Software Fault Isolation using the CompCert compiler

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Flash vulnerable plugin

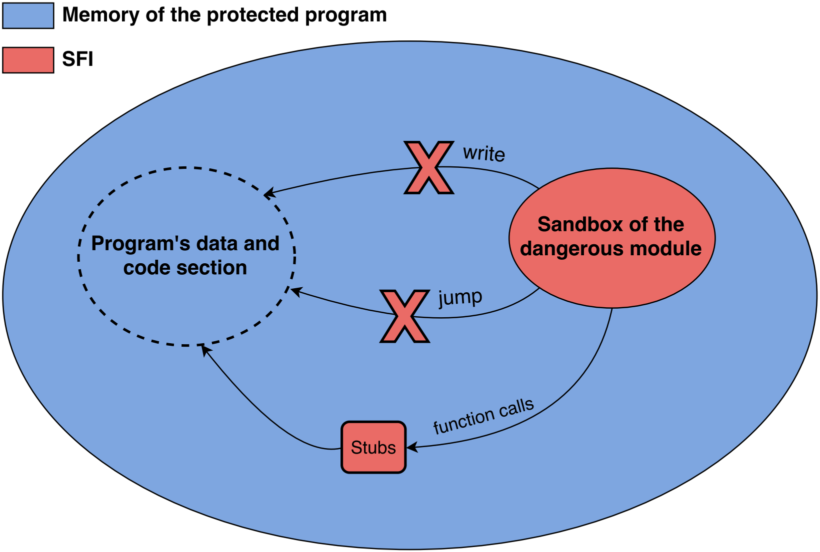
Do you know this logo?

Flash is famous for its multiple vulnerabilities
$\rightarrow$ consequences on Flash
$\rightarrow$ but ALSO endangers your browser

Goals of Software Fault Isolation (SFI)

- SFI aims to allow a protected program to execute dangerous modules in its own memory space without dangers.
- SFI confines the execution of the dangerous modules in a reserved area called sandbox
- `jump` and `write` instructions are protected by runtime checks
- function calls to the protected programs are controlled by SFI

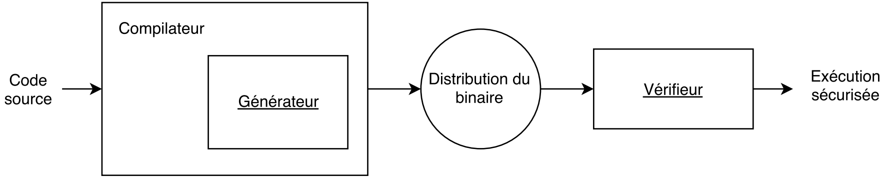
Goals of SFI


Memory of the protected program
SFI
write
jump
Program's data and code section
Sandbox of the dangerous module
function calls
Stubs

Overview of SFI

SFI chain is composed of two elements:

- the **generator** transforms the assembly code of the dangerous modules in order to confine the modules in their sandbox
- the **verifier** checks that the SFI transformations are present and valid before loading the code in memory



Problematics of SFI

We want to prevent attackers from using vulnerable modules to compromise our system

- SFI gives us a way to face such issue
- However SFI is currently lacking against Returned Oriented Programing attacks
- ROP attacks focus function return addresses to execute malicious code they injected

ROP attack example (1/2)

```
void reset_password() {
   ... reset password ...
}

void foo(char* input){
   char buf[1];
   ... code ...
   strcpy(buf, input);      //Vulnerability
   ... code ...
}
```

ROP attack example (2/2)

schema

Modern ROP attacks

- ROP attacks are a common kind of attack in the industry
- Modern ROP attacks are much more complicated
- *Return-to-libc* attacks uses code from the *glibc* library to construct malicious code and uses return addresses to execute it

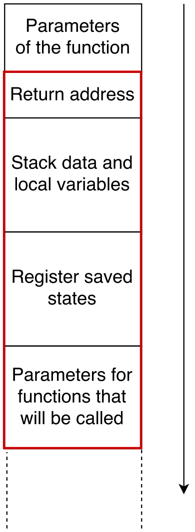
Goals of our approach

We want to have a way to protect return addresses at runtime.

