[n];
    }
}
```

Example 4

```
char first[16];
char second[16];

Defined behaviour:
  concat_print(first, 16, second, 16)   // OK (copy 32 bytes)
  concat_print(first, 16, second, 256)  // OK (wont copy anything)

Undefined behaviour:
  concat_print(first, 16, second, UINT_MAX)  // -> BOF
```

Integer Overflow: Example 5

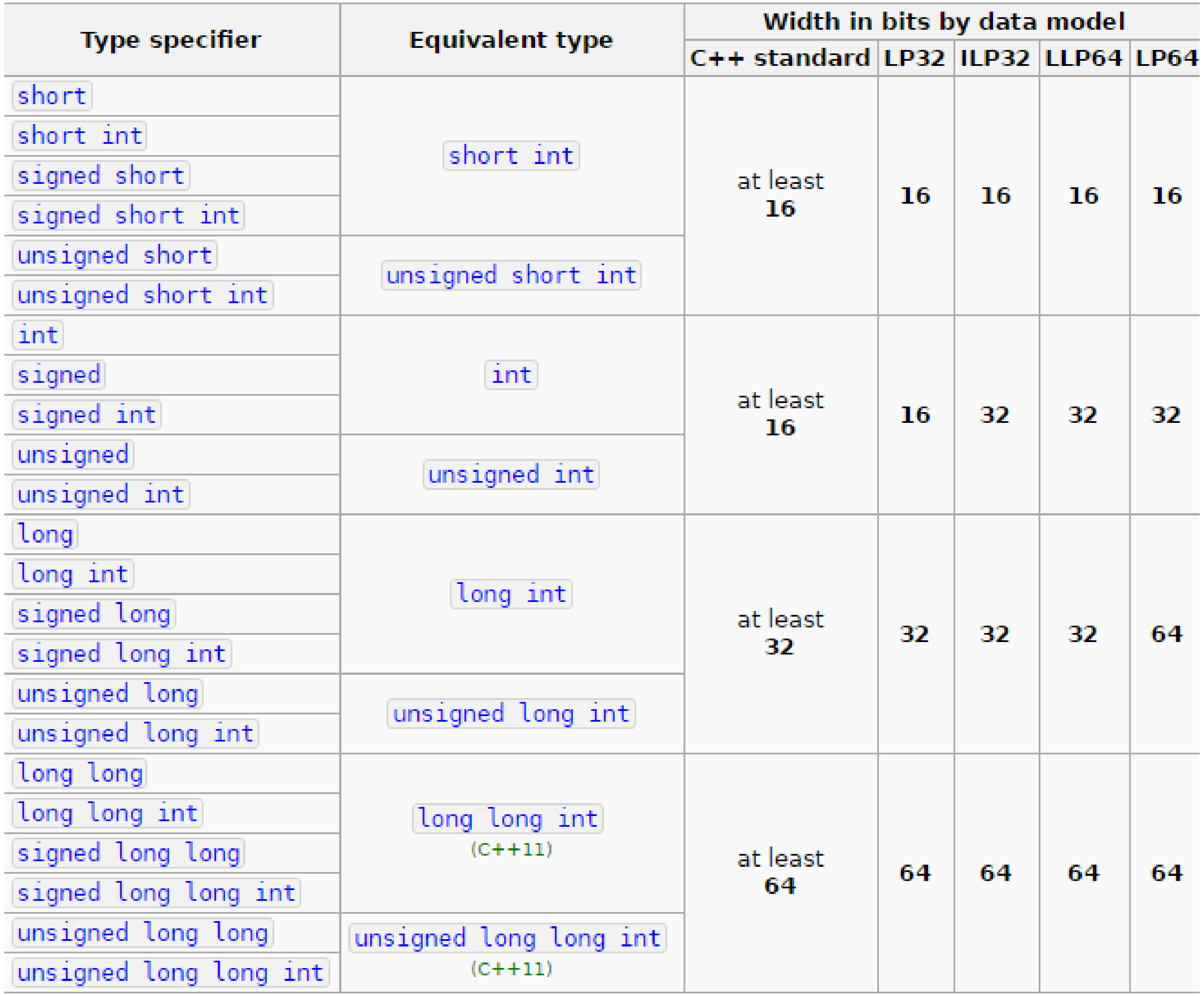
Integer Overflow – Example 5

Multiplication overflow:

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

   myarray = malloc(len * sizeof(int));  /*[1]*/
   if(myarray == NULL){
       return -1;
   }

   for(i = 0; i < len; i++){              /*[2]*/
       myarray[i] = array[i];
   }

   return myarray
}
```

