Unit 03

Basic Linux Exploits

List of Contents

- Agenda
- Why Software Vulnerabilities Matter?
- Attacks Exploiting Software Vulnerabilities
- Common Software Vulnerabilities
- Source of Input that need validation
- Input validation issues in Web applications
- What is Buffer Overflow Attack
- Types of Buffer Overflow Attack
- Conclusion

Agenda of session

- Presentation will defines the fundamentals of vulnerabilities of different programming platforms like C,C++,Python, Linux Shell code etc.

- Students will be able to list out different vulnerabilities along with the most common exploit of Buffer Overflow & Overwrite issues.

Why Software Vulnerabilities Matter?

- When a process reads input from attacker, the process may be exploited if it contains vulnerabilities.
- When an attacker successfully exploits a vulnerability, he can
  - Crash programs: Compromises availability
  - Execute arbitrary code: Compromises integrity
  - Obtain sensitive information: Compromises confidentiality

- Software vulnerability enables the attacker to run with privileges of other users, violating desired access control policy

Attacks Exploiting Software Vulnerabilities

- Drive-by download (drive-by installation)
  - malicious web contents exploit vulnerabilities in browsers (or plugins) to download/install malware on victim system.
- Email attachments in PDF, Word, etc.
- Network-facing daemon programs (such as http, ftp, mail servers, etc.) as entry points.
- Privilege escalation
  - Attacker on a system exploits vulnerability in a root process and gains root privilege

Common Software Vulnerabilities

- Input validation
- Race conditions
  - Time-of-check-to-time-of-use (TOCTTOU)
- Buffer overflows
- Format string problems
- Integer overflows

Sources of Input that Need Validation

- What are sources of input for local applications?
  - Command line arguments
  - Environment variables
  - Configuration files, other files
  - Inter-Process Communication call arguments
  - Network packets
- What are sources of input for web applications?
  - Web form input
  - Scripting languages with string input

Command line as a Source of Input: A Simple example

```
void main(int argc, char ** argv) {
   char buf[1024];
   sprintf(buf,”cat %s”,argv[1]);
 system (“buf”);
}
```

What can go wrong?

- Can easily add things to the command by adding ;, using e.g., “a; ls”
- User can set command line arguments to almost anything, e.g., by using execve system call to start a program, the invoker has complete control over all command line arguments.

Environment variables

- Users can set the environment variables to anything
  - Using execve
  - Has some interesting consequences

- Examples:
  - PATH
  - LD_LIBRARY_PATH
  - IFS

Attack by Resetting PATH

- A setuid program has a system call: system(ls);
- The user sets his PATH to be . (current directory) and places a program ls in this directory
- The user can then execute arbitrary code as the setuid program

- Solution: Reset the PATH variable to be a standard form (i.e., “/bin:/usr/bin”)

Attack by Resetting IFS

- However, you must also reset the IFS variable
  - IFS is the characters that the system considers as white space
- If not, the user may add “s” to the IFS
  - system(ls) becomes system(l)
  - Place a function l in the directory

Attack by Resetting LD_LIBRARY_PATH

- Assume you have a setuid program that loads dynamic libraries.
- UNIX searches the environment variable LD_LIBRARY_PATH for libraries.
- A user can set LD_LIBRARY_PATH to /tmp/attack and places his own copy of the libraries here.
- Most modern C runtime libraries have fixed this by not using the LD_LIBRARY_PATH variable when the EUID is not the same as the RUID or the EGID is not the same as the RGID

Input Validation Issues in Web Applications

- SQL injection
- SQL injection is a code injection technique that might destroy your database.
- SQL injection is one of the most common web hacking techniques.
- SQL injection is the placement of malicious code in SQL statements, via web page input.
- Cross Site Scripting
- Cross-site scripting (also known as XSS) is **a web security vulnerability that allows an attacker to compromise the interactions that users have with a vulnerable application**. It allows an attacker to circumvent the same origin policy, which is designed to segregate different websites from each other.

