StackArmor: Stopping Stack-based Memory Error exploits in binaries

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Introduction

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  - CVE-2014-9163, Stack-based buffer overflow in Adobe Flash Player on Windows/OS X/Linux
  - CVE-2014-1593, Stack-based buffer overflow in Mozilla Firefox before 34.0

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- The predictability of the stack is by design.

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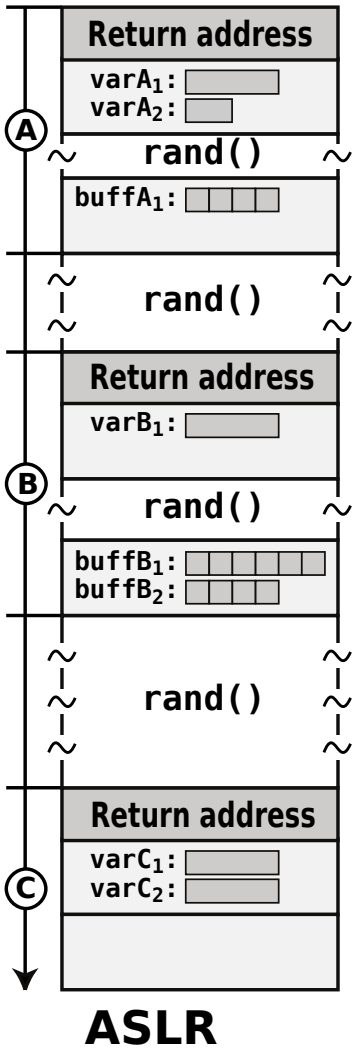
- Both attacks can happened intra-procedure or inter-procedure

Different stack protection techniques



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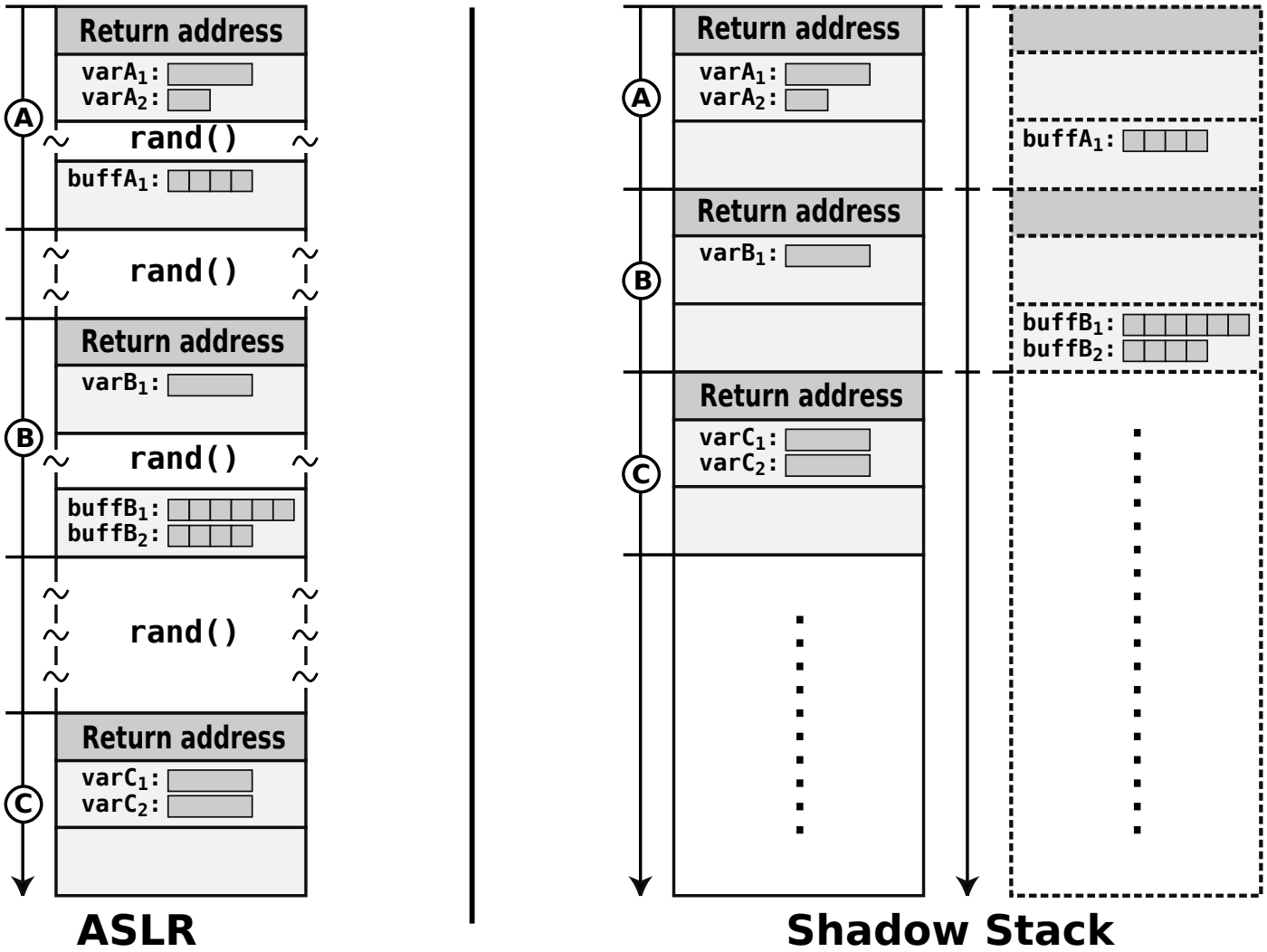
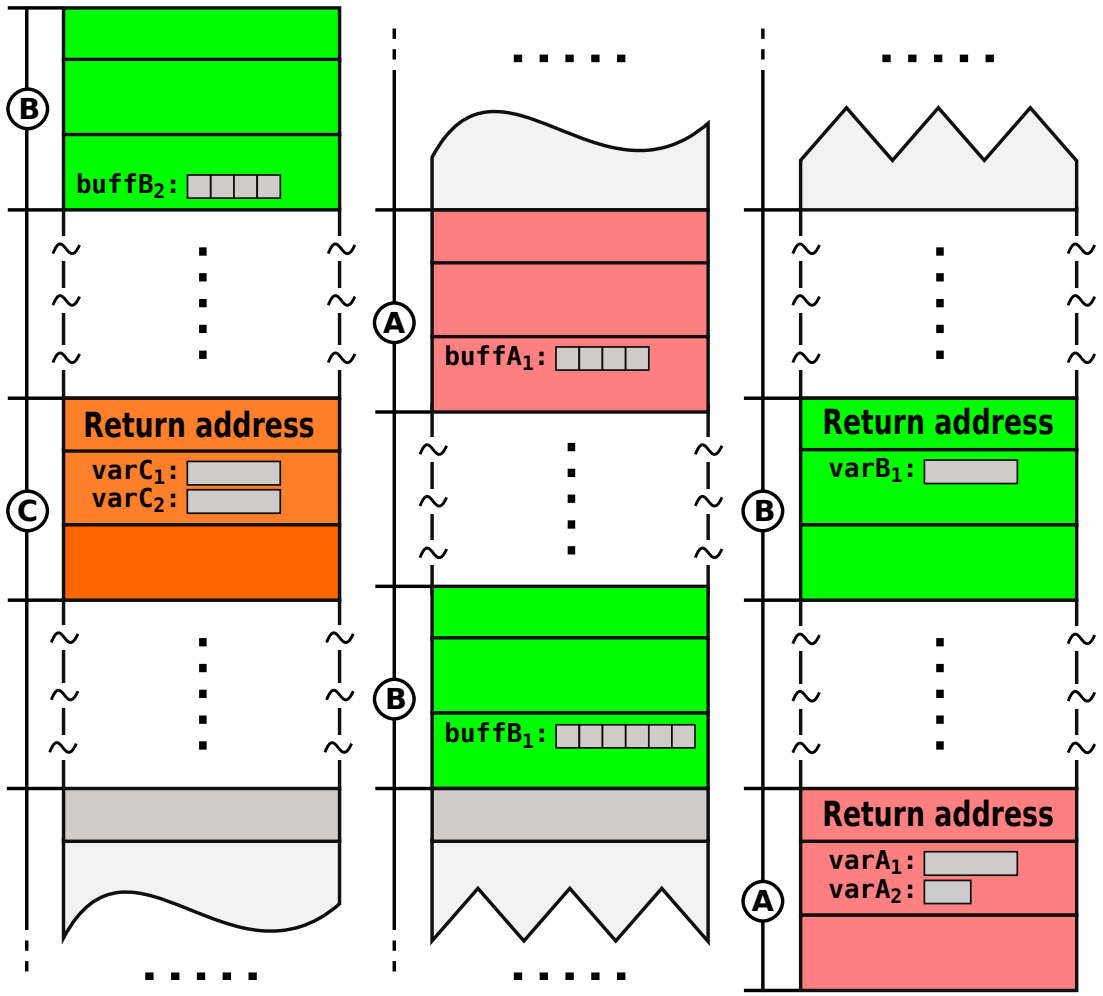


