Module 4
Software Security

Submodule 2: Low-level Attacks and Defense

What is Buffer Overflow Attack?

- One of the most common OS bugs is a buffer overflow
  - The developer fails to include code that checks whether an input string fits into its buffer array.
  - An input to the running process exceeds the length of the buffer.
  - The input string overwrites a portion of the memory of the process.
  - Causes the application to behave improperly and unexpectedly.

Effect of Buffer Overflow Attack

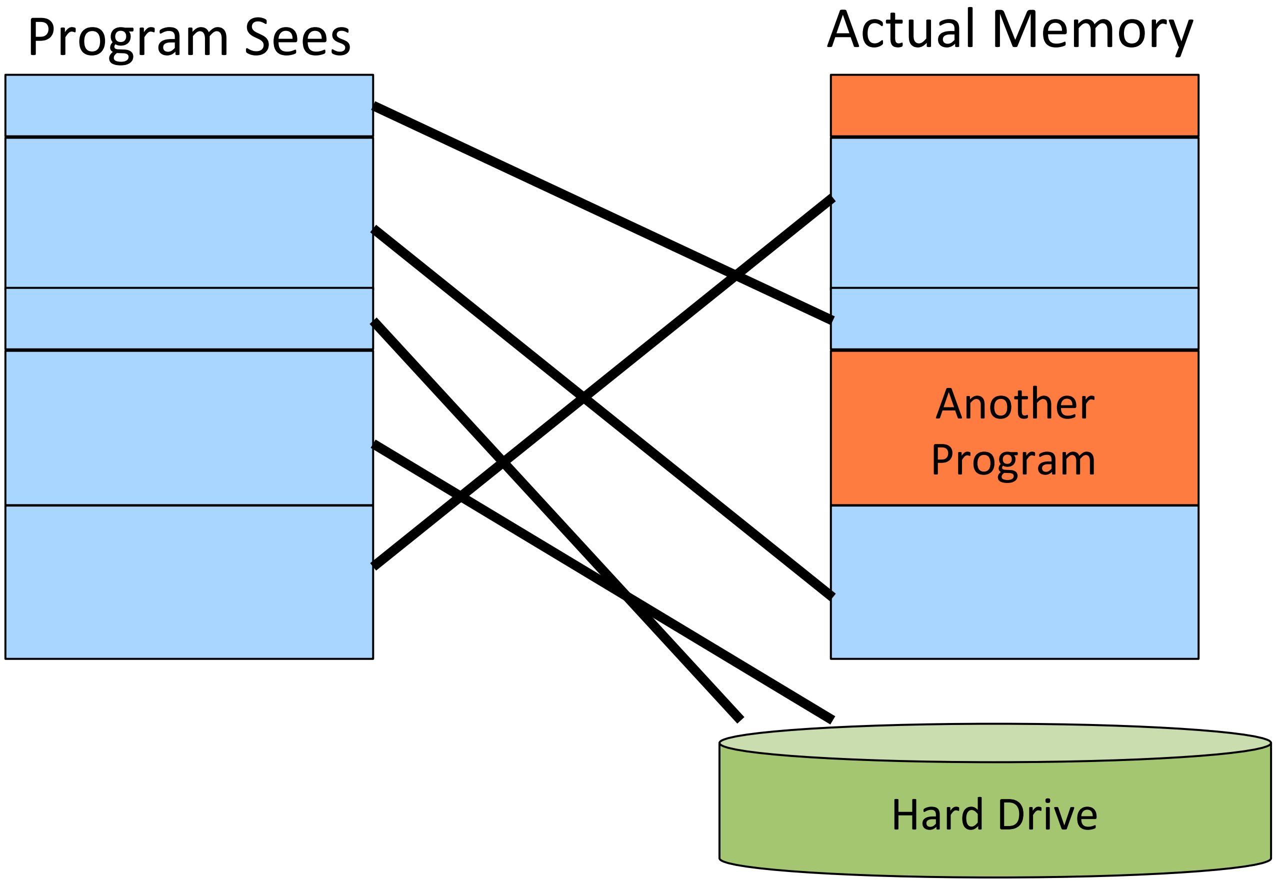
- The process can operate on malicious data or execute malicious code passed in by the attacker.
- If the process is executed as root, the malicious code will be executing with root privileges.

