Secure Computing Environments

Memory, Compiler and Virtual Machines

Christian Barthel,
Christian Kawalar,
Daniel Schlager

30.01.2015

A word of caution...

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Disclaimer

It is not our intent to show you how to break into computer systems!

A word of caution...

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But!

“While you do not know life, how can you know about death?”

—Confucius

Memory Layout revisited

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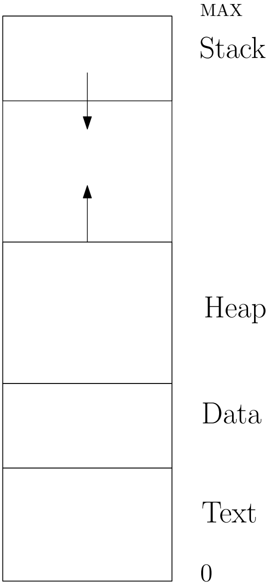

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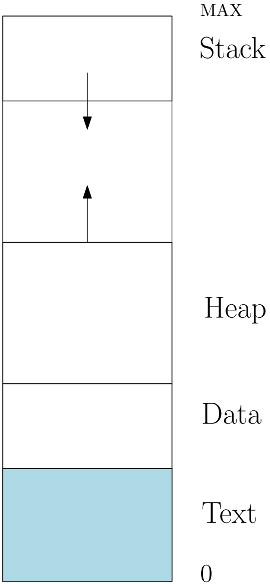

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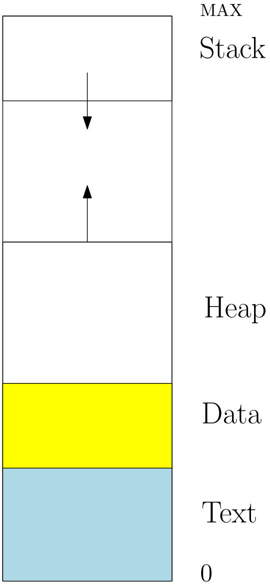

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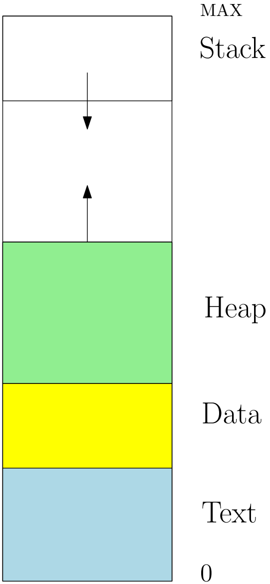

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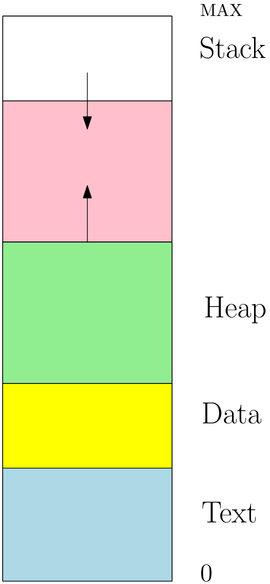

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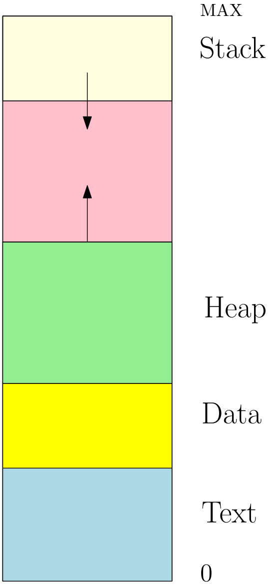

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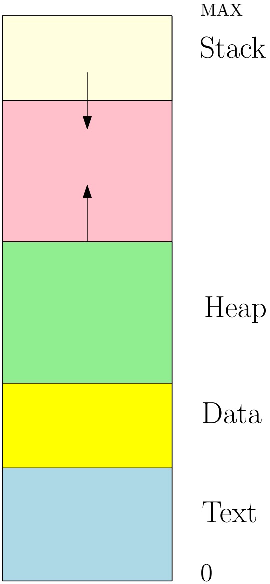