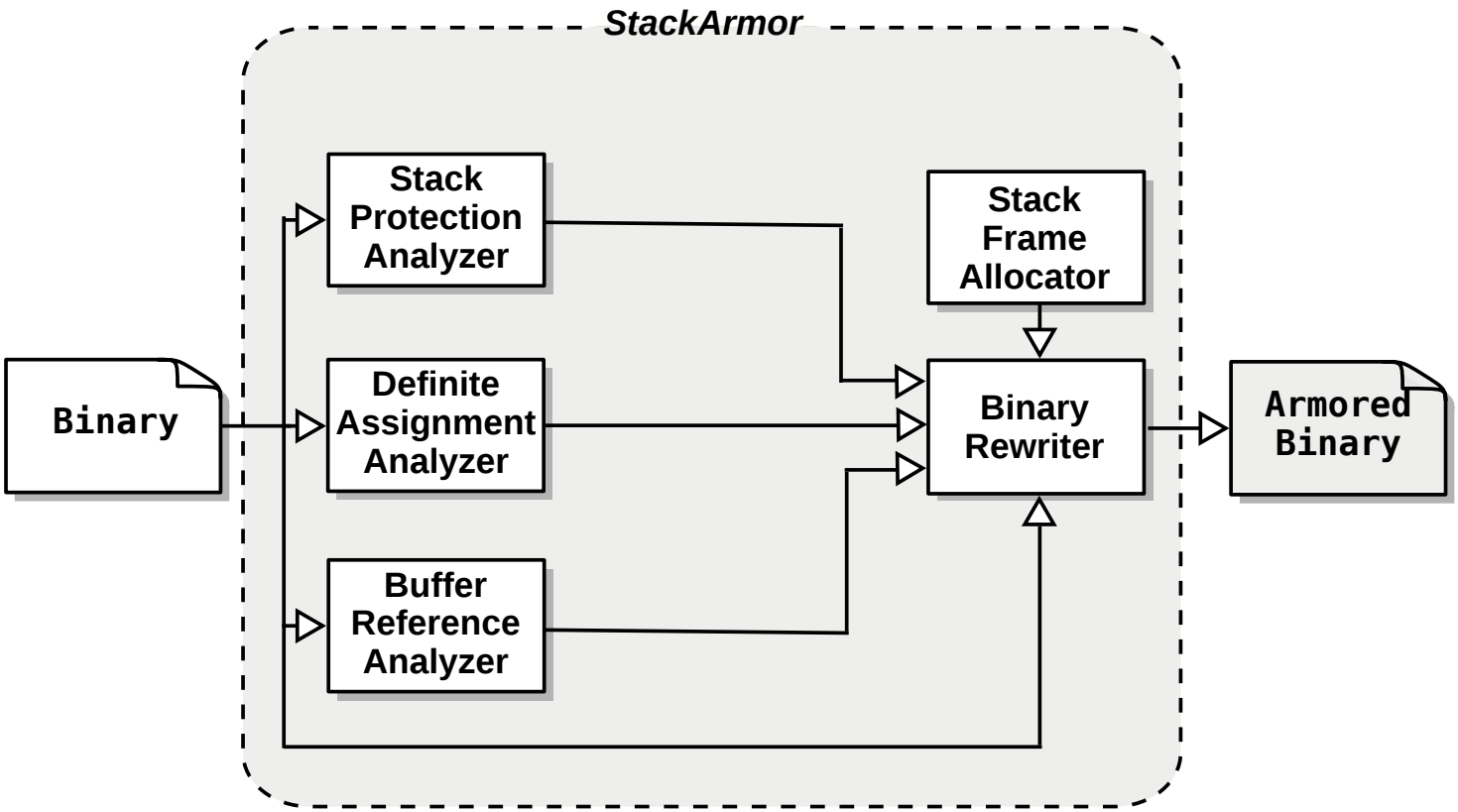
StackArmor

- Comprehensive approach against spatial and temporal Attacks
- A binary rewriting approach.
- No traditional stack, i.e., no predictable stack organization
- Combining stack frame randomization, buffer isolation and stack object zero initialization.