Integer overflows

C types http://en.cppreference.com/w/cpp/language/types



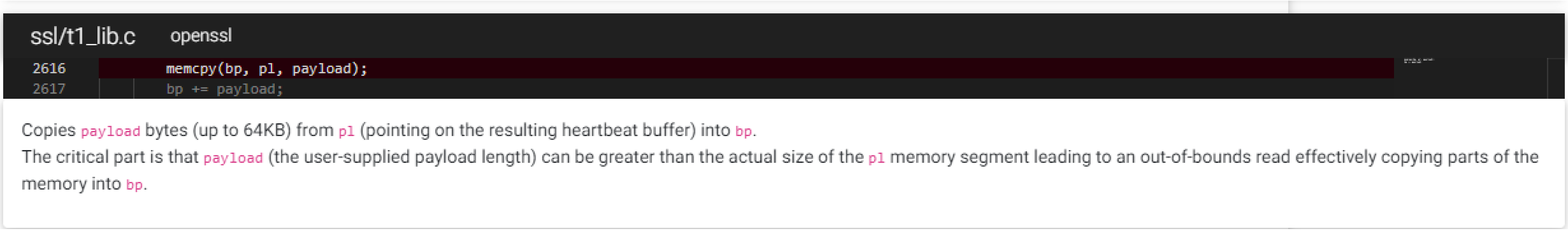
Type specifier	Equivalent type	Width in bits by data model				
		C++ standard	LP32	ILP32	LLP64	LP64
short	short int	at least 16	16	16	16	16
short int						
signed short						
signed short int						
unsigned short	unsigned short int					
unsigned short int						
int	int	at least 16	16	32	32	32
signed						
signed int						
unsigned	unsigned int					
unsigned int						
long	long int	at least 32	32	32	32	64
long int						
signed long						
signed long int						
unsigned long	unsigned long int					
unsigned long int						
long long	long long int (C++11)	at least 64	64	64	64	64
long long int						
signed long long						
signed long long int						
unsigned long long	unsigned long long int (C++11)					
unsigned long long int						

Information Disclosure

Heartbleed

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

“The Hearbleed 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.”



ssl/t1_lib.c openssl

```
        memcpy(bp, pl, payload);
        bp += payload;
```

Copies payload bytes (up to 64KB) from pl (pointing on the resulting heartbeat buffer) into bp.
The critical part is that payload (the user-supplied payload length) can be greater than the actual size of the pl memory segment leading to an out-of-bounds read effectively copying parts of the memory into bp.

Format String Vulnerabilities

Format String Vulnerability: Lazy/wrong code

Correct:

```
printf("%s: %i", user_input, some_int);
```

Possible, but wrong:

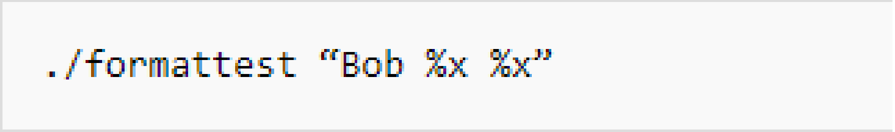
```
printf(user_input);
```

will create mischief with:

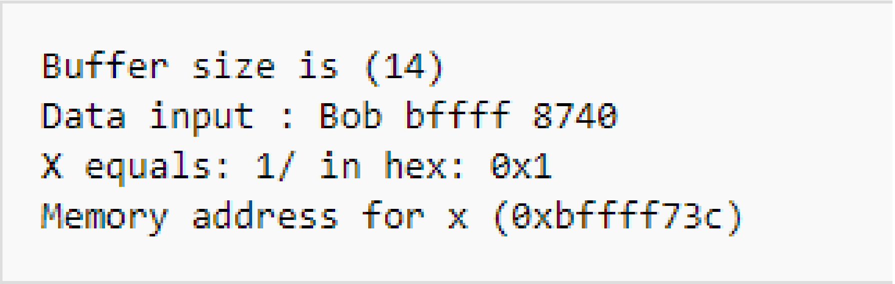
```
user_input = "Its me, mario! %x %x %x"
```

Format String Vulnerability: User-supplied format string

```
int main (int argc, char **argv)
{
        char buf [100];
        int x = 1 ;
        snprintf ( buf, sizeof buf, argv[1] ) ;
        buf [ sizeof buf -1 ] = 0;
        printf ( “Buffer size is: (%d) \nData input: %s \n” , strlen (buf) , buf ) ;
        printf ( “X equals: %d/ in hex: %#x\nMemory address for x: (%p) \n” , x, x, &x) ;
        return 0 ;
}
```



```
./formattest “Bob %x %x”
```



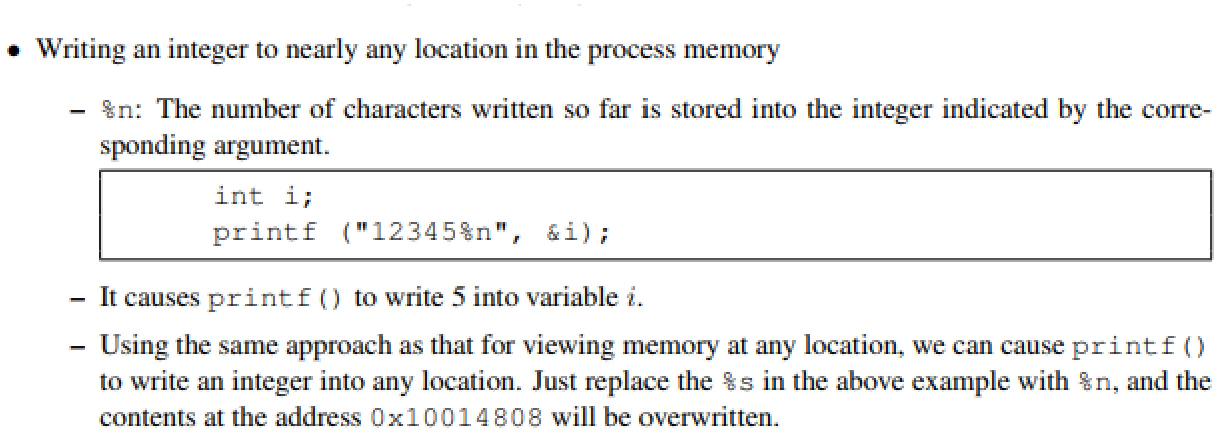
```
Buffer size is (14)
Data input : Bob bffff 8740
X equals: 1/ in hex: 0x1
Memory address for x (0xbffff73c)
```

Because:

```
int snprintf(char *str, size_t size, const char *format, ...);
snprintf(buf, sizeof(buf), "%s", user_supplied);
```

Format String Vulnerability Exploitation

http://www.cis.syr.edu/~wedu/Teaching/cis643/LectureNotes_New/Format_String.pdf



- Writing an integer to nearly any location in the process memory
  - `%n`: The number of characters written so far is stored into the integer indicated by the corresponding argument.

```
        int i;
        printf ("12345%n", &i);
```

  - It causes `printf()` to write 5 into variable *i*.
  - Using the same approach as that for viewing memory at any location, we can cause `printf()` to write an integer into any location. Just replace the `%s` in the above example with `%n`, and the contents at the address `0x10014808` will be overwritten.

