Software Fault Isolation using the CompCert compiler

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Flash vulnerable plugin

Do you know this logo?

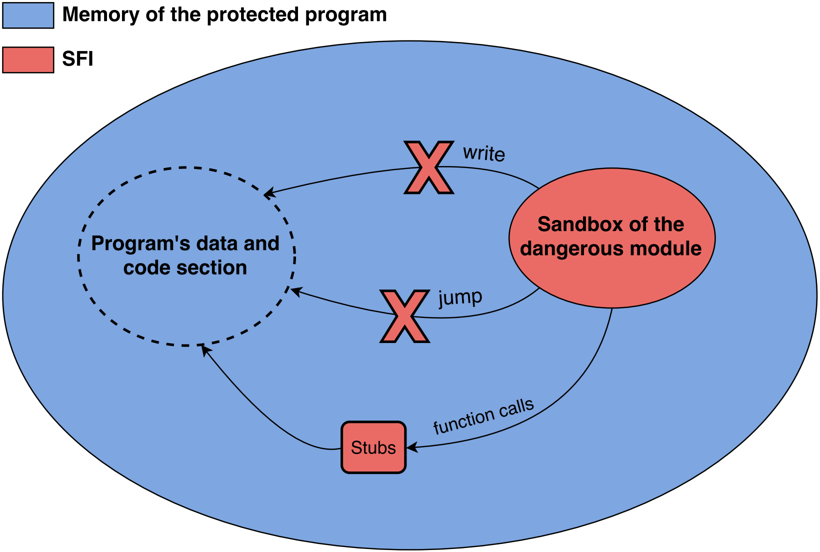
Flash is famous for its multiple vulnerabilities
$\rightarrow$ consequences on Flash
$\rightarrow$ but ALSO endangers your browser

Goals of Software Fault Isolation (SFI) [4]

- 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 memory space called sandbox

Goals of SFI

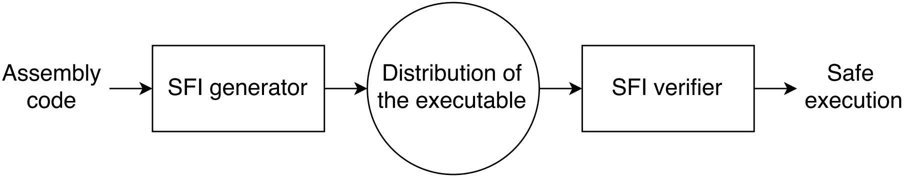


Memory of the protected program
SFI
write
Program's data and code section
Sandbox of the dangerous module
jump
function calls
Stubs

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)
- ROP attacks focus function return addresses to execute malicious code they injected

Contributions

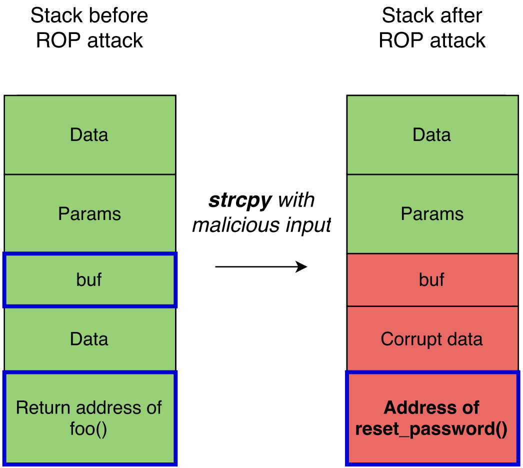
- An approach inspired from SFI protecting return addresses against ROP attacks
- An implementation of our approach with the compiler CompCert for the x86-32 architecture

