Attacks on Memory Buffers

- Buffer is a data storage area inside computer memory (stack or heap)
  - Intended to hold pre-defined amount of data
    - If more data is stuffed into it, it spills into adjacent memory
  - If executable code is supplied as “data”, victim’s machine may be fooled into executing it – we’ll see how
    - Code will self-propagate or give attacker control over machine
- First generation exploits: stack smashing
- Second gen: heaps, function pointers, off-by-one
- Third generation: format strings and heap management structures

Stack Buffers

buf

- Suppose Web server contains this function

```
void func(char *str) {
     char buf[126];
     ...
     strcpy(buf,str);
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- No bounds checking on strcpy()
- If str is longer than 126 bytes
  - Program may crash
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Changing Flags

	buf	authenticated	

- Suppose Web server contains this function

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      int authenticated = 0;
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- Authenticated variable non-zero when user has extra privileges
- Morris worm also overflowed a buffer to overwrite an authenticated flag in in.fingerd

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- Text region: Executable code of the program
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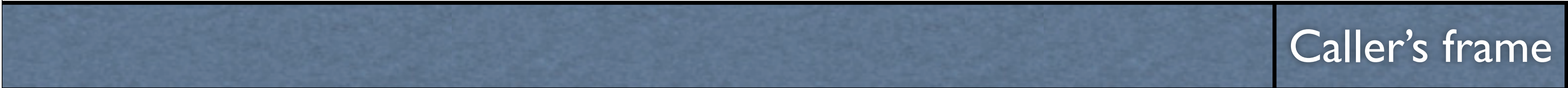
- When this function is invoked, a new frame with local variables is pushed onto the stack



Addr 0xFF...F

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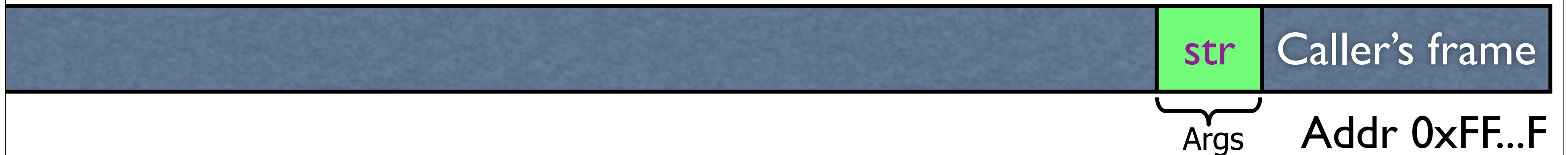

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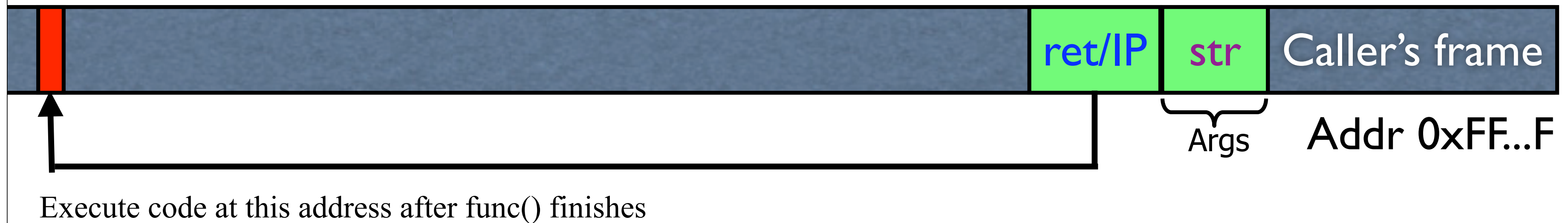

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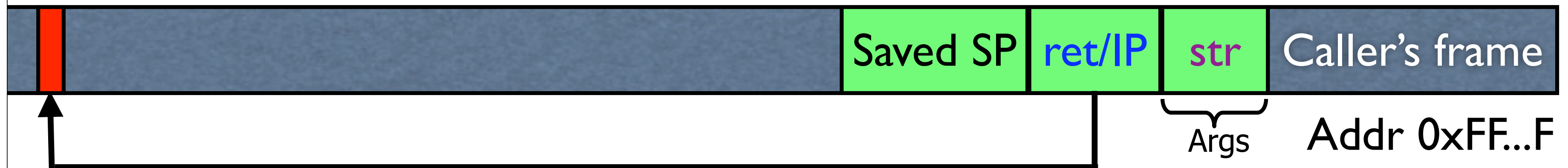

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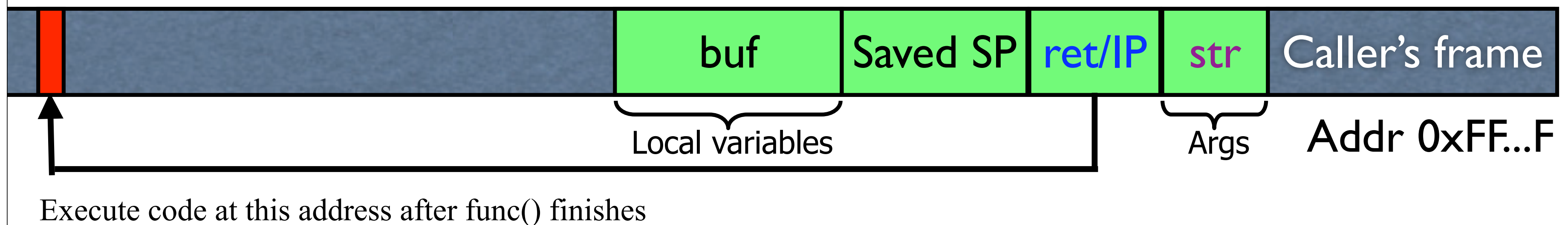

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What If Buffer is Overstuffed?

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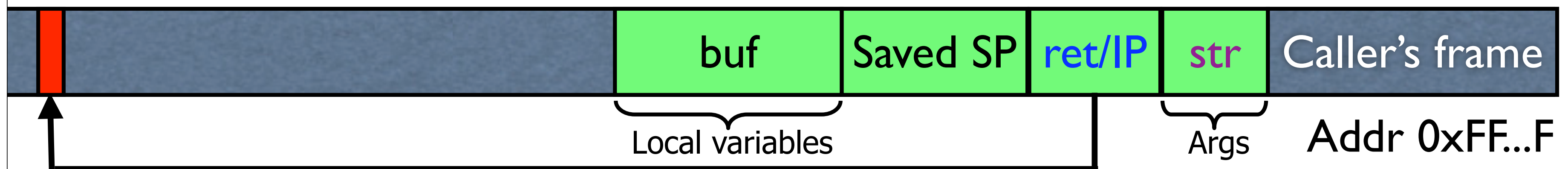

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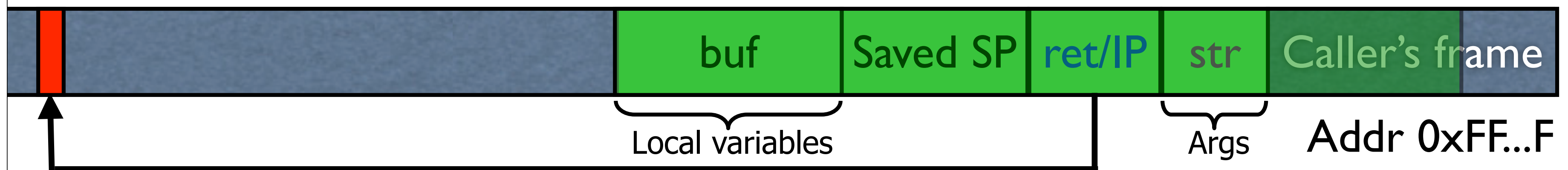

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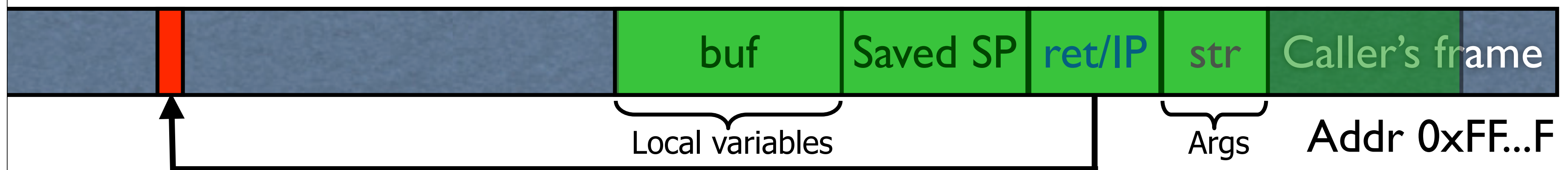
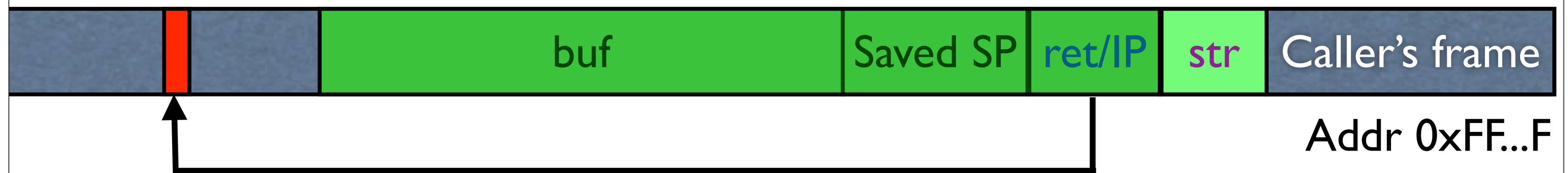


Executing Attack Code

- Suppose buffer contains attacker-created string
  - For example, *str contains a string received from the network as input to some network service daemon



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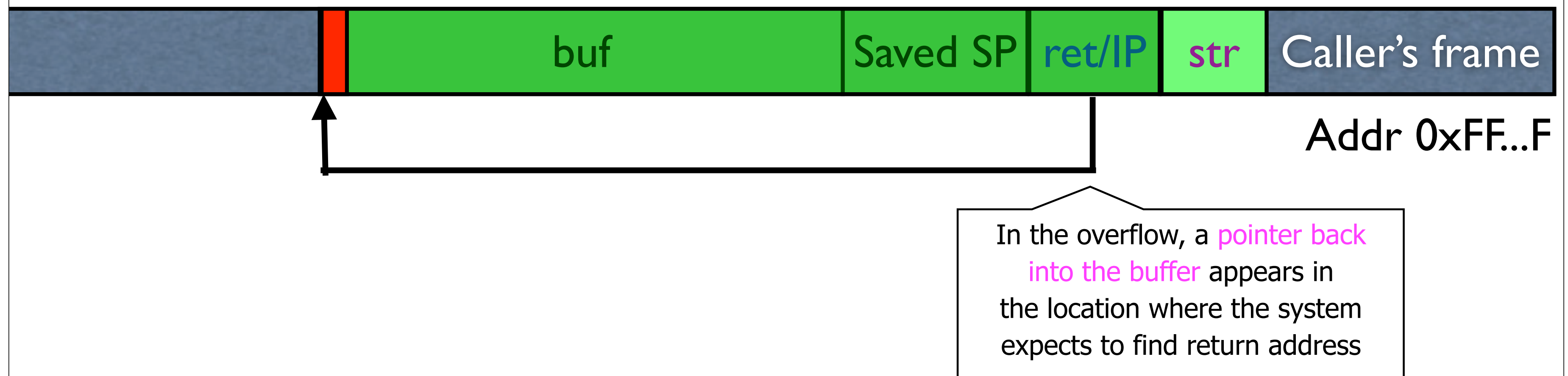