- Modifications of the memory layout in order to have an easy way to know return addresses location
- Code transformations which add runtime checks on the dangerous instruction in order to forbid any illegal `write` on the return addresses locations

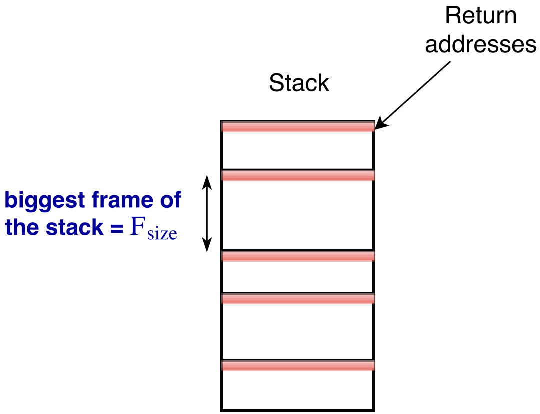
Stack structure

- Programs memory is separated into multiple area like the heap, the stack or the code section
- Return addresses are solely located in the stack
- The stack is composed of piled up frames each related to a function being executed
- Frames store data of their respective function



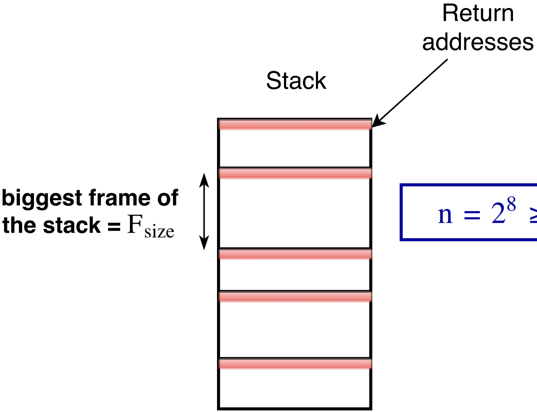
Stack transformations (1/6)

Find the biggest frames size



Stack transformations (2/6)

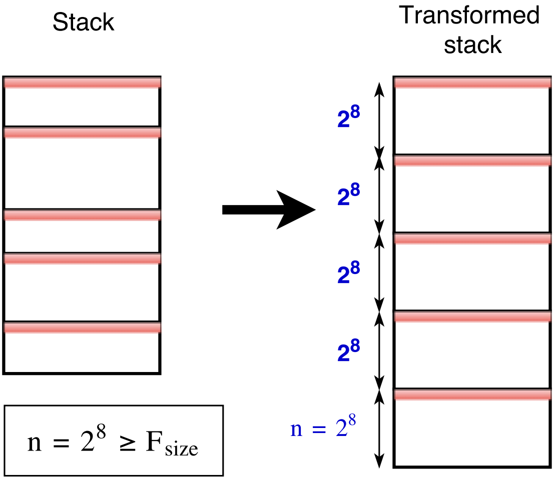
Calculate the new frames size



$$n = 2^8 \geq F_{size}$$

Stack transformations (3/6)

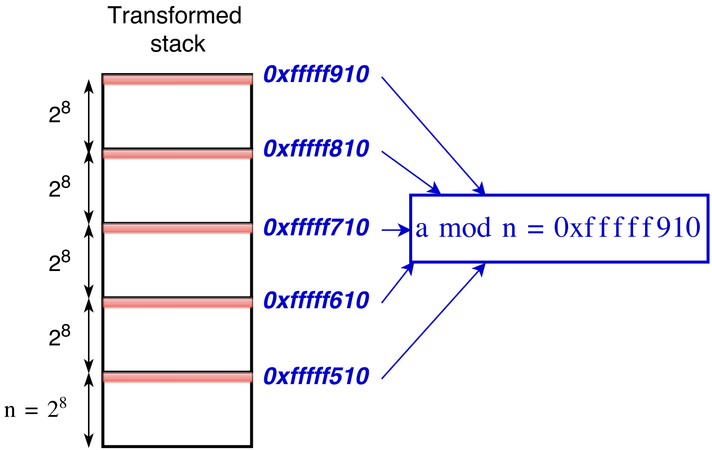
Fix the size of the frames



$$n = 2^8 \geq F_{size}$$

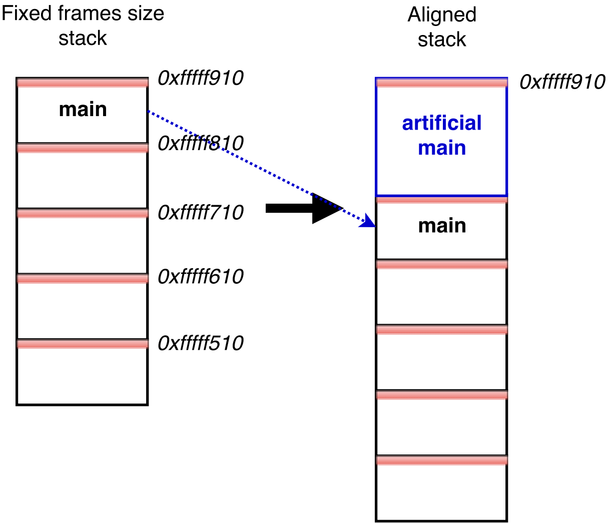
Stack transformations (4/6)