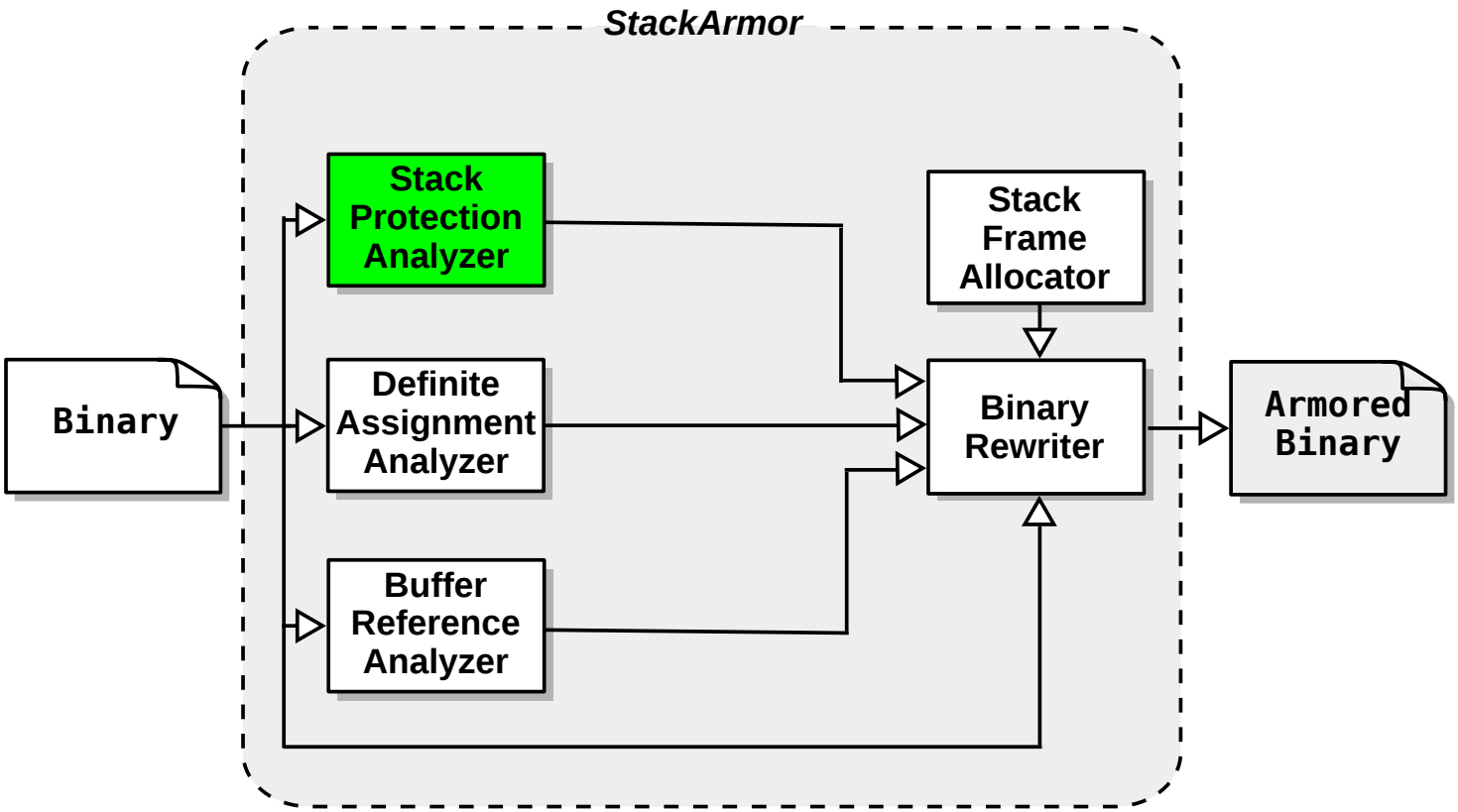
Stack frame layout under StackArmor



Overview of StackArmors's components



Stack protection analyzer



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  - Stack variables should only be accessed via stack/frame pointer with constant offset
  - Stack/frame pointer or derived pointer can not store into register/memory outside prologue/epilogue
  - Stack/frame pointer can not be manipulated outside prologue/epilogue
- Seems very conservative, but we have simliar result comparing with GCC option

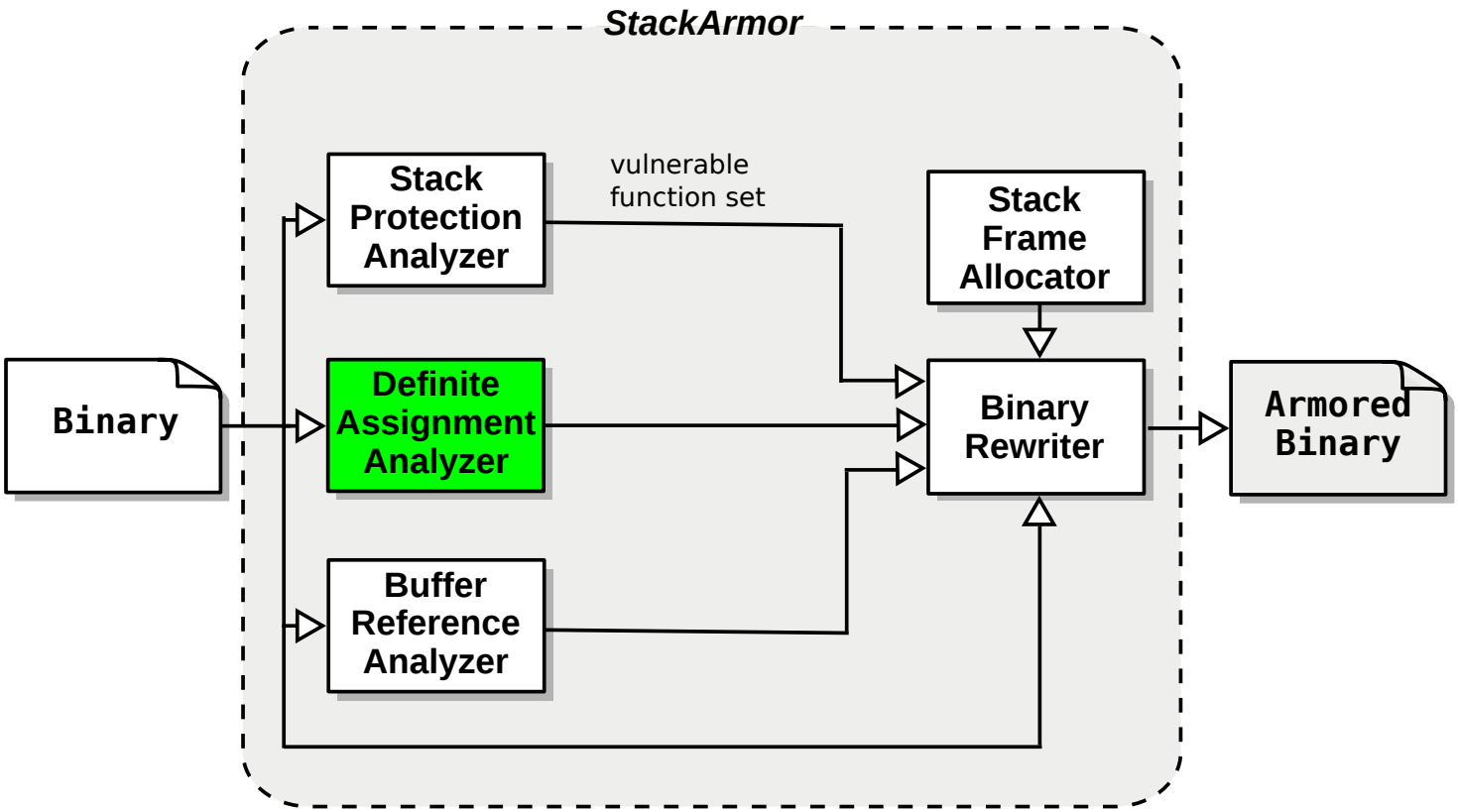
Violation example

```
extern void
helper_sp(int, int *, void *);

int
test_sp(int i, unsigned long size)
{
    int ret;
    char args[] = {1, 2, 3, 4};
    helper_sp(
        args[i],
        &ret,
        alloca(size));
    return ret;
}
```

```
function test_sp:
  pushq   %rbp
  movq    %rsp, %rbp
  subq    $32, %rsp
  movl    %edi, -4(%rbp)
  movq    %rsi, -16(%rbp)
  movl    $67305985, -24(%rbp)
  movslq  -4(%rbp), %rax
  movsbl  -24(%rbp,%rax), %edi
  movq    -16(%rbp), %rax
  addq    $15, %rax
  andq    $-16, %rax
  leaq    -20(%rbp), %rsi
  movq    %rsp, %rdx
  subq    %rax, %rdx
  movq    %rdx, %rsp
  callq   helper_sp
  movl    -20(%rbp), %eax
  movq    %rbp, %rsp
  popq    %rbp
  ret
```

Definite assignment analyzer



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- Functions that pass stack protection analyzer: no need to be checked.
- Static analysis remaining functions to find read-before-write bytes.
- False positive is acceptable

Definite assignment analyzer example

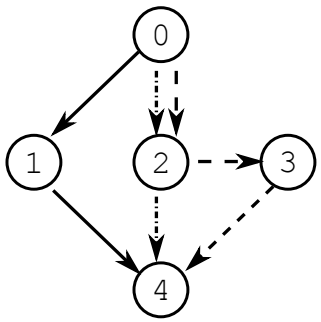
```
extern void
helper_da(int);

int
test_da(unsigned long size)
{
    int arg;
    if (size > 10)
        arg = 10;
    else if (size > 1)
        arg = 1;

    helper_da(arg)
}
```

