Final Project CTF Challenge

CSE 5272 Cyber Threats
Group Members: Garrett Gmeiner, Maria Linkins-Nielson, Logan Klaproth

Background: The CIA Triad in Cybersecurity

In the realm of cybersecurity, the CIA triad represents three fundamental principles that guide secure system design: **Confidentiality**, **Integrity**, and **Availability**.

- **Confidentiality** ensures that sensitive data is accessible only to authorized individuals. Protecting passwords, encryption keys, and system memory from unauthorized access is critical to confidentiality.
- **Integrity** guarantees that data is accurate and unaltered. Mechanisms that detect tampering or corruption help uphold integrity.
- **Availability** ensures systems and data remain accessible and usable when needed, even under attack or error conditions.

In this project, we integrate these principles while securing a vulnerable C source file (`vuln.c`) that was susceptible to buffer overflow attacks.

Source Code (vuln.c)

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <fcntl.h>
#include <unistd.h>

void vuln() {
    int password_size = 0xa;
    char buf1[8];
    char secret[8]="12345678";
    char buf2[8];
    printf("User >>> ");
    fflush(stdout);
    read(0, buf1, password_size);
    printf("Password >>> ");
    fflush(stdout);
```

```
    read(0, buf2, password_size);
    if (strncmp(secret, "CSE5272!",8) == 0) {
        printf("\nYou have won!\n");
    } else {
        printf("\n<<< Incorrect password: %s\n",&secret);
    }
}

int main (int argc, char *argv[]) {
    vuln();
}
```

How to compile

```
$ gcc vuln.c -o vuln
```

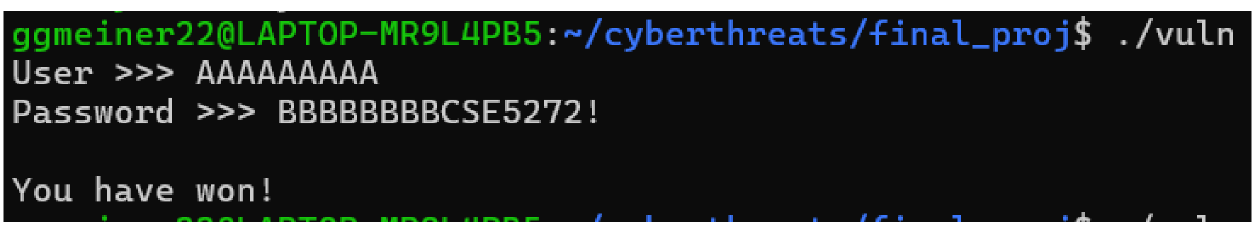
or if the OS doesn't allow:

```
$ gcc -std=gnu89 -fno-stack-protector -z execstack vuln.c -o vuln
```

Run the object file

```
./vuln
```

Solution



Must have a username of 9 bytes
Password must use 8 bytes to fill buf2 and the remaining 8 slip into the variable secret

How it fails

```
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./vuln
User >>> hello
Password >>> CSE5272!

<<< Incorrect password:
2345678hello

ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$
```

```
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./vuln
User >>> AAAAAAAA
Password >>> BBBBBBBBCSE5272!

<<< Incorrect password: CS345678AAAAAAAA
```

Username less than or equal to 8 bytes

```
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./vuln
User >>> AAAAAAAAAA
Password >>>
<<< Incorrect password: 12345678AAAAAAAAAA
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$
```

Username of more than 10 bytes

Securing the Source Code

In this project, we will discuss three (3) ways to secure the vulnerability in vuln.c. Below are three methods to secure the code against buffer overflow attacks. Each method involves a different approach to ensuring that no more data is written than the buffers can hold.

1. Input Length Validation

CIA Principle: Confidentiality & Availability
Before processing the input, it should check that the number of bytes read does not exceed the buffer size. If it does, it should reject the input or handle it appropriately.

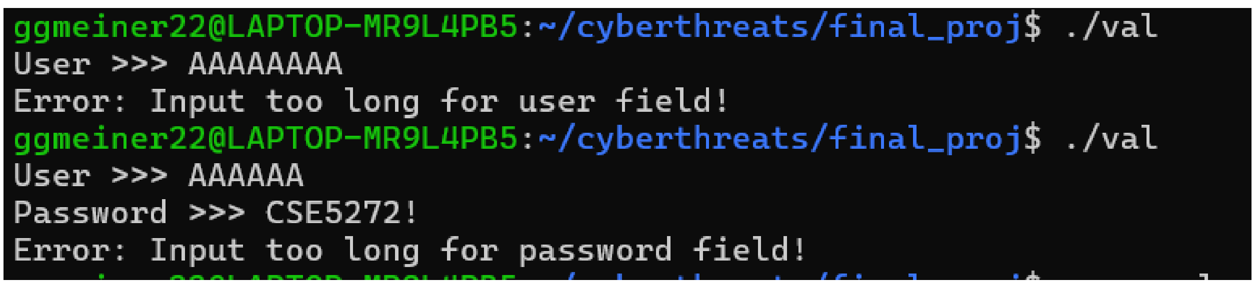
Source Code

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>

void vuln() {
    char tmp[100];   // Temporary buffer to hold input
    char buf1[8];
    char secret[8] = "12345678";
    char buf2[8];
    ssize_t bytes_read;

    printf("User >>> ");
    fflush(stdout);
    bytes_read = read(0, tmp, sizeof(tmp));
    if (bytes_read < 0) {
        perror("read error");
        exit(EXIT_FAILURE);
    }
    tmp[bytes_read] = '\0';
    if (bytes_read >= sizeof(buf1)) {
        fprintf(stderr, "Error: Input too long for user field!\n");
        exit(EXIT_FAILURE);
    }
    strcpy(buf1, tmp);

    printf("Password >>> ");
    fflush(stdout);
    bytes_read = read(0, tmp, sizeof(tmp));
    if (bytes_read < 0) {
        perror("read error");
        exit(EXIT_FAILURE);
    }
    tmp[bytes_read] = '\0';
    if (bytes_read >= sizeof(buf2)) {
        fprintf(stderr, "Error: Input too long for password field!\n");
        exit(EXIT_FAILURE);
    }
    strcpy(buf2, tmp);

    if (strncmp(secret, "CSE5272!", 8) == 0) {
```

```
        printf("\nYou have won!\n");
    } else {
        printf("\n<<< Incorrect password: %s\n", secret);
    }
}

int main(void) {
    vuln();
    return 0;
}
```