ROP attack example (1/2)

```
void reset_password() {
  ... reset password ...        //Sensitive code
}

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

ROP attack example (2/2)



Modern ROP attacks

- ROP attacks are a common kind of attack in the industry
- Modern ROP attacks are much more complicated [1]

“Skype URI handling routine contains a buffer overflow”, 2005[1]

“Apple Mail buffer overflow vulnerability“, 2006

”glibc vulnerable to stack buffer overflow in DNS resolver“, 2016

[1] From CERT vulnerability database

Problematic

We want to add additional checks at runtime to protect the return addresses.

How do we know the return addresses locations in the memory?

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How do we know the return addresses locations in the memory?

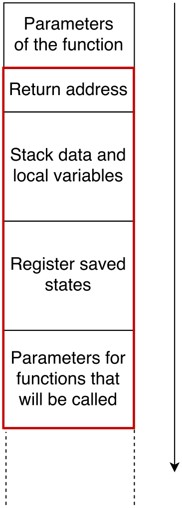
$\Rightarrow$ Modify the memory structure to have an easy way to distinguish return addresses locations

Presentation of our approach

1. Presentation of the stack
2. Transformation of the stack structure
3. Insertion of runtime checks in the protected code
4. Evaluation of the approach

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

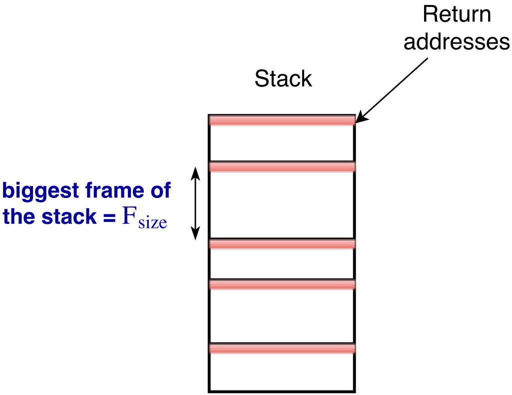