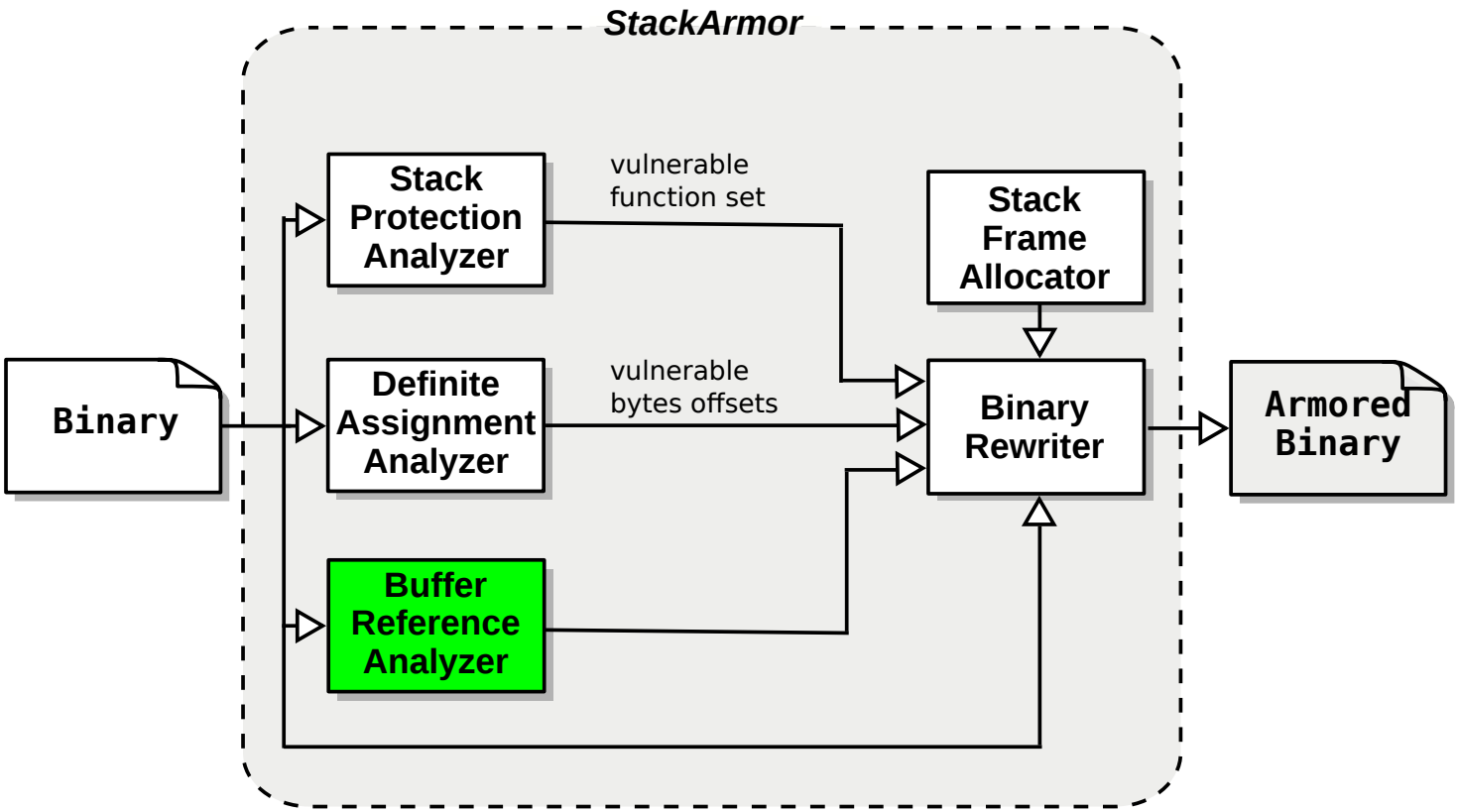
```
function test_da:
.LBB1_0:
  subq    $24, %rsp
  movq    %rdi, 16(%rsp)
  cmpq    $11, %rdi
  jb      .LBB1_2
.LBB1_1
  movl    $10, 12(%rsp)
  jmp     .LBB1_4
.LBB1_2:
  cmpq    $2, 16(%rsp)
  jb      .LBB1_4
.LBB1_3
  movl    $1, 12(%rsp)
.LBB1_4:
  movl    12(%rsp), %edi
  callq   helper_da
  addq    $24, %rsp
  ret
```

Control flow graph and the DA analyzer's results:



	12(%rsp)	16(%rsp)
→	unsafe	safe
-·->	safe	safe
- ->	safe	safe
DA result:	**unsafe**	**safe**

Buffer reference analyzer



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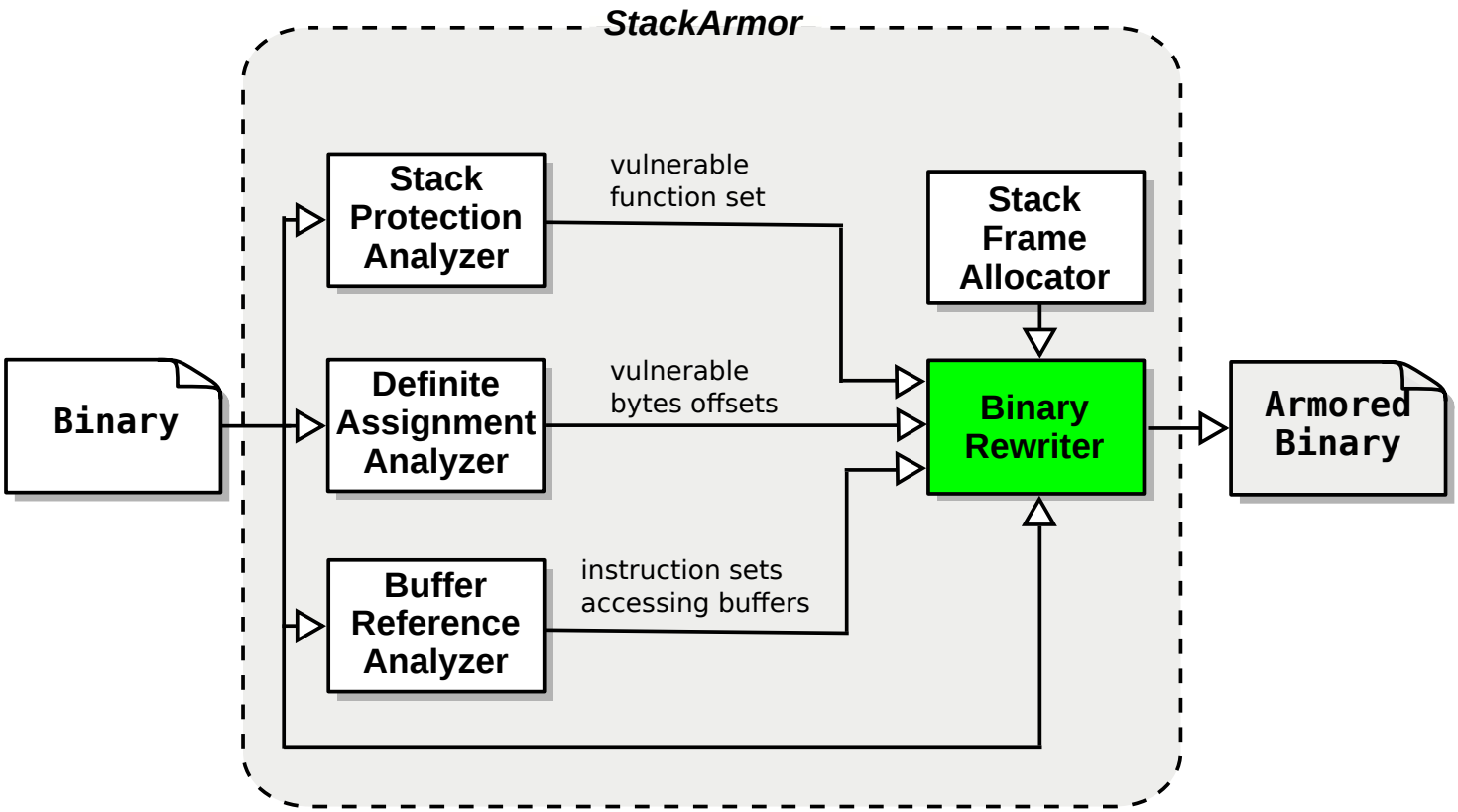
- Ask buffer location and size information either from debug symbols or dynamic reverse engineering techniques.
- Static data-flow tracking analysis to find instructions which access buffers
  - Can afford neither false positives nor false negatives
  - If can not resolve the address being de-referenced, give up
  - If a insturction can access different objects, give up