Format String Vulnerabilities: Solved

Anti-Formatstring Vulnerability:

Compiler:

```
-Wformat-security
```

Code:

```
printf(argv[1]);
```

Warning:

```
warning: format not a string literal and no format arguments [-Wformat-security]
```

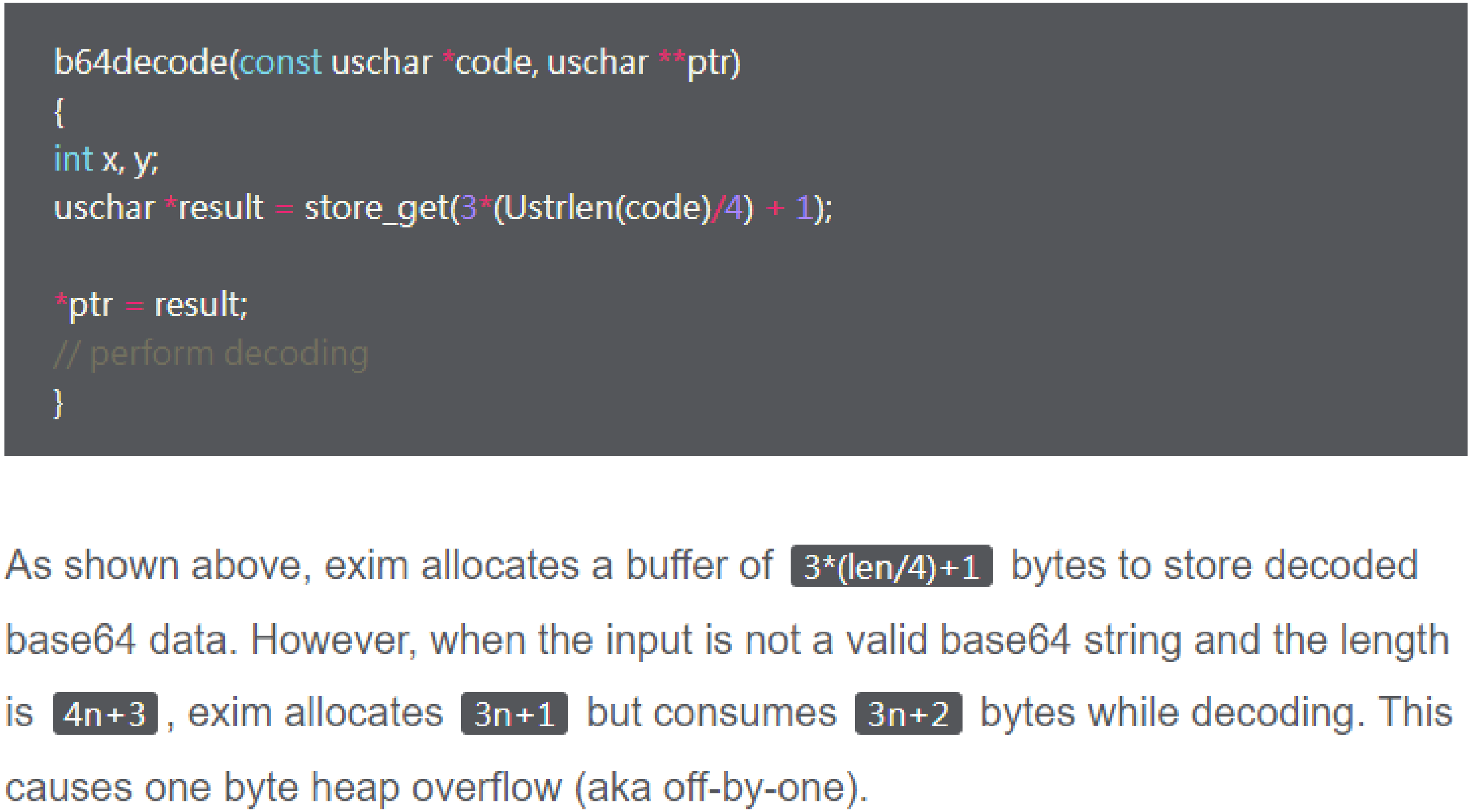
Some Buffer Overflow Bugs

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/