Address Space

- Every program needs to access memory in order to run.
- For simplicity sake, it would be nice to allow each process (i.e., each executing program) to act as if it owns all of memory.
- The address space model is used to accomplish this
  - Each process can allocate space anywhere it wants in memory
  - Most kernels manage each process' allocation of memory through the virtual memory model
  - How the memory is managed is irrelevant to the process

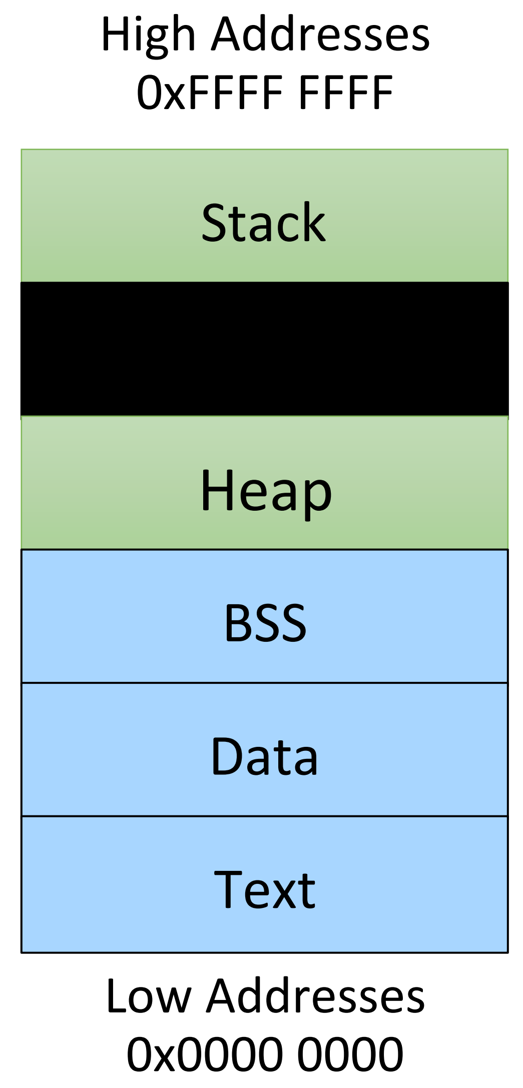
Virtual Memory

- Mapping virtual addresses to real addresses



Unix Address Space

- Text: machine code of the program, compiled from the source code.
- Data: static program variables initialized in the source code prior to execution.
- BSS (block started by symbol): static variables that are uninitialized.
- Heap : data dynamically generated during the execution of a process.
- Stack: structure that grows downwards and keeps track of the activated method calls, their arguments and local variables.



Vulnerabilities and Attack Method

- Vulnerability scenarios
  - The program has root privileges (setuid) and is launched from a shell
  - The program is part of a web application

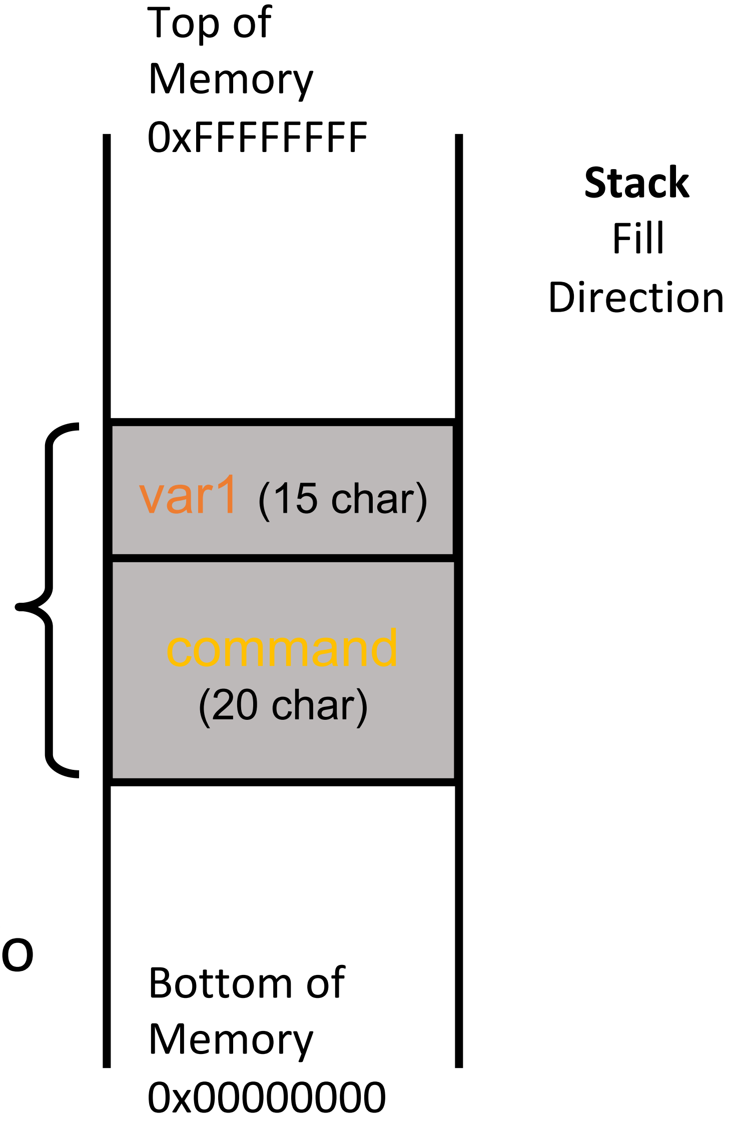
- Typical attack method
  1. Find vulnerability
  2. Reverse engineer the program
  3. Build the exploit