Binary instrumentation



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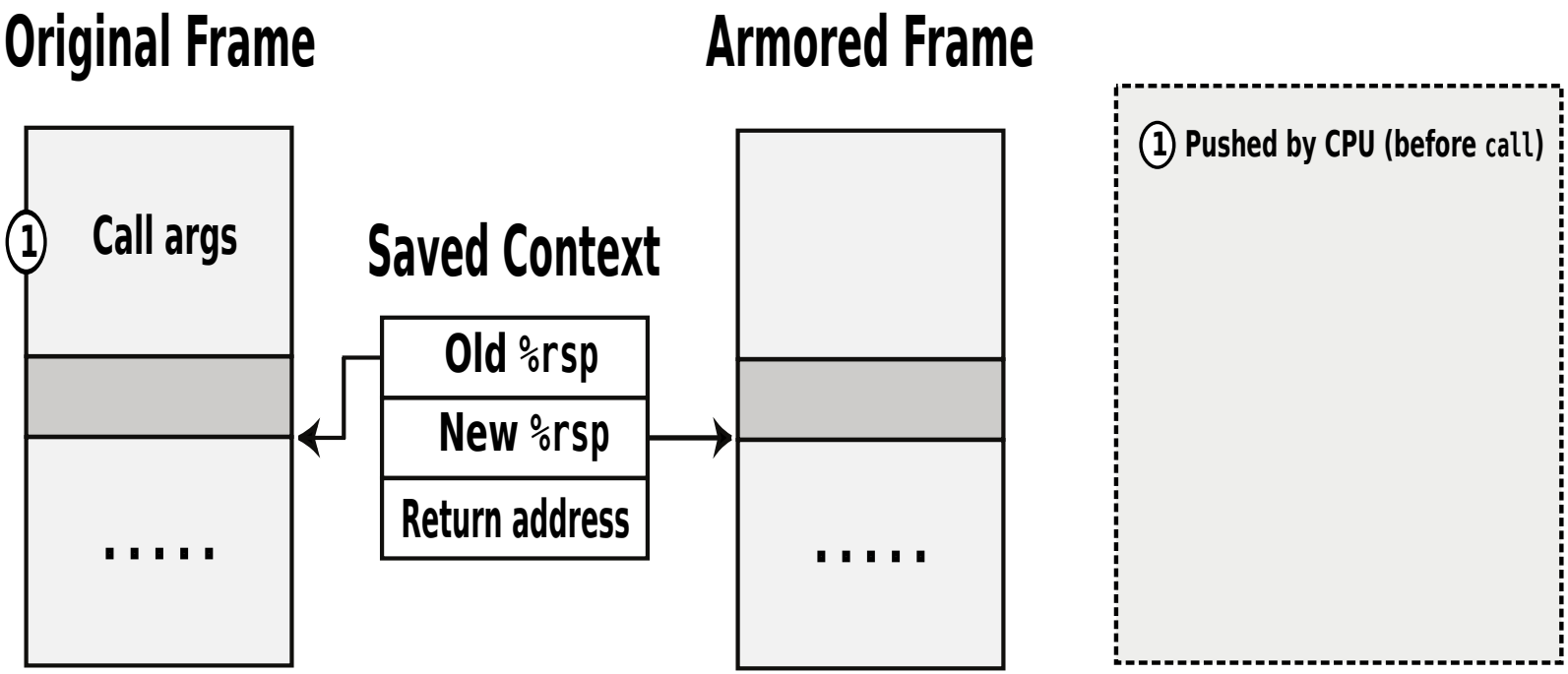
- Stack frame randomization : Call site instrumentation

Call site instrumentation



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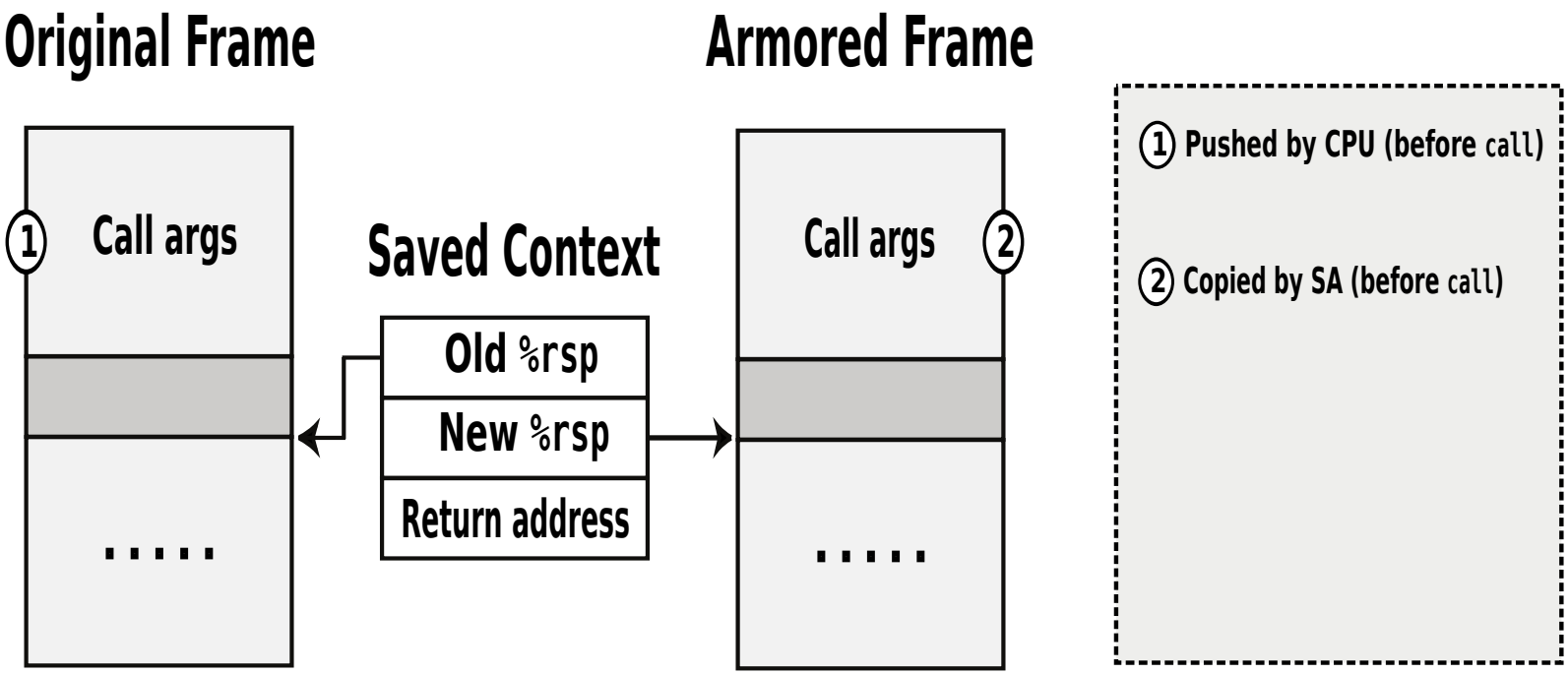

