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MEMORY SAFETY DEFENSES

Key techniques against memory safety attacks

1. Use memory-safe languages - checks on buffer bounds are automated by the compiler
2. Apply safe programming practices - when using non-memory safe languages check all the bounds, and validate user input
3. Code hardening - OS and compiler based techniques to defend against BOs
   - 3.1 Stack canaries
   - 3.2 Data Execution Protection (DEP) / Write XOR Execute (W^X)
   - 3.3 Address Space Layout Randomisation (ASLR)

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Memory-safe languages

- Memory-safe languages are not subject to memory safety vulnerabilities:
  - Access to memory is well-defined
  - Checks on array bounds and poiner dereferences are automatically included by the compiler
  - Garbage collection takes away from the programmer the error-prone task of managing memory
- Plenty of memory-safe languages: Java, Python, Rust, Go, *etc.*
- Whenever possible in new projects use a memory-safe programming language!

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Safe programming practices

- Use safe C libraries - Size-bounded analogues of unsafe libc functions

```
size_t strlcpy(char *destination, const char *source, size_t size);
size_t strlcat(char *destination, const char *source, size_t
size);
char *fgets(char *str, int n, FILE *stream);
...
```

- Check bounds and validate user input

```
#include <stdio.h>
int main(int argc, char *argv[]){
  // Create a buffer on the stack
  char buf[256];
  // Only copy as much of the argument as can fit in the buffer
  strlcpy(buf, argv[1], sizeof(buf));
  // Print the contents of the buffer
 printf(''%s\n'', buf);
 return 1;
 }
```

- instead of strcpy(buf, argv[1])

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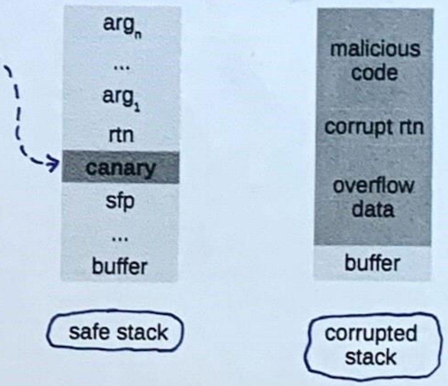
1. Stack canaries

- Goal: detect a stack buffer overflow before execution of malicious code
- Idea: place trap (the canary) just before the stack return pointer
- The value of the canary needs to be a randomly chosen fresh value for each execution of the program
- To overwrite the return pointer the canary value must also be overwritten
- The canary is checked to make sure it has not changed before returning

  ↳ If it has changed, the OS detects buffer overflow



Limitations of stack canaries

Stack canaries will detect a BO if

1) The attacker does not learn the value of the canary - this could happen through a buffer overread
2) The attacker cannot jump over the canary - the assumption is that the attacker has to write consecutively memory from buffer to return address
3) The attacker cannot guess the canary value - on 32-bits the attacker might be able to brute force the canary value
4) The buffer overrun occurs on the stack - canaries will not detect heap overruns

→ 1 byte is the null character, so we now only have 24 bits randomness [2^{24}]

Take way

Stack canaries make attacks harder but not impossible!

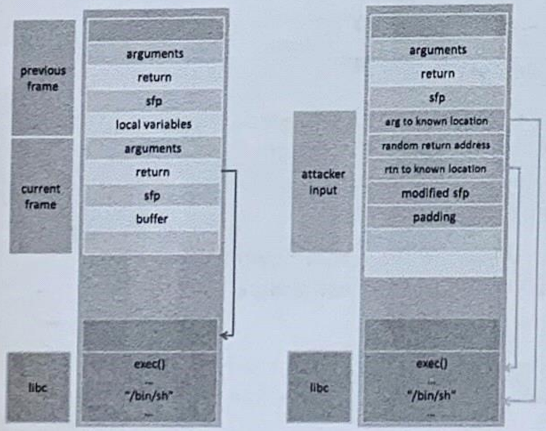
2. Data Execution Protection (DEP) Write XOR Execute (W^X)

- Goal: prevent malicious code from being executed.
- Idea: Make regions in memory either executable or writable (but not both)
- The stack and heap will be writable but not executable because they only store data
- The text segment will only be executable and not writable because it only stores code

:-) Even if the attacker manages to put his malicious code on stack or heap, it will never get executed :-)

Limitation of W^X: `return-to-libc` attacks

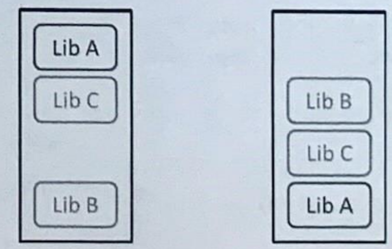
- the attacker does not need to inject any code
- the `libc` library is linked to most C programs
- `libc` provides useful calls for an attacker



Attacker overflows buffer and overwrites return addr. w/ the addr. in the txt. segment where exec() is loaded

3. Address Space Layout Randomization (ASLR)

- Goal: prevent that attacker from predicting where things are in memory
- Idea: place standard libraries to random locations in memory
  - ⟶ for each process, `exec()` is situated at a different location
  - ⟶ the attacker cannot directly point to `exec()`
- Supported by most operating systems (Linux, Windows, MAC OS, Android, iOS, ...)


Lib A
Lib C
Lib B
Lib B
Lib C
Lib A