A Remote Example: PHP passthru

- Idea
  - PHP passthru(*string*) executes command
  - Web-pages can construct *string* from user input and execute the commands to generate web content
  - Attackers can put “;” in input to run desired commands
- Example

```
echo 'Your usage log:<br />';
  $username = $_GET['username'];
  passthru(“cat /logs/usage/$username”);
```

- What if: “username=andrew;cat%20/etc/passwd”?

Directory Traversal Vulnerabilities in Web Applications

- A typical example of vulnerable application in php code is:

```
<?php
    $template = 'red.php';
    if ( isset( $_COOKIE['TEMPLATE'] ) )
    $template = $_COOKIE['TEMPLATE'];              include
    ( "/home/users/phpguru/templates/" . $template );
?>
```

- Attacker sends

```
GET /vulnerable.php HTTP/1.0
Cookie: TEMPLATE=../../../../../../../../../etc/passwd
```

Checking input can be tricky: Unicode vulnerabilities

- Some web servers check string input
  - Disallow sequences such as ../ or \
  - But may not check unicode %c0%af for '/'
- IIS Example, used by Nimda worm

http://victim.com/scripts/../../winnt/system32/cmd.exe?<some command>

  - passes <some command> to cmd command
  - scripts directory of IIS has execute permissions
- Input checking would prevent that, but not this

http://victim.com/scripts/..%c0%af..%c0%afwinnt/system32/...

  - IIS first checks input, then expands unicode

Time-of-check-to-time-of-use

- **TOCTTOU**, pronounced "*TOCK too*“
- A class of software bug caused by changes in a system between the checking of a condition (such as authorization) and use of the results of the check.
- Time-of-check-to-time-of-use (TOCTTOU - pronounced TOCK-too) is a file-based race condition that occurs when a resource is checked for a particular value, such as whether a file exists or not, and that value then changes before the resource is used, invalidating the results of the check.
  - When a process P requests to access resource X, the system checks whether P has right to access X; the usage of X happens later
  - When the usage occurs, perhaps P should not have access to X anymore.
  - The change may be because P changes or X changes.

An Example TOCTTOU

- In Unix, the following C code, when used in a setuid program, is a TOCTTOU bug:

```
if (access("file", W_OK) != 0)
{ exit(1); }

fd = open("file", O_WRONLY);
write(fd, buffer, sizeof(buffer));
```

Attacker tries to execute the following line in another process when this process reaches exactly this time:
Symlink("/etc/passwd", "file")

- Here, *access* is intended to check whether the real user who executed the setuid program would normally be allowed to write the file (i.e., *access* checks the real userid rather than effective userid).

TOCTTOU

- Exploiting a TOCTTOU vulnerabilities requires precise timing of the victim process.
- Most general attack may require “single-stepping” the victim, i.e., can schedule the attacker process after each operation in the victim
  - Techniques exist to “single-step” victim
- Preventing TOCTTOU attacks is difficult

What is Buffer Overflow?

- A **buffer overflow**, or **buffer overrun**, is an anomalous condition where a process attempts to store data beyond the boundaries of a fixed-length buffer.
- The result is that the extra data overwrites adjacent memory locations. The overwritten data may include other buffers, variables and program flow data, and may result in erratic program behavior, a memory access exception, program termination (a crash), incorrect results or — especially if deliberately caused by a malicious user — a possible breach of system security.
- Most common with C/C++ programs