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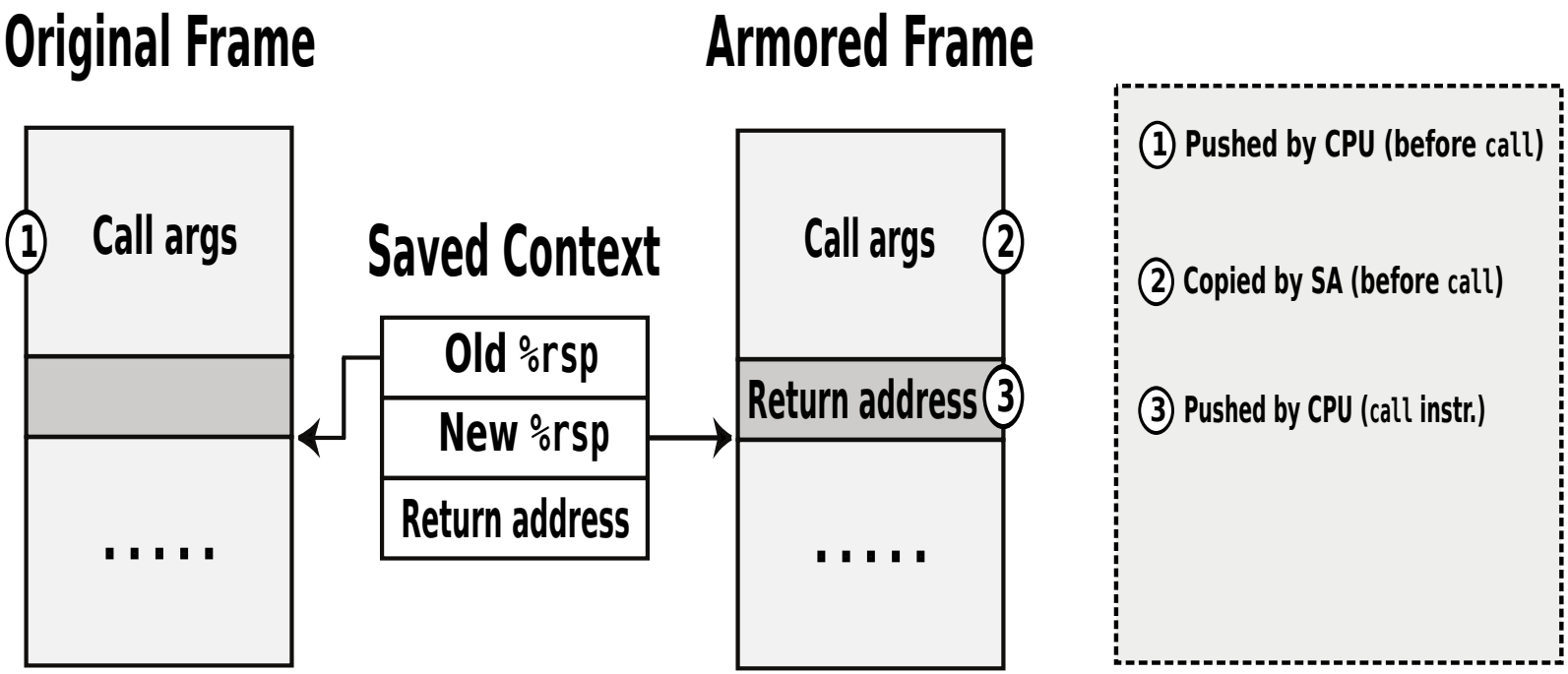

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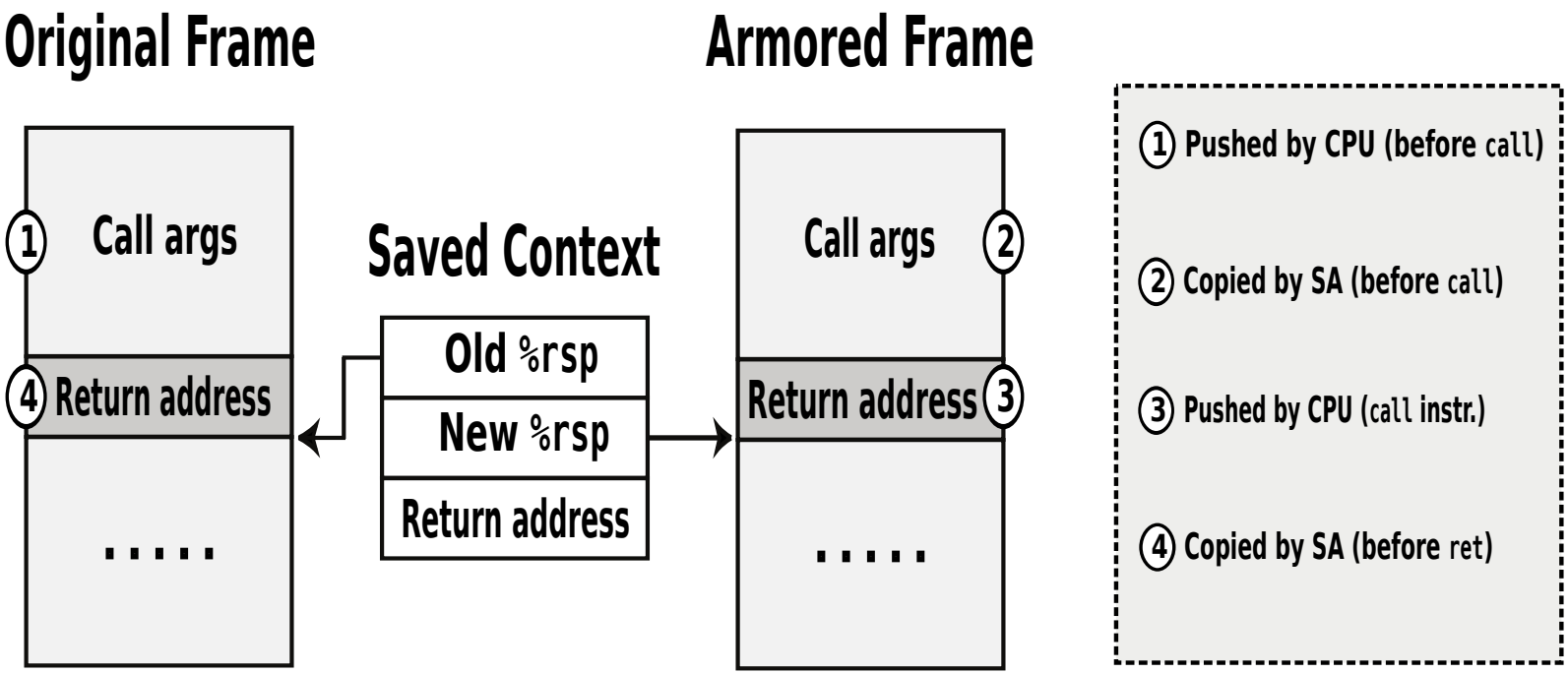
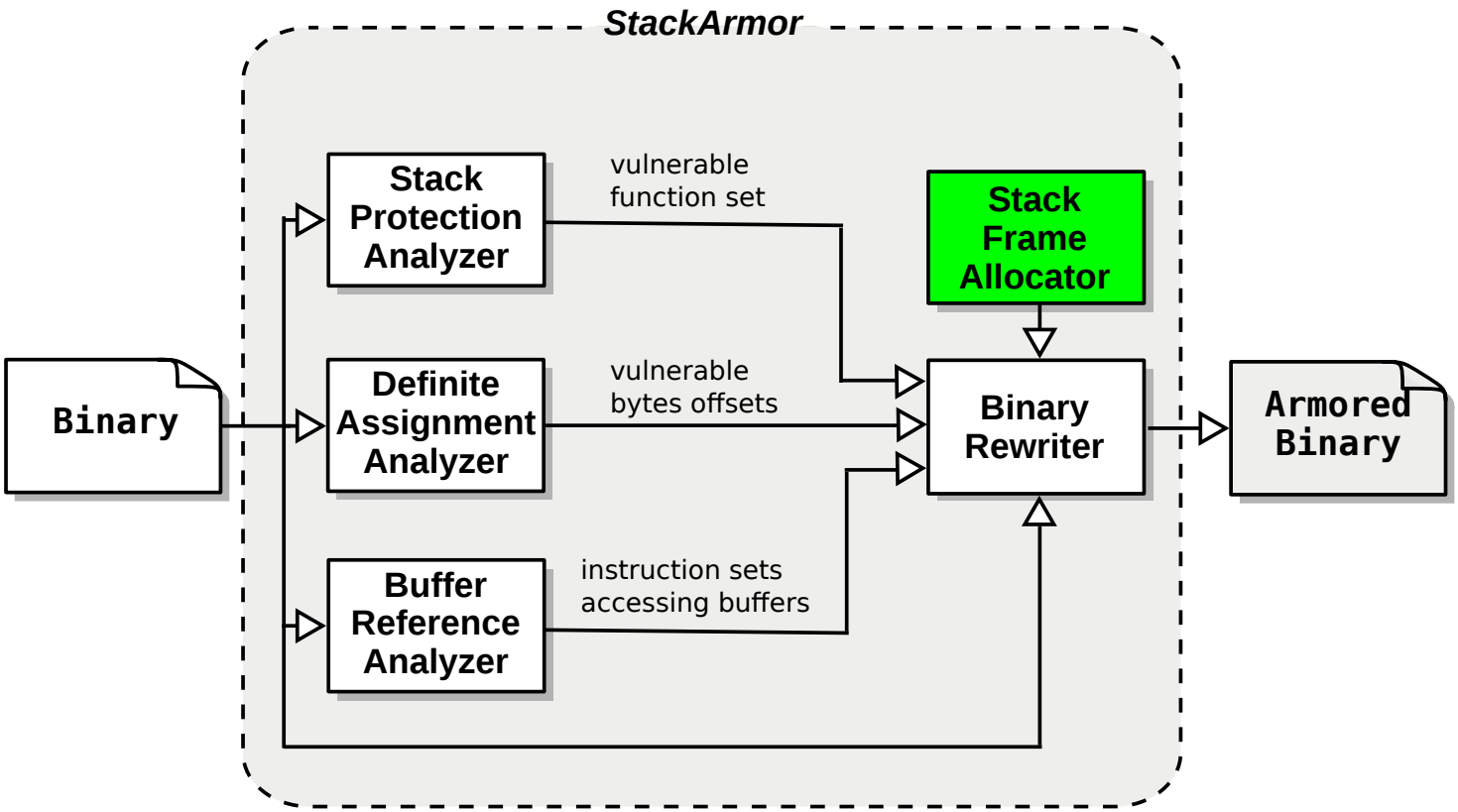