Buffer Overflow Attack in a Nutshell

- First described in
  - Aleph One. Smashing The Stack For Fun And Profit. e-zine www.Phrack.org #49, 1996
- The attacker exploits an unchecked buffer to perform a buffer overflow attack.
- The ultimate goal for the attacker is getting a shell that allows to execute arbitrary commands with high privileges.
- Kinds of buffer overflow attacks:
  - Heap smashing
  - Stack smashing

Buffer Overflow

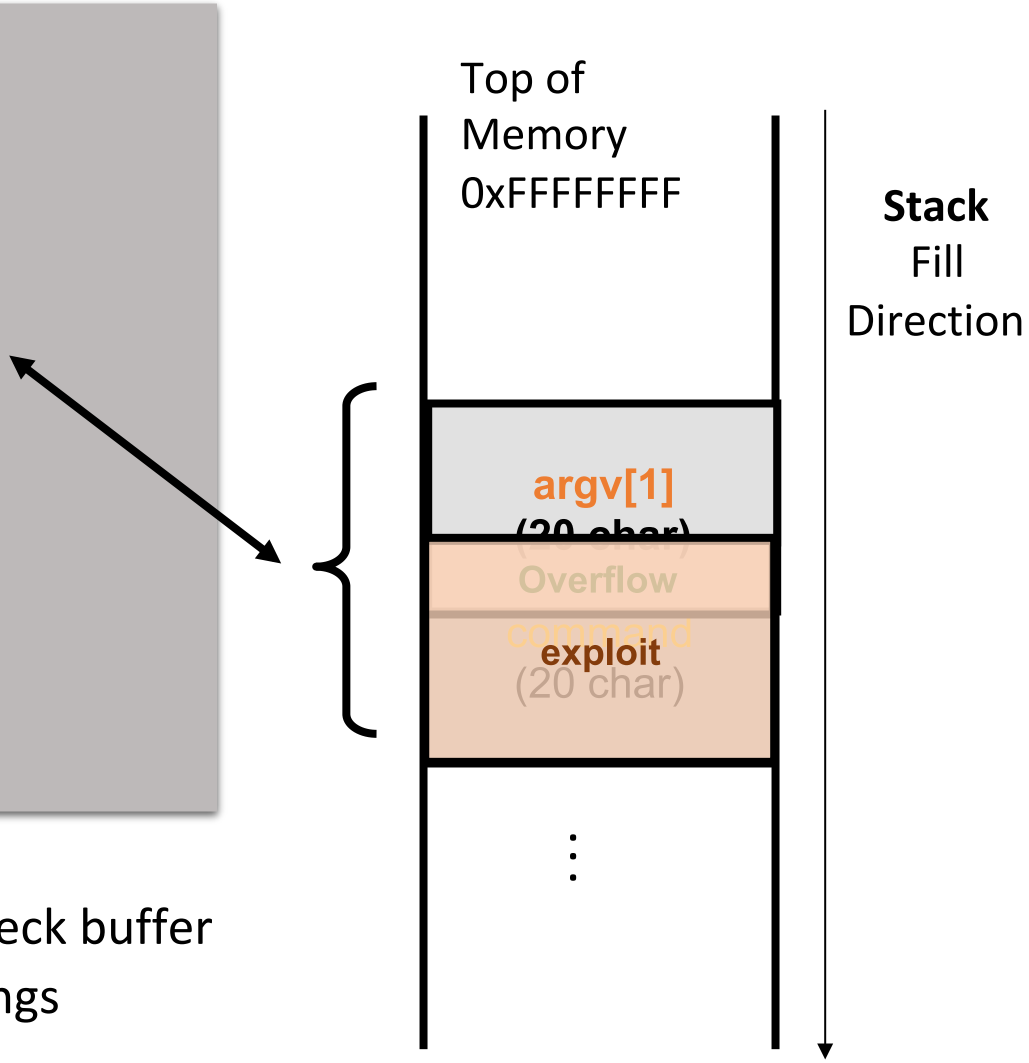
```
domain.c
Main(int argc, char *argv[ ])
/* get user_input */
{
   char var1[15];
   char command[20];
   strcpy(command, “whois ");
   strcat(command, argv[1]);
   strcpy(var1, argv[1]);
   printf(var1);
   system(command);
}
```