History

- Used in 1988’s Morris Internet Worm

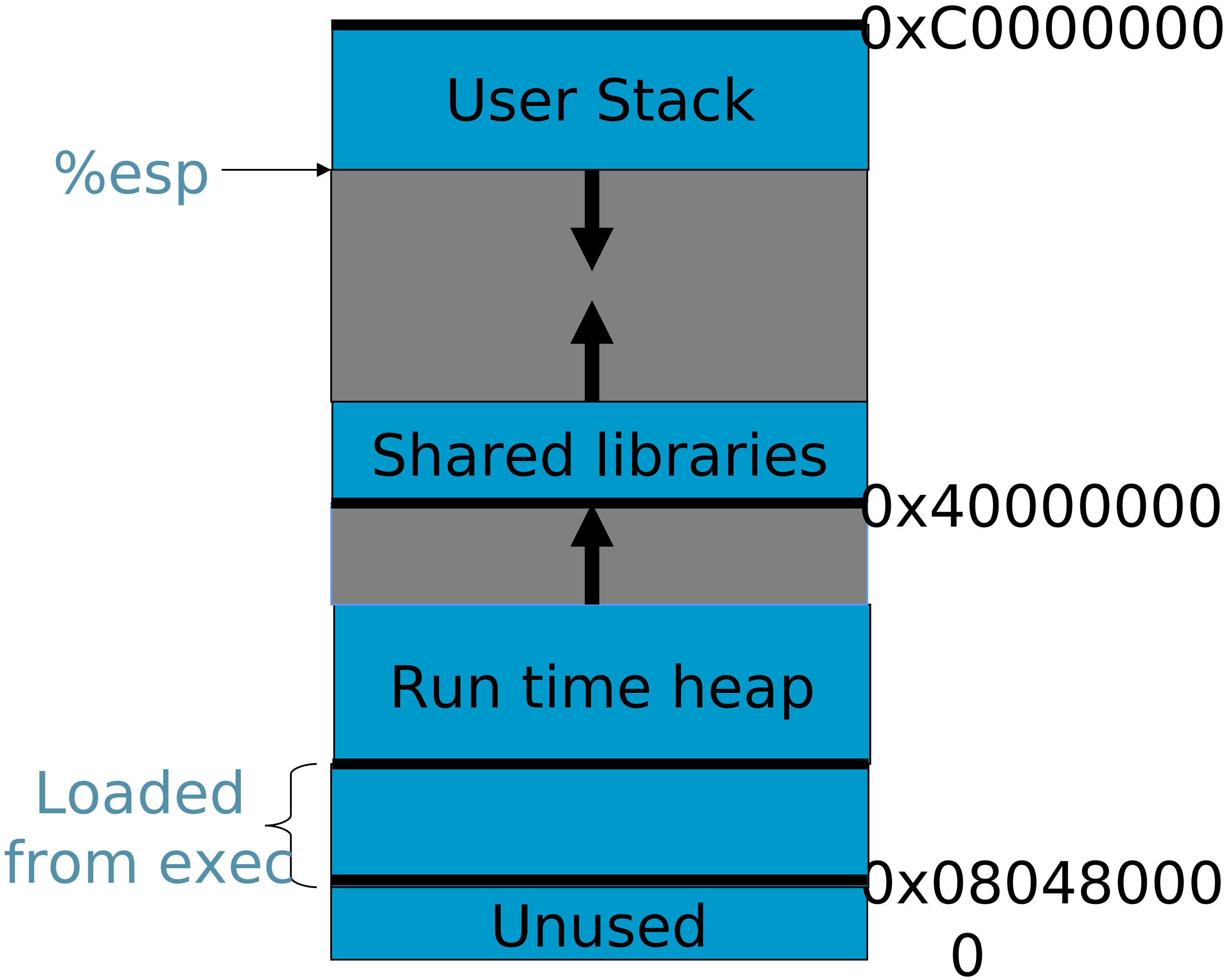
- Alphe One’s “Smashing The Stack For Fun And Profit” in Phrack Issue 49 in 1996 popularizes stack buffer overflows