Stack frame allocator



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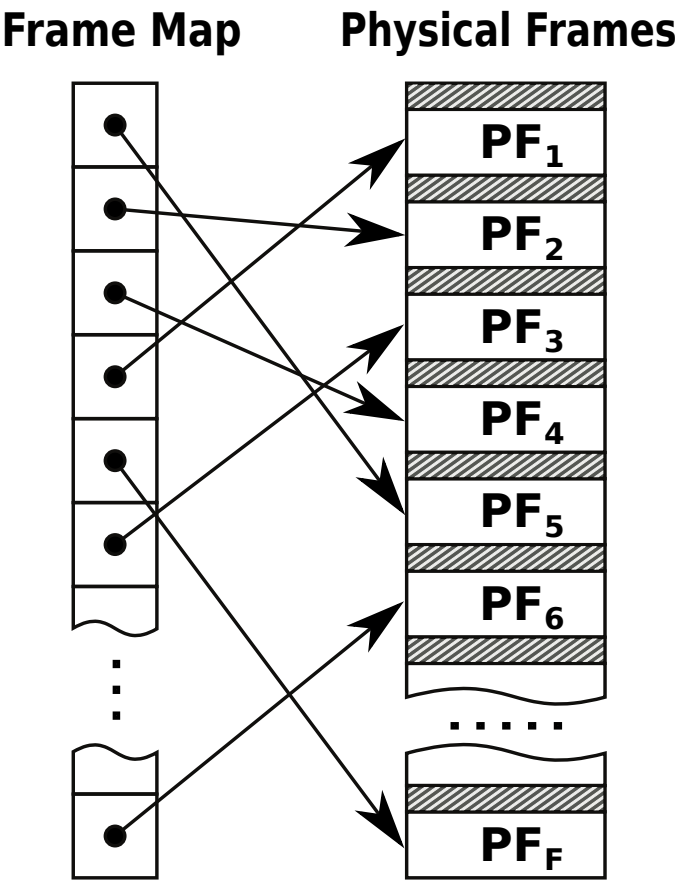

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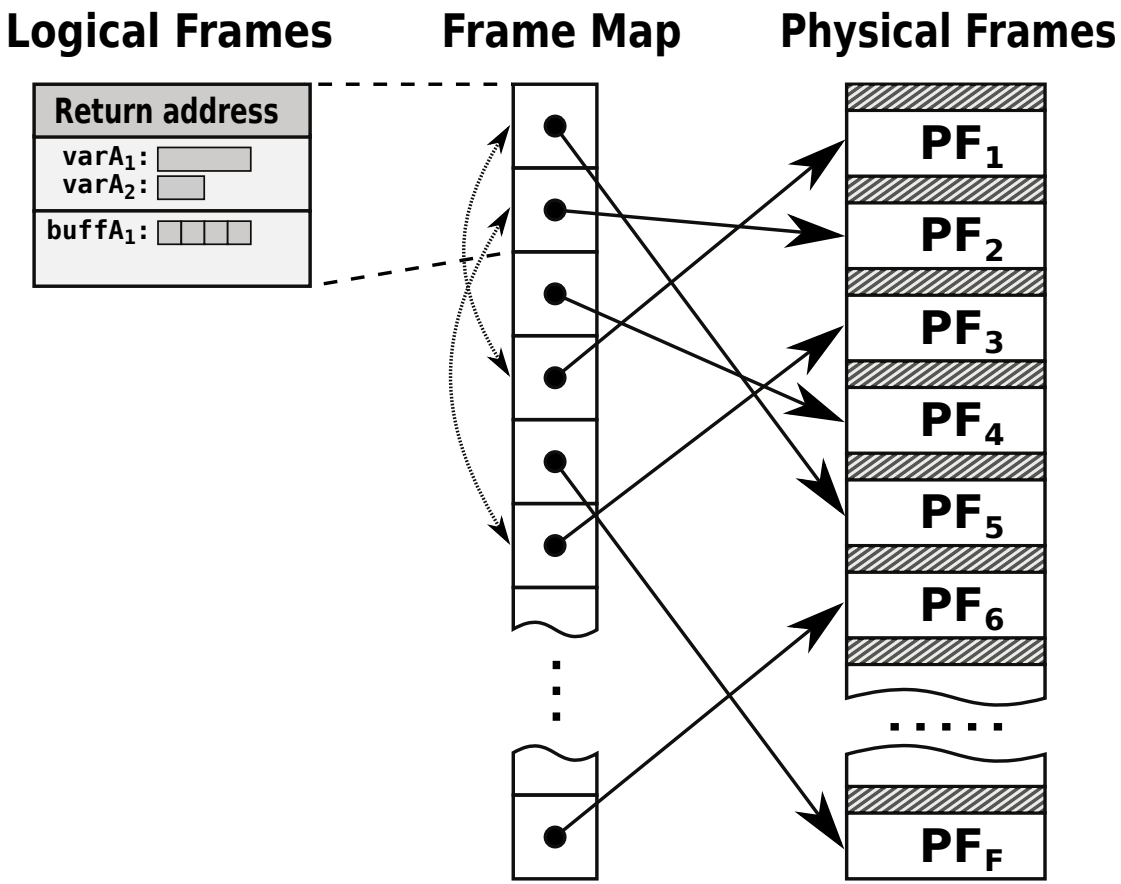