- Retrieves domain registration info
- e.g., domain brown.edu

domain.c

```
Main(int argc, char *argv[])
/*get user_input*/
{
   char var1[15];
   char command[20];
   strcpy(command, “whois ");
   strcat(command, argv[1]);
   strcpy(var1, argv[1]);
   printf(var1);
   system(command);
}
```



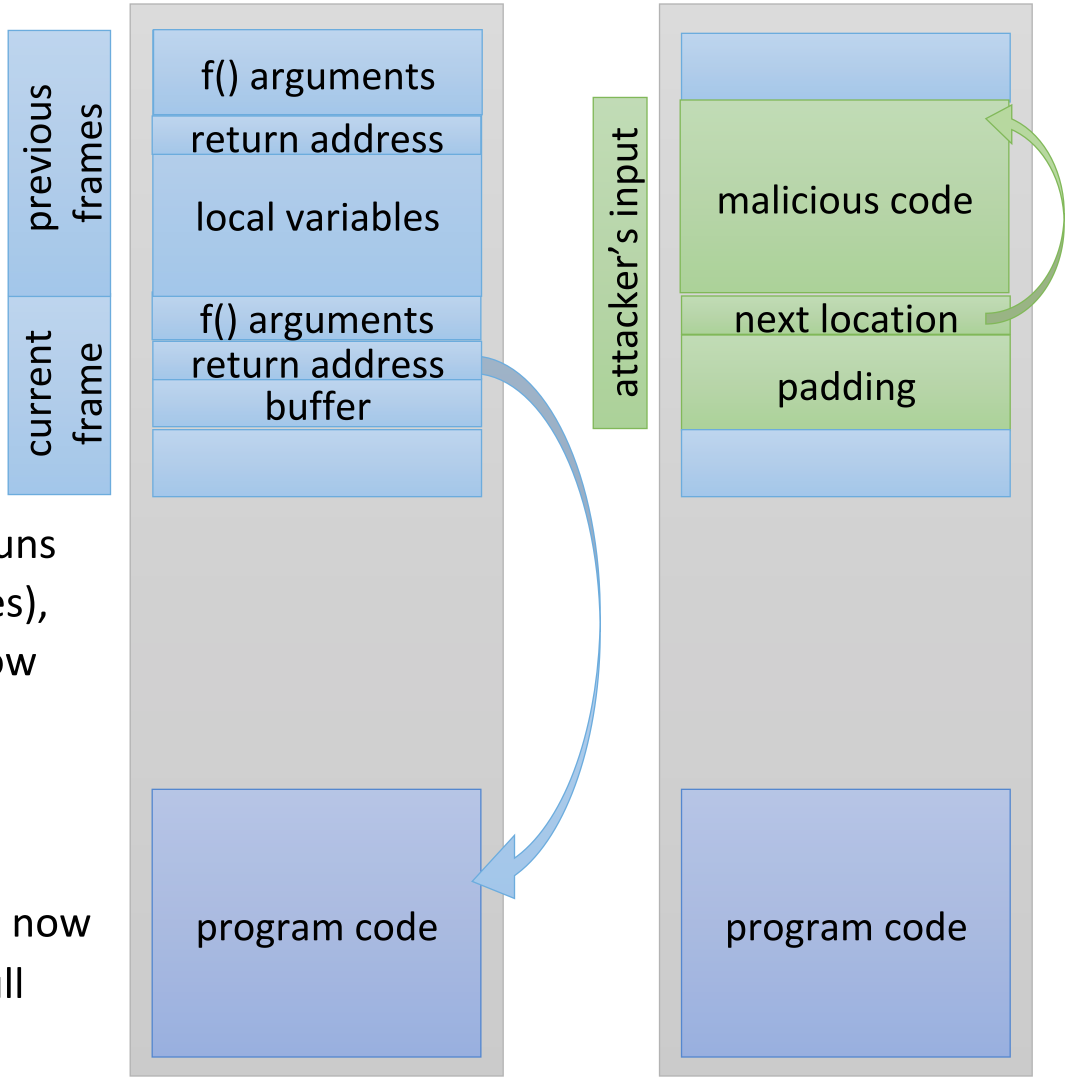
- argv[1] is the user input
- strcpy(dest, src) does not check buffer
- strcat(d, s) concatenates strings

strcpy() vs. strncpy()