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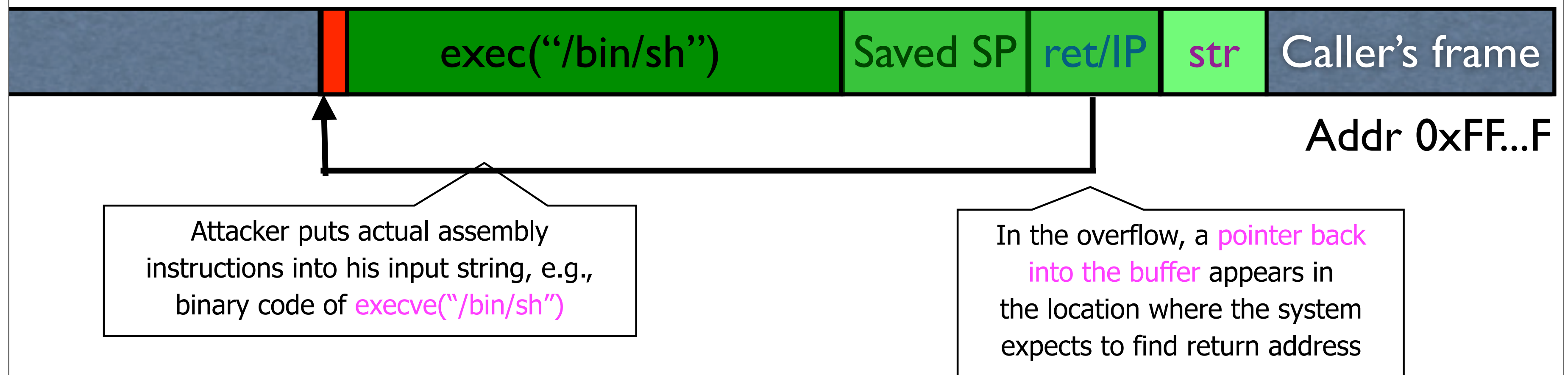

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Buffer Overflow Issues

- Executable attack code is stored on stack, inside the buffer containing attacker's string
  - Stack memory is supposed to contain only data, but…
- Overflow portion of the buffer must contain correct address of attack code in the RET position
  - The value in the RET position must point to the beginning of attack assembly code in the buffer
    - Otherwise application will crash with segmentation violation
  - Attacker must correctly guess in which stack position his buffer will be when the function is called

Problem: No Range Checking

- strcpy does not check input size
  - strcpy(buf, str) simply copies memory contents into buf starting from *str until "\0" is encountered, ignoring the size of area allocated to buf
- Many C library functions are unsafe
  - strcpy(char *dest, const char *src)
  - strcat(char *dest, const char *src)
  - gets(char *s)
  - scanf(const char *format, ...)
  - printf(const char *format, ...)

Does Range Checking Help?

- strncpy(char *dest, const char *src, size_t n)
  - If strncpy is used instead of strcpy, no more than n characters will be copied from *src to *dest
    - Programmer has to supply the right value of n
- Potential overflow in htpasswd.c (Apache 1.3):