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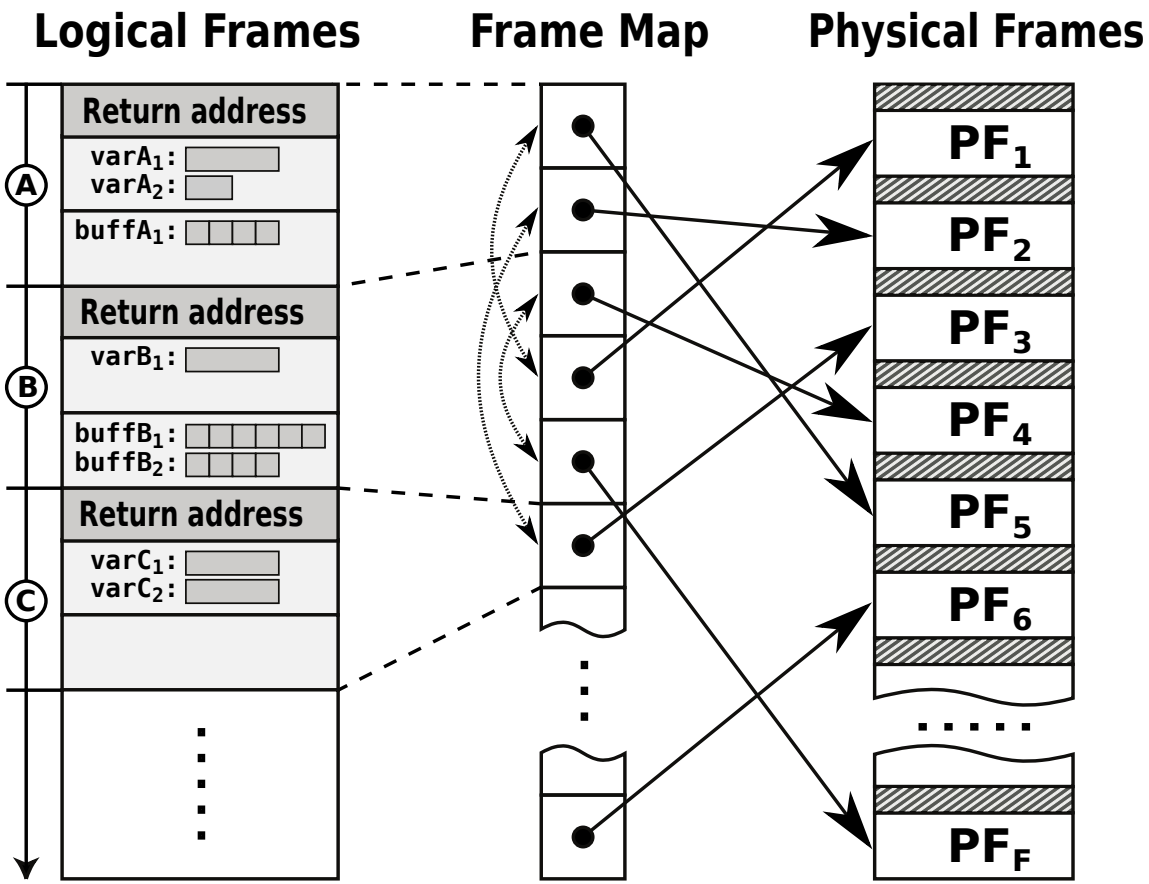
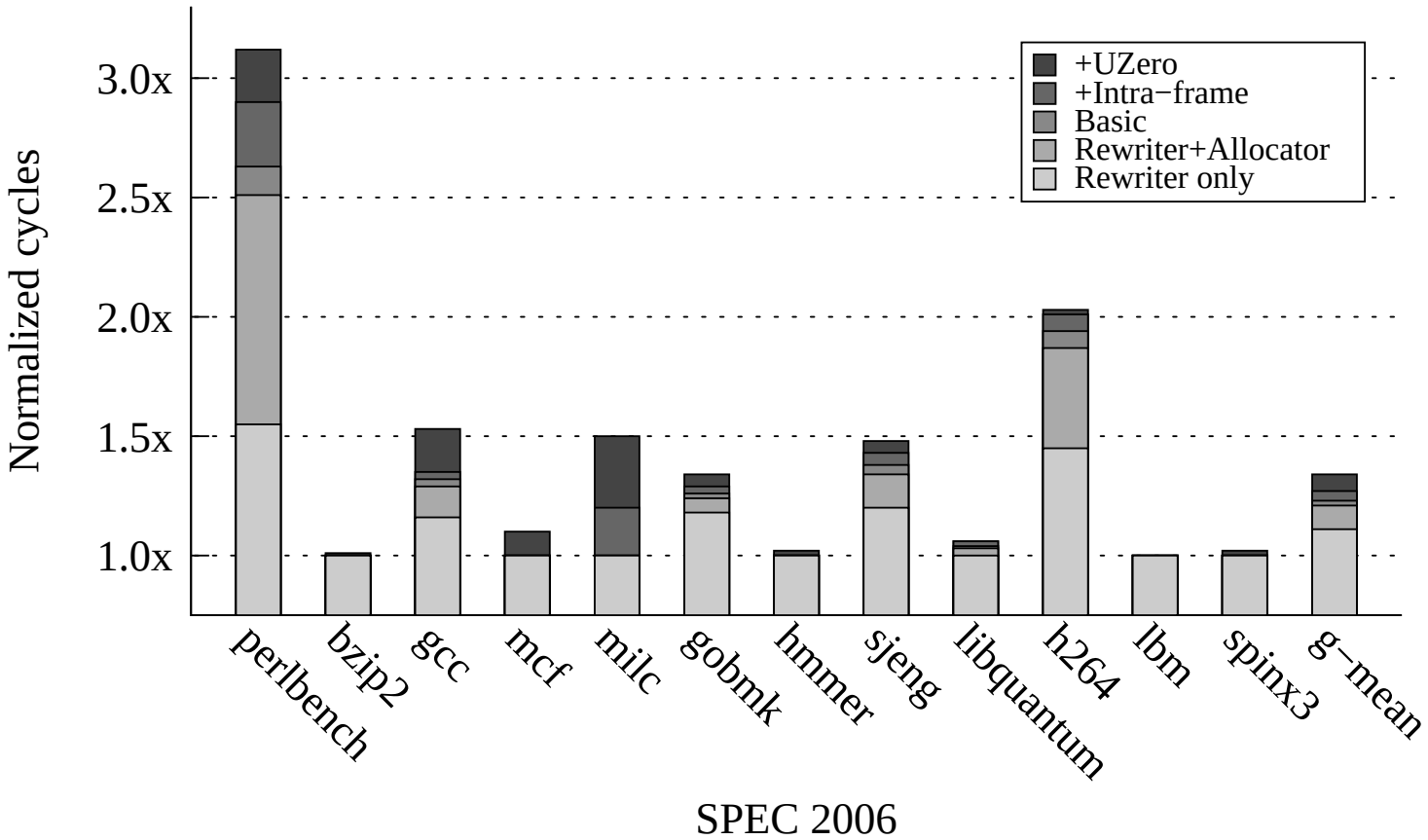


Run time overhead

App	Basic	+Buffer-Isolation	+Zero-Initialization
lighttpd	1.06x	1.07x	1.10x
exim	1.01x	1.04x	1.05x
openssh	1.00x	1.01x	1.01x
vsftpd	1.00x	1.01x	1.04x
SPEC_{gm}	1.16x	1.22x	1.28x

Detailed run time overhead on SPEC 2006



Conclusions

- StackArmor "destroys" traditional stack organization to provide fully randomized stack space
- It can protect against stack-based spatial and temporal attacks
- And it provides tunable trade-off between performance and security

Thanks, any questions?