Stack transformation objective

- We want a stack structure with a property on the return addresses locations
- Every return addresses location a verifies the equality $\underline{a \ mod \ n = 0}$
- The transformation is composed of two steps:
  1. Constant frames size
  2. Stack alignment

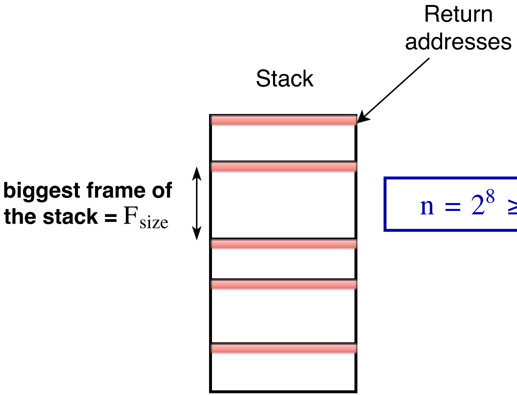
Stack transformation (1/6)

Find the biggest frames size



Stack transformation (2/6)

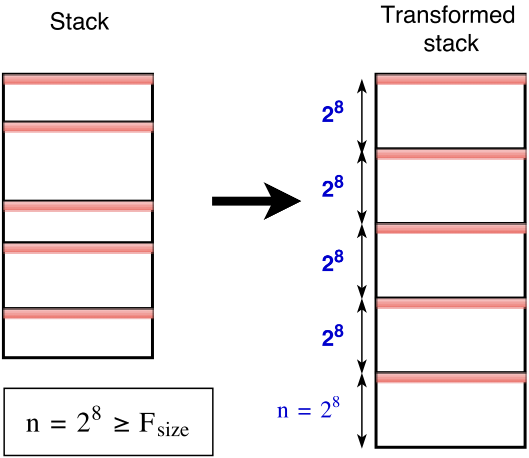
Calculate the new frames size



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

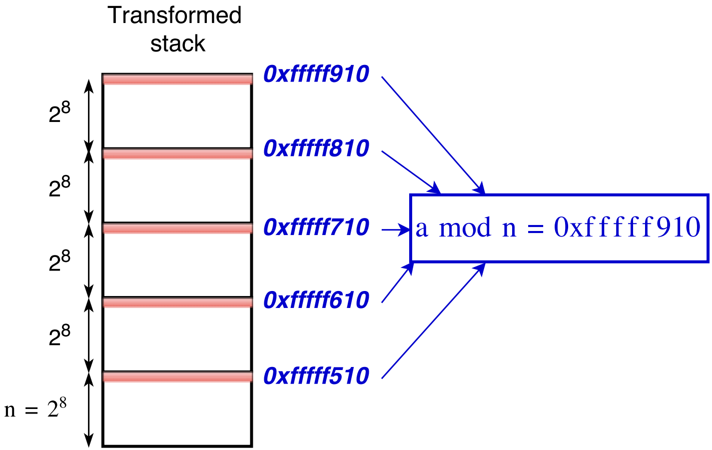
Stack transformation (3/6)

Fix the size of the frames



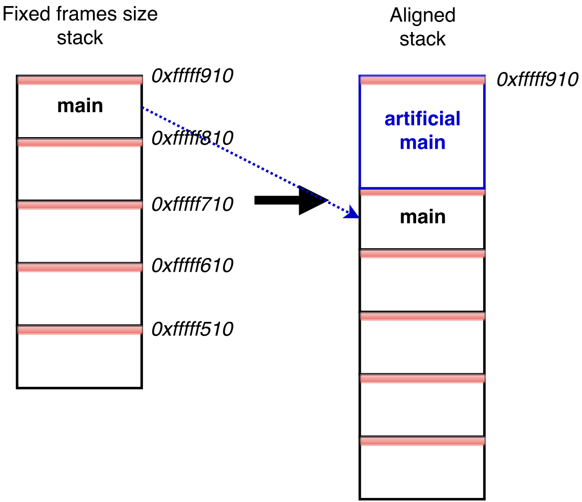
Stack transformation (4/6)

Return addresses locations



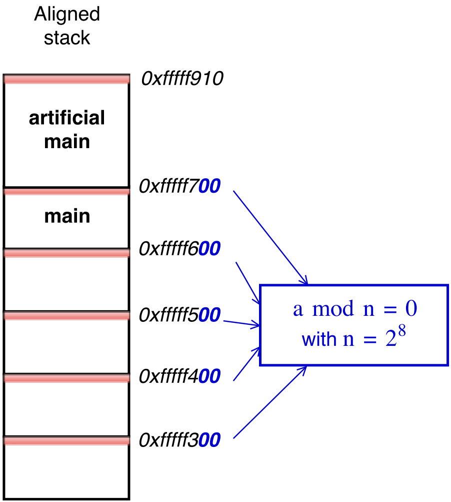
Stack transformation (5/6)

Insertion of a new artificial main



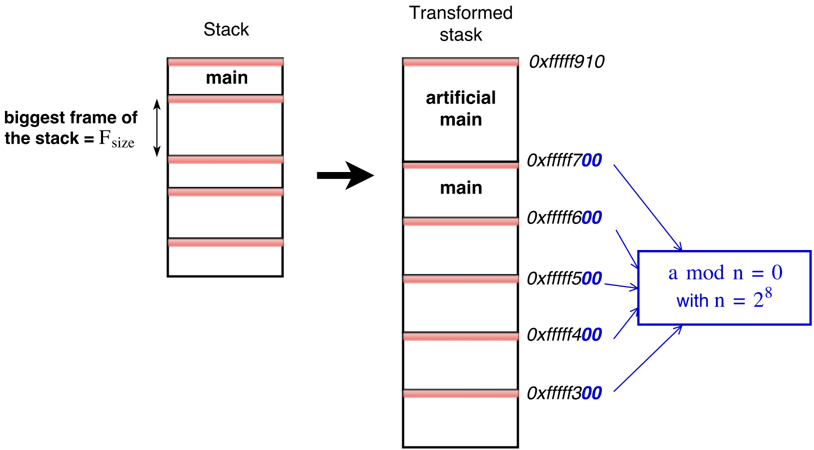
Stack transformation (6/6)

Return addresses locations



Stack transformation

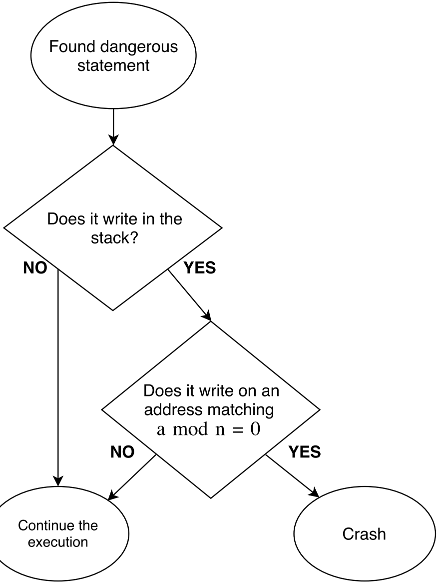
Summary



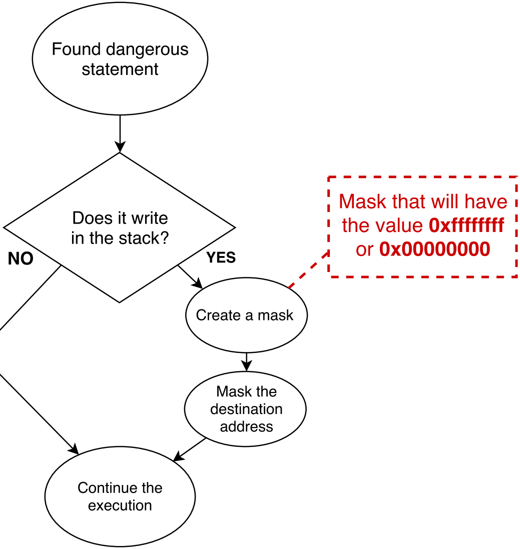
Code transformation

- We have now an easy way to differentiate return addresses locations with $a \ mod \ n = 0$