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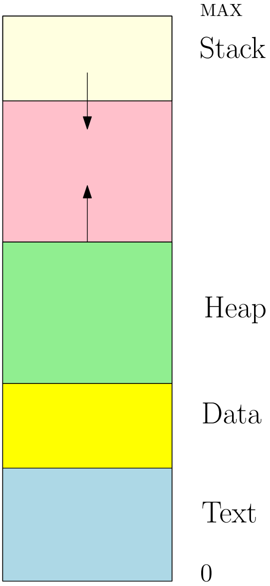

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- Almost everything is predictable
- Most of the memory is write- and executable

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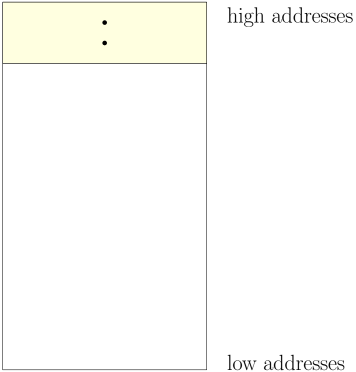

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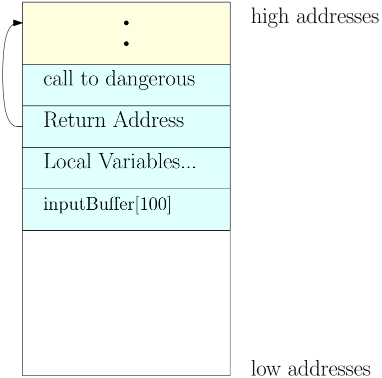

high addresses

call to dangerous

Return Address

Local Variables...

inputBuffer[100]

low addresses

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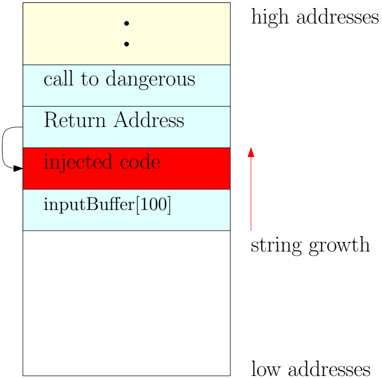

Memory Protection

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- W^X
- Address space layout randomization (ASLR)

W^X with static binaries

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- Statically compiled binaries have a simple memory layout

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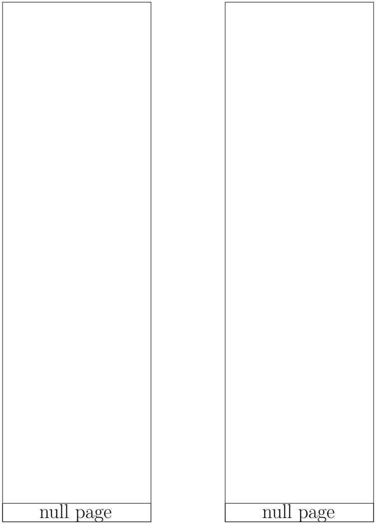

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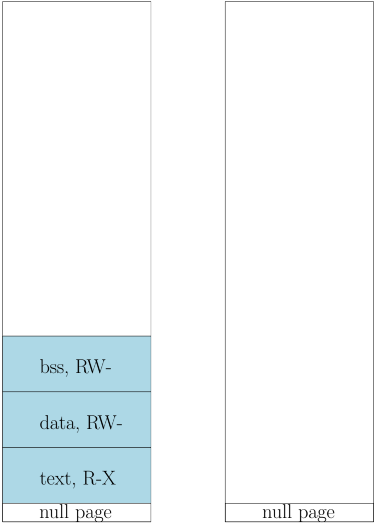

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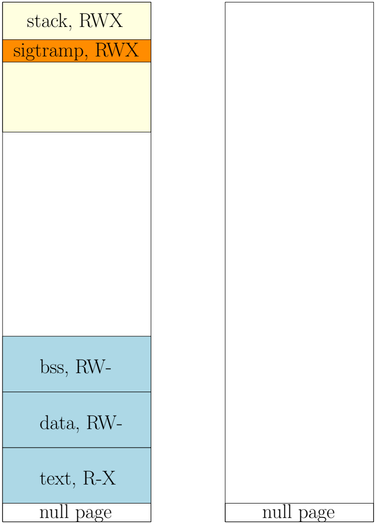