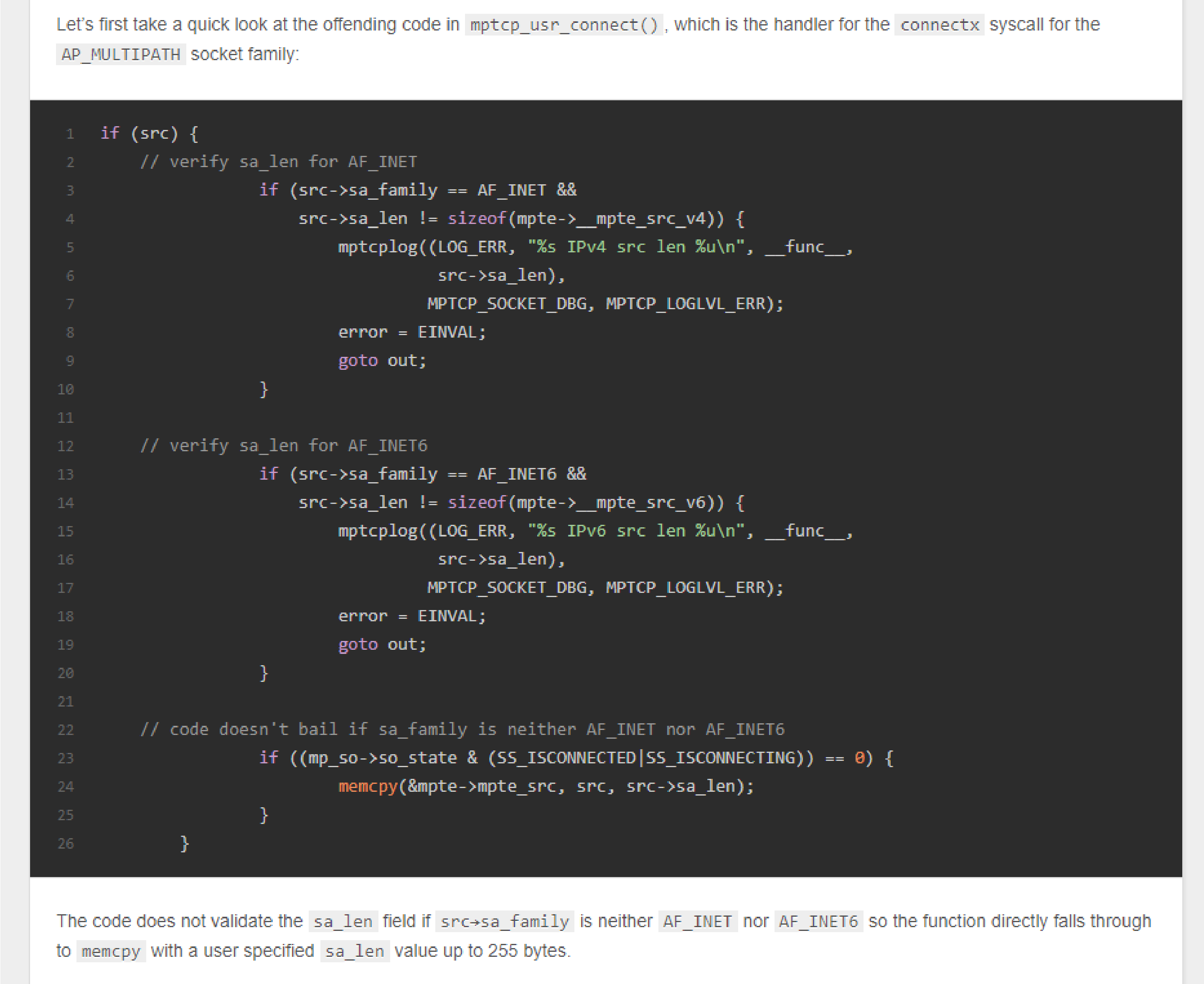
```
b64decode(const uschar *code, uschar **ptr)
{
int x, y;
uschar *result = store_get(3*(Ustrlen(code)/4) + 1);

*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
Pimp My Gun
C
pimpmygun.doctornoob.com
VIA 9GAG.COM
C++
Pimp My Gun
pimpmygun.doctornoob.com
Python

References

References:

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