- Still extremely common today

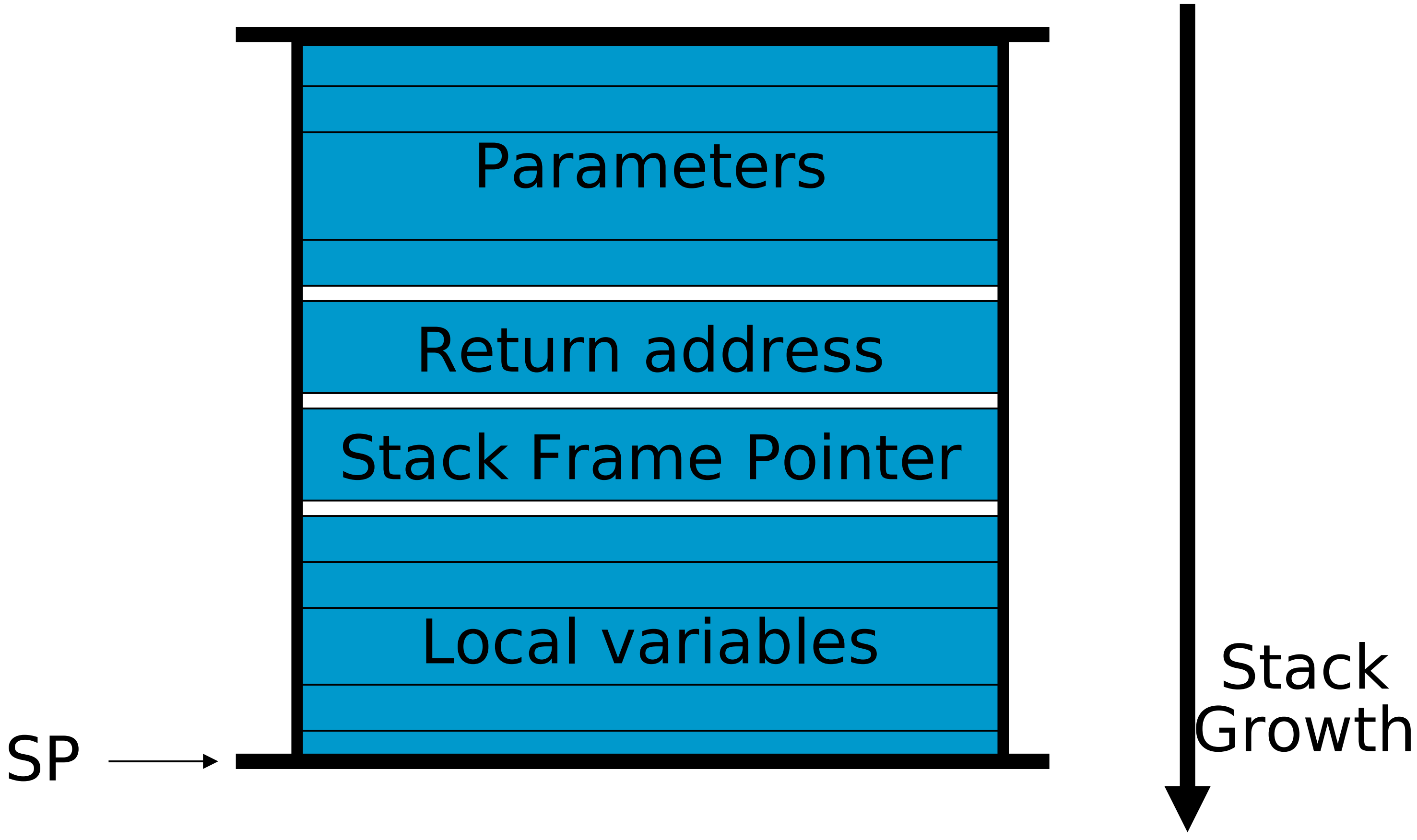
Types of Buffer Overflow Attacks

- Stack overflow
  - Shell code
  - Return-to-libc
    - Overflow sets ret-addr to address of libc function
  - Off-by-one
  - Overflow function pointers & longjmp buffers
- Heap overflow

Linux process memory layout



Stack Frame


Parameters
Return address
Stack Frame Pointer
Local variables
SP
Stack
Growth

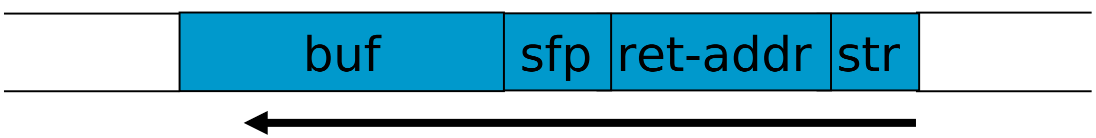
What are buffer overflows?