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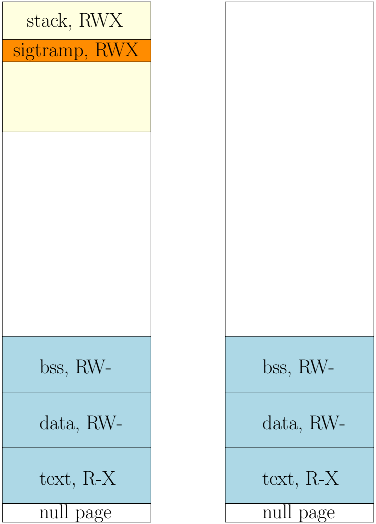

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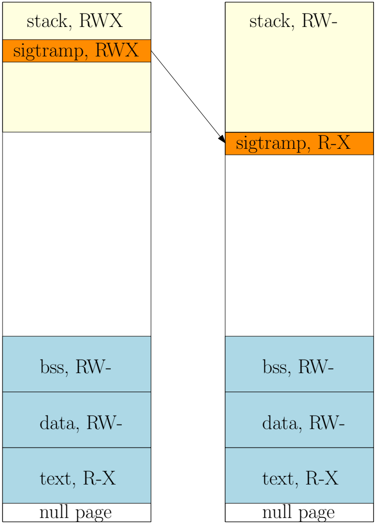

- Statically compiled binaries have a simple memory layout
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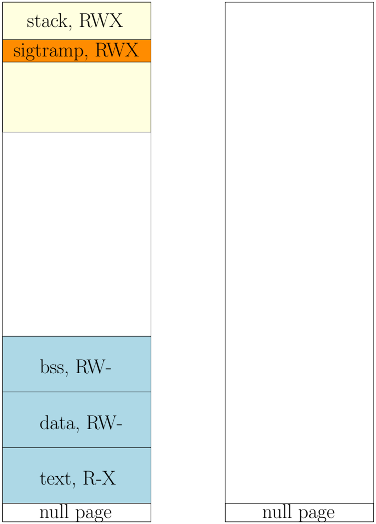
- Separate `sigtramp` from the stack, give it its own page

W^X with dynamic libraries



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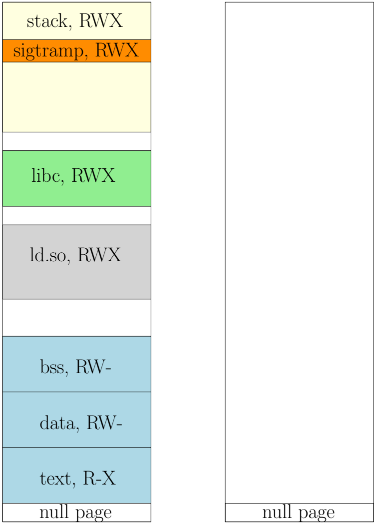


stack, RWX

sigtramp, RWX

libc, RWX

ld.so, RWX

bss, RW-

data, RW-

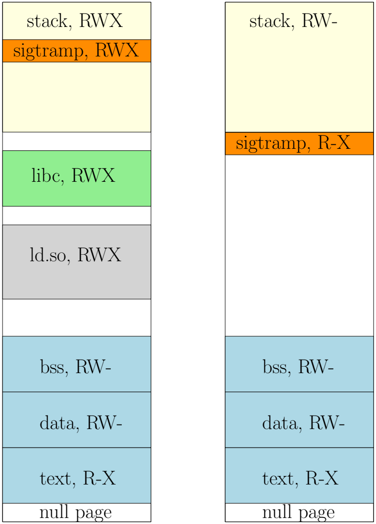
text, R-X

null page

null page

- shared libraries are mapped into the address space of a process

W^X with dynamic libraries



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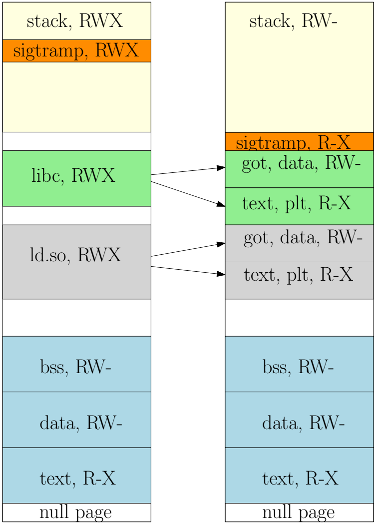