```
strcpy(record,user);
strcat(record,":");
strcat(record,cpw); …
```

Copies username ("user") into buffer ("record"), then appends ":" and hashed password ("cpw")

- Published "fix" (do you see problem?):

```
… strncpy(record,user,MAX_STRING_LEN-1);
  strcat(record,":");
  strncat(record,cpw,MAX_STRING_LEN-1); …
```

Off-By-One Overflow

- Home-brewed range-checking string copy

```
void notSoSafeCopy(char *input) {
     char buffer[512]; int i;
     for (i=0; i<=512; i++)
          buffer[i] = input[i];
}
void main(int argc, char *argv[]) {
     if (argc==2)
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This will copy **513** characters into buffer. Oops!

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This will copy **513** characters into buffer. Oops!

- 1-byte overflow: can't change RET, but can change pointer to previous stack frame
  - On little-endian architecture, make it point into buffer
  - RET for previous function will be read from buffer!

Memory Layout

- Text region: Executable code of the program
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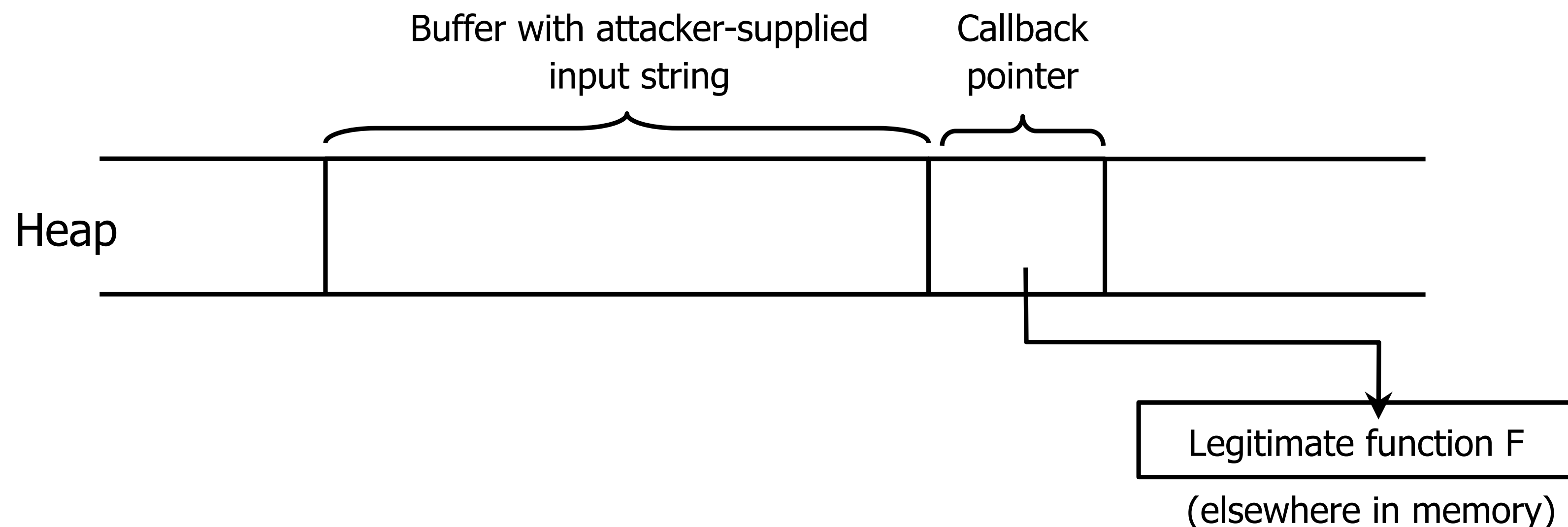
Function Pointer Overflow

- C uses function pointers for callbacks: if pointer to F is stored in memory location P, then another function G can call F as (*P)(…)



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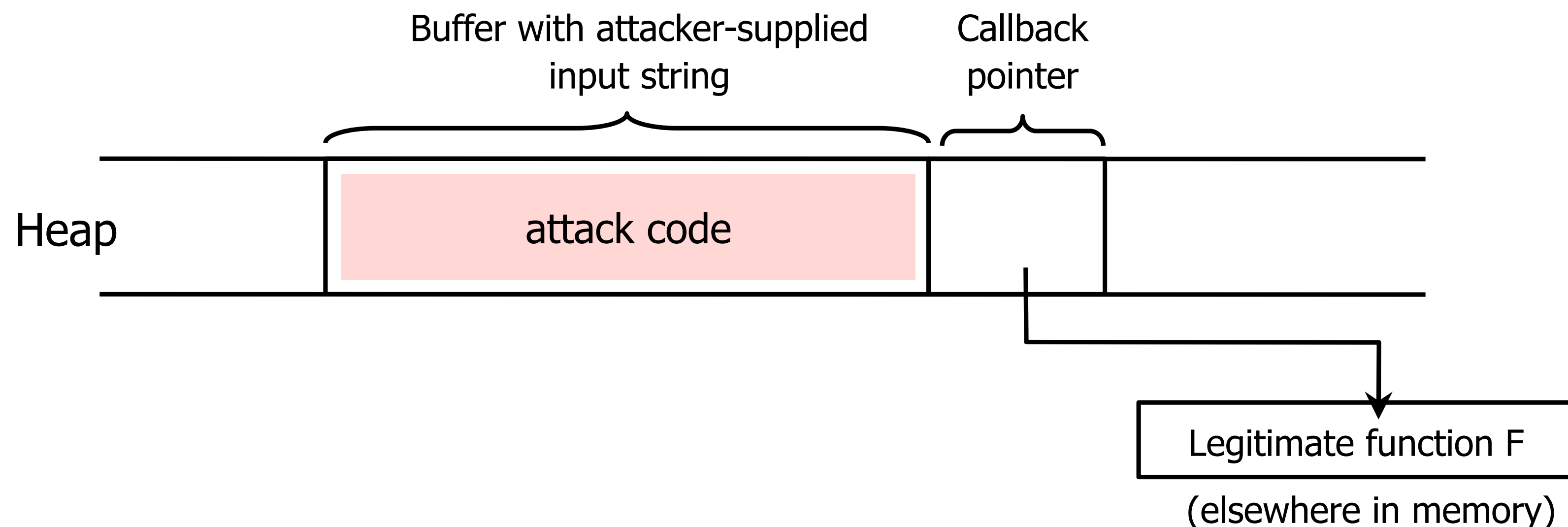