- Suppose a web server contains a function:

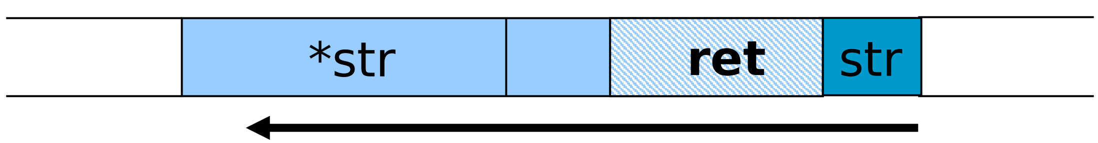
```
void func(char *str) {
   char buf[128];

strcpy(buf, str);
   do-something(buf);
}
```

- When the function is invoked the stack looks like:

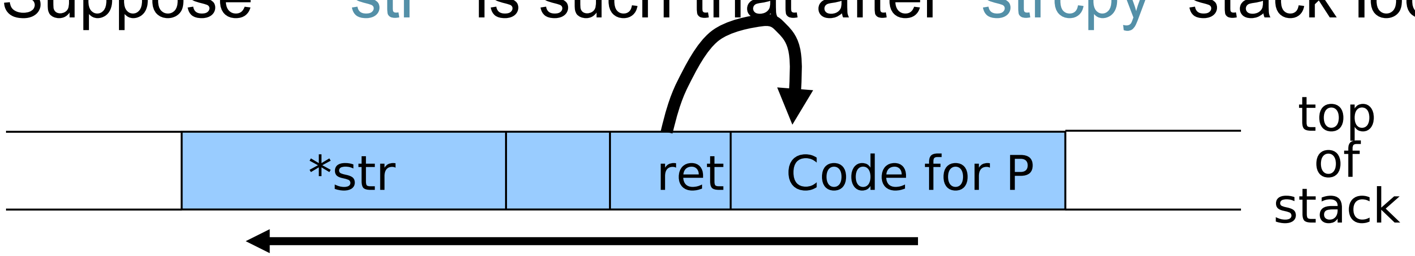


- What if `*str` is 136 bytes long? After `strcpy`:



Basic stack exploit

- Main problem: no range checking in strcpy().
- Suppose *str is such that after strcpy stack looks like:



Program P: `exec( "/bin/sh" )`

(exact shell code by Aleph One)

- When func() exits, the user will be given a shell !!
- Note: attack code runs *in stack*.

Carrying out this attack requires

- Determine the location of injected code position on stack when func() is called.
  - Location of injected code is fixed relative to the location of the stack frame
- Program P should not contain the '\0' character.
  - Easy to achieve
- Overflow should not crash program before func() exits.

Some unsafe C lib functions

strcpy (char *dest, const char *src)

strcat (char *dest, const char *src)

gets (char *s)

scanf (const char *format, …)

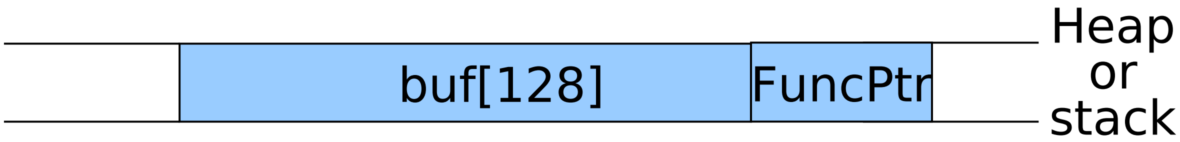
sprintf (conts char *format, …)

⋮

Other control hijacking opportunities

- In addition to overwrite return address on the stack, can also use overflow to overwrite the following:

- Function pointers: (used in attack on PHP 4.0.2)



  – Overflowing buf will override function pointer.

- Longjmp buffers: longjmp(pos) (used in attack on Perl 5.003)
  – Overflowing buf next to pos overrides value of pos.