- Function strcpy() copies the string in the second argument into the first argument
  - e.g., strcpy(dest, src)
  - If source string > destination string, the overflow characters may occupy the memory space used by other variables
  - The null character is appended at the end automatically
- Function str**n**cpy() copies the string by specifying the number n of characters to copy
  - e.g., strncpy(dest, src, n); dest[n] = ‘\0’
  - If source string is longer than the destination string, the overflow characters are discarded automatically
  - You have to place the null character manually

Return Address Smashing

```
void fingerd (…) {
        char buf[80];
        …
        get(buf);
        …
}
```



- The Unix fingerd() system call, which runs as root (it needs to access sensitive files), used to be vulnerable to buffer overflow
- Write malicious code into buffer and overwrite return address to point to the malicious code
- When return address is reached, it will now execute the malicious code with the full rights and privileges of root

Unix Shell Command Substitution

- The Unix shell enables a command argument to be obtained from the standard output of another.
- This feature is called command substitution.
- When parsing command line, the shell replaces the output of a command between back quotes with the output of the command.
- Example:
  - File name.txt contains string farasi
  - The following two commands are equivalent
  - finger `cat name.txt`
  - finger farasi

Shellcode Injection

- An exploit takes control of attacked computer so injects code to “spawn a shell” or “shellcode”.
- A shellcode is:
  - Code assembled in the CPU’s native instruction set (e.g. x86 , x86-64, arm, sparc, risc, etc.)
  - Injected as a part of the buffer that is overflowed.
- We inject the code directly into the buffer that we send for the attack.
- A buffer containing shellcode is a “payload”.

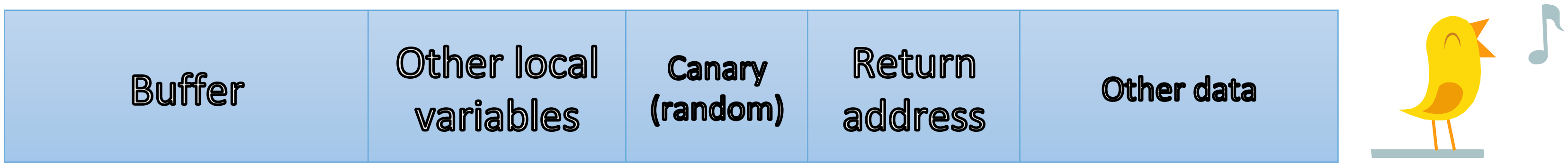
Buffer Overflow Mitigation

- We know how a buffer overflow happens, but why does it happen?
- This problem could not occur in Java; it is a C problem
  - In Java, objects are allocated dynamically on the heap (except ints, etc.)
  - Also cannot do pointer arithmetic in Java
  - In C, however, you can declare things directly on the stack

Buffer Overflow Mitigation (cont.)

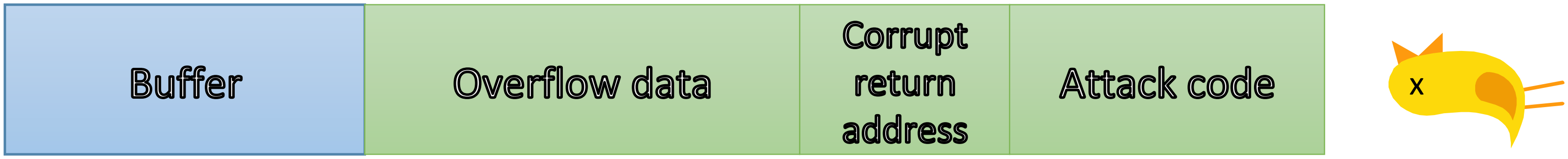
- One solution is to make the buffer dynamically allocated.
- Another (OS) problem is that fingerd had to run as root.
  - Just get rid of fingerd’s need for root access (solution eventually used)
  - The program needed access to a file that had sensitive information in it
  - A new world-readable file was created with the information required by fingerd

Using Random Canary



Buffer	Other local variables	Canary (random)	Return address	Other data

Buffer overflow attack attempt:



Buffer	Overflow data	Corrupt return address	Attack code

- The canary is placed in the stack prior to the return address, so that any attempt to over-write the return address also over-writes the canary.

Acknowledgement

- Part of the content in this document is adopted from the recommended textbook:

Michael Goodrich, Roberto Tamassia, “Introduction to Computer Security”, 1st Edition. Pearson. ISBN-13: 978-0321512949, ISBN-10: 9780321512949