- We need to insert additional runtime check to protect these locations from being overwritten illegally
- Thus we transform the code adequately during the compilation phase

Runtime check



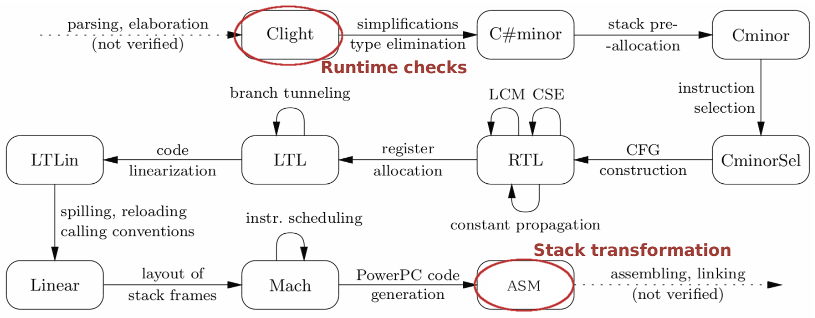
Branchless check



Implementation environment

CompCert the certified compiler [2]

- CompCert has been proven with the proof assistant Coq
- CompCert has performance similar to gcc -O1



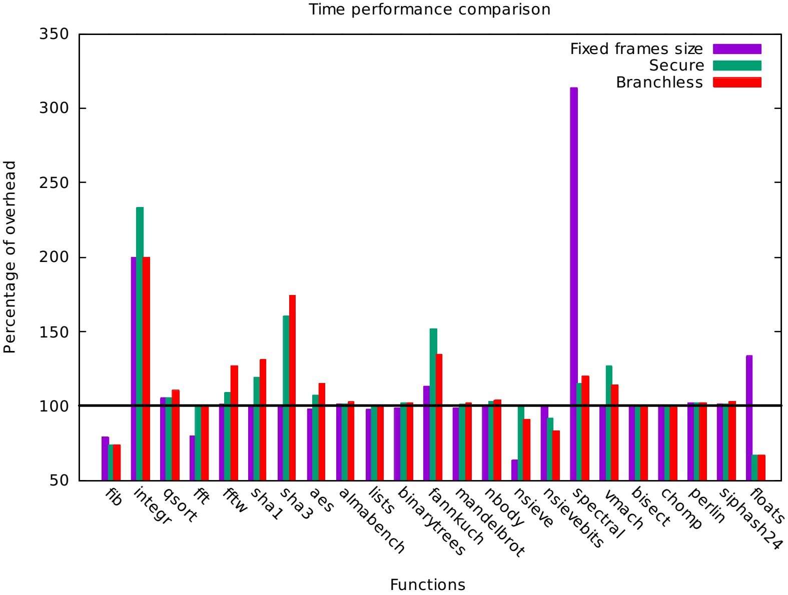
Requirements

- No modifications of the stack (inline assembly)

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

- No function pointers to protect our runtime checks
- Need to recompile external libraries with the same frames size

Evaluation of performance



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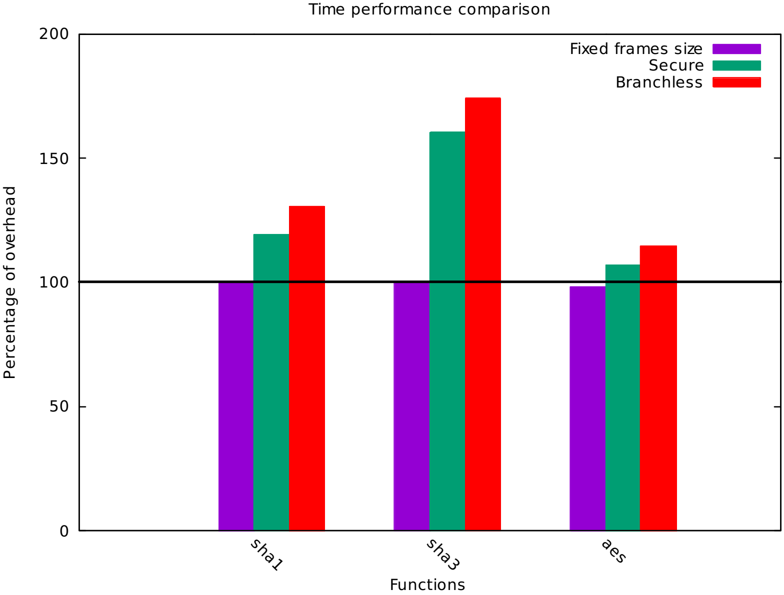

Conclusion

Prospectives

- Test our implementation against more complicated ROP attacks
- Reduce the number of runtime checks with static analysis [5]
- Improve the performance of the runtime checks with a super-optimizer
- See the impact of our approach on memory consumption
- Prove the security properties of our implementation

References

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