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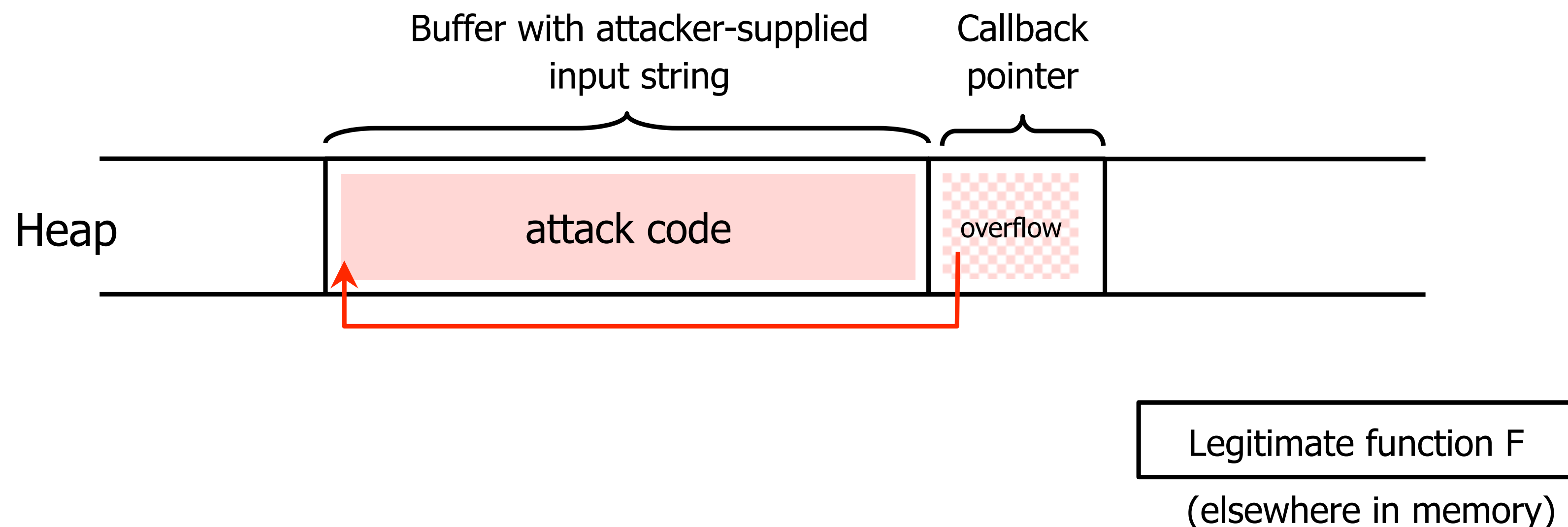

Format Strings in C

- Proper use of printf format string:

```
… int foo=1234;
  printf("foo = %d in decimal, %X in hex",foo,foo); …
```

  – This will print

```
foo = 1234 in decimal, 4D2 in hex
```

- Sloppy use of printf format string:

```
… char buf[14]="Hello, world!";
  printf(buf);
   // should've used printf("%s", buf); …
```

  – If buffer contains format symbols starting with %, location pointed to by printf's internal stack pointer will be interpreted as an argument of printf. This can be exploited to move printf's internal stack pointer.

Viewing Memory

- %x format symbol tells printf to output data on stack

```
… printf("Here is an int:  %x",i); …
```

- What if printf does not have an argument?

```
… char buf[16]="Here is an int:  %x";
  printf(buf); …
```

  – Stack location pointed to by printf's internal stack pointer will be interpreted as an int. (What if crypto key, password, ...?)

- Or what about:

```
… char buf[16]="Here is a string:  %s";
  printf(buf); …
```

  – Stack location pointed to by printf's internal stack pointer will be interpreted as a pointer to a string

Writing Stack with Format Strings

- %n format symbol tells printf to write the number of characters that have been printed

```
… printf("Overflow this!%n",&myVar); …
```

  - Argument of printf is interpeted as destination address
  - This writes 14 into myVar ("Overflow this!" has 14 characters)

- What if printf does not have an argument?

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Lab: GDB will be helpful too!

- disassemble
- run
- continue
- break
  - break main
  - break *0x08048643
- step / stepi
- info register
- x
  - x/200x buf
  - x/200i buf
  - x/200a buf
  - x/200x $sp - 16