Solution

Due to the input length validation, buffer overflows no longer pose a threat. This is because the bytes read are checked after each input stream. This prevents overflows, protects sensitive memory, and keeps the program running safely.



2. Stack Canary

CIA Principle: Integrity
Stack canaries are predetermined values placed between local variables and the return address on the stack. If a buffer overflow changes the canary, the program detects the change and aborts execution to prevent exploitation. Modern compilers can automatically insert these protections using flags like -fstack-protector.

Source Code

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>

#define CANARY 0xDEADBEEF
```

```c
void vuln() {
    int password_size = 0xa;
    char buf1[8];
    char secret[8] = "12345678";
    char buf2[8];
    unsigned int canary = CANARY;

    printf("User >>> ");
    fflush(stdout);
    read(0, buf1, password_size);
    printf("Password >>> ");
    fflush(stdout);
    read(0, buf2, password_size);

    if (canary != CANARY) {
        fprintf(stderr, "Stack corruption detected!\n");
        exit(EXIT_FAILURE);
    }

    if (strncmp(secret, "CSE5272!", 8) == 0) {
        printf("\nYou have won!\n");
    } else {
        printf("\n<<< Incorrect password: %s\n", secret);
    }
}

int main(void) {
    vuln();
    return 0;
}
```

Solution

Due to the stack canary, the program is no longer vulnerable to buffer overflow attacks. The canary protects against memory corruption, preserving the correctness and trustworthiness of program data.

```
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./canary
User >>> AAAAAAAAA
Password >>> BBBBBBBBCSE5272!
Stack corruption detected!
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ E5272!
E5272!: command not found
```

3. Input Size Limiting and Null-Termination

CIA Principle: Confidentiality & Integrity
fgets() reads a specified number of characters from the input stream and automatically appends a null terminator. This prevents overflow by ensuring that no more data than the buffer can hold is read.

Source Code

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

void vuln() {
    char buf1[8];
    char secret[8] = "12345678";
    char buf2[8];

    printf("User >>> ");
    fflush(stdout);
    if (fgets(buf1, sizeof(buf1), stdin) == NULL) {
        perror("fgets error");
        exit(EXIT_FAILURE);
    }
    buf1[strcspn(buf1, "\n")] = '\0';

    printf("Password >>> ");
    fflush(stdout);
    if (fgets(buf2, sizeof(buf2), stdin) == NULL) {
        perror("fgets error");
        exit(EXIT_FAILURE);
    }
    buf2[strcspn(buf2, "\n")] = '\0';

    if (strncmp(secret, "CSE5272!", 8) == 0) {
        printf("\nYou have won!\n");
    } else {
        printf("\n<<< Incorrect password: %s\n", secret);
    }
}

int main(void) {
    vuln();
```

```
    return 0;
}
```

Solution

Due to fgets(), the input length is bounded. This ensures that buffer overflow attacks will not get through. Further, it prevents hackers from injecting extra data, and ensures consistent data formatting.

```
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./fgets
User >>> AAAAAAAAA
Password >>>
<<< Incorrect password: 12345678AA
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./fgets
User >>> AAAAAAAA
Password >>>
<<< Incorrect password: 12345678A
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./fgets
User >>> AAAAAAA
Password >>>
<<< Incorrect password: 12345678
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$ ./fgets
User >>> AAAAAA
Password >>> CSE5272!

<<< Incorrect password: 12345678CSE5272
ggmeiner22@LAPTOP-MR9L4PB5:~/cyberthreats/final_proj$
```

Summary

- **Confidentiality**: Secure input handling avoids unintended memory reads.
- **Integrity**: Stack canaries detect tampering of sensitive variables.
- **Availability**: Safe input bounds and fail-safes keep the program stable.

These changes not only eliminate the buffer overflow vulnerability but demonstrate how core cybersecurity principles can be enforced through secure coding practices.