Return addresses locations



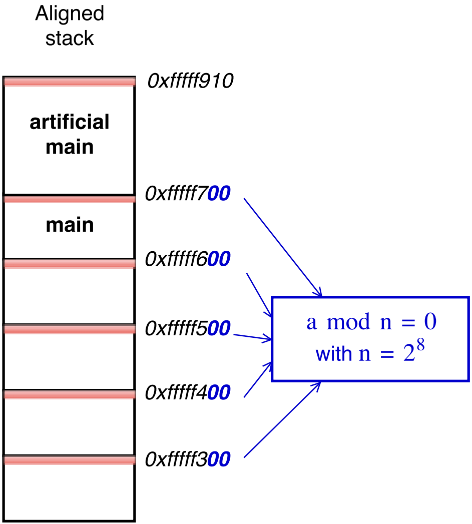
Stack transformations (5/6)

Insertion of a new artificial main



Stack transformations (6/6)

Return addresses locations



Code transformation

We now know where the return addresses are located Prevent them from being overwritten by modifying the code

Injection of runtime checks

1. Check if the address is part of the stack
2. Check if the address verifies $a \ mod \ n = 0$

```
if (targeted_address > 0xff000000) {
  temp_var = targeted_address & (n-1);
  if (temp_var < 3) {
    Error behaviour
  }
}
*targeted_address = value;
Continue execution...
```

Branchless runtime checks

In certain cases branchless code shows much better performance

```
if (targeted_address > 0xff000000) {
    temp_var = targeted_address & (n-1);
    temp_var = temp_var - 3;
    temp_var = temp_var >> 31;
    temp_var = ~temp_var;
    targeted_address = temp_var &
        targeted_address;
}
*targeted_address = value;
Continue execution...
```

Implementation environment

CompCert montrer les languages concerns par les transfos

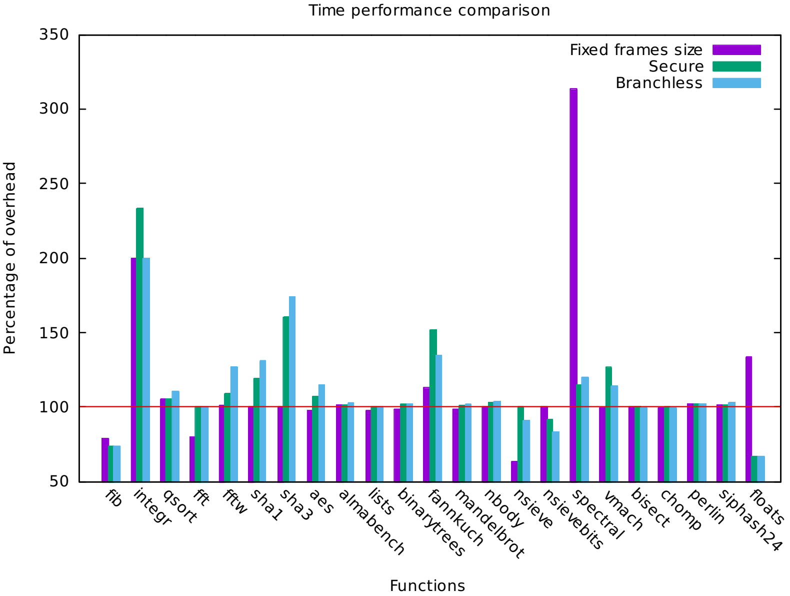
Conditions of our approach

- No modifications of the stack (inline assembly)

```
int foo(int a) {
  asm(``\$sub 50, \%esp'');
   printf("Hello world!");
}
```

- Need to recompile extern libraries with the same frames size

Evaluation of performance (1/2)



Conclusion

Prospectives

- Test our implementation against more complicated ROP attacks
- Reduce the number of runtime checks with static analysis
- Improve the performance of the runtime checks with a super-optimizer
- See the impact of our approach on memory consumption