Return-oriented programming

- Goal: executing arbitrary code without injecting any code.
- Observations:
  - Almost all instructions already exist in the process's address space, but need to piece them together to do what the attacker wants
- Attack:
  - Find instructions that are just before "return"
  - Set up the stack to include a sequence of addresses so that executing one instruction is followed by returning to the next one in the sequence.
- Effectiveness: has been shown that arbitrary program can be created this way

Heap Overflow

- Heap overflow is a general term that refers to overflow in data sections other than the stack
  - buffers that are dynamically allocated, e.g., by malloc
  - statically initialized variables (data section)
  - uninitialized buffers (bss section)

- Heap overflow may overwrite other data allocated on heap
- By exploiting the behavior of memory management routines, may overwrite an arbitrary memory location with a small amount of data.

Finding buffer overflows

- Hackers find buffer overflows as follows:
  - Run web server on local machine.
  - **Fuzzing:** Issue requests with long tags.
    All long tags end with "$$$$$".
  - If web server crashes,
    search core dump for "$$$$$" to find
    overflow location.
- Some automated tools exist.
- Then use disassemblers and debuggers (e..g IDA-Pro) to construct exploit.
- How to defend against buffer overflow attacks?

Preventing Buffer Overflow Attacks

- Use type safe languages (Java, ML).
- Use safe library functions
- Static source code analysis.
- Non-executable stack
- Run time checking: StackGuard, Libsafe, SafeC, (Purify), and so on.
- Address space layout randomization.

- Detection deviation of program behavior
- Access control to control aftermath of attacks…

Static source code analysis

- Statically check source code to detect buffer overflows.
  - Several consulting companies.

- Main idea: automate the code review process.

- Several tools exist:
  - Example: Coverity (Engler et al.): Test trust inconsistency.

- Find lots of bugs, but not all.

Bugs to Detect in Source Code Analysis

- Some examples

- Crash Causing Defects
- Null pointer dereference
- Use after free
- Double free
- Array indexing errors
- Mismatched array new/delete
- Potential stack overrun
- Potential heap overrun
- Return pointers to local variables
- Logically inconsistent code
- Uninitialized variables
- Invalid use of negative values
- Passing large parameters by value
- Underallocations of dynamic data
- Memory leaks
- File handle leaks
- Network resource leaks
- Unused values
- Unhandled return codes
- Use of invalid iterators

Format string problem

```
int  func(char *user)  {
    fprintf( stdout, user);
}
```

Problem: what if   user = “%s%s%s%s%s%s%s” ??

- Most likely program will crash: DoS.
- If not, program will print memory contents. Privacy?
- Full exploit using   user = “%n”

Correct form:

```
int  func(char *user)  {
    fprintf( stdout, “%s”, user);
}
```

Format string attacks (“%n”)

- printf(“%n”, &x) will change the value of the variable x
  - in other words, the parameter value on the stack is interpreted as a pointer to an integer value, and the place pointed by the pointer is overwritten

Vulnerable functions

Any function using a format string.

Printing:

- printf, fprintf, sprintf, …
- vprintf, vfprintf, vsprintf, …

Logging:

- syslog, err, warn

Conclusion

- Presentation describes various types of vulnerabilities of memory management and operating system which can be exploit by any attacker to take the advantages by misusing it .

- Session describes that How we can protect our system from Buffer overflow attacks and its various types.

Integer Overflow

- Integer overflow: an arithmetic operation attempts to create a numeric value that is larger than can be represented within the available storage space.
- Example:

Test 1:

```
short x = 30000;
short y = 30000;
printf("%d\n", x+y);
```

Test 2:

```
short x = 30000;
short y = 30000;
short z = x + y;
printf("%d\n", z);
```

Will two programs output the same?
What will they output?

Off by one buffer overflow

- Sample code

```
func  f(char *input) {
  char buf[LEN];
  if (strlen(input) <= LEN) {
     strcpy(buf, input)
  }
}
```

What could go wrong here?