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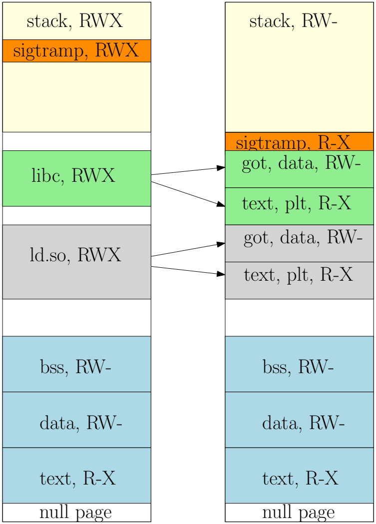

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- They include additional `GOT` and `PLT` tables which must be written during execution
- `GOT` is the shared lib global offset table
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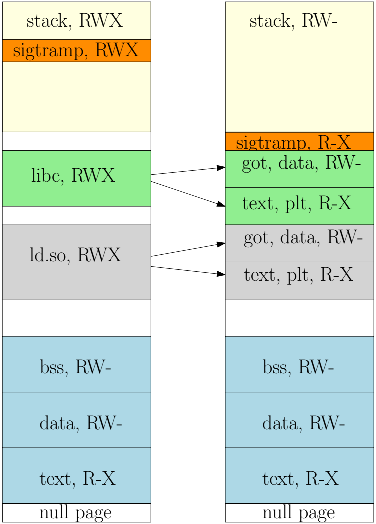

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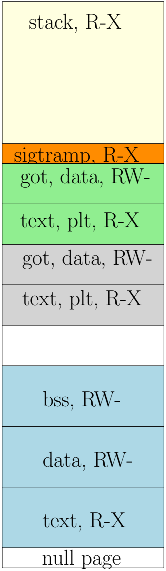
- `GOT` is the shared lib global offset table
- `PLT` is the shared lib procedure linkage table
- Since the `PLT` needs to be written and executed, an additional conversion is necessary.

ASLR - Randomized Memory



stack, R-X

sigtramp, R-X

got, data, RW-

text, plt, R-X

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bss, RW-

data, RW-

text, R-X

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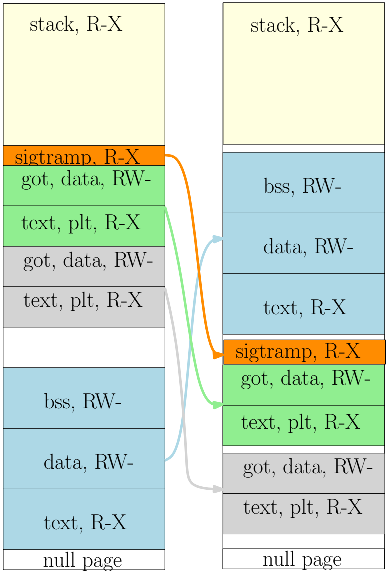

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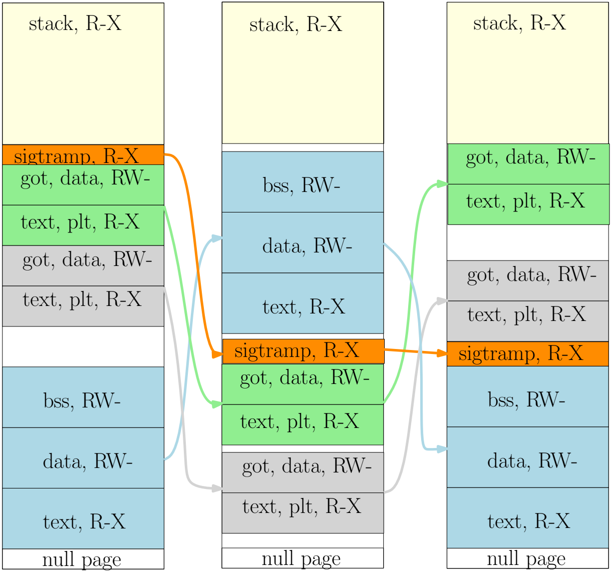


1 Introduction

2 Memory Protection
- Problem
- OpenBSD's ASLR and W^X

3 Compiler Options
- Stack Smashing Protection

4 Virtual Machines
- Overview of Virtual Machines
  - Security in Virtual machines
- Process Virtual Machines
  - Dalvik
- A Closer Look at Android and their Security
  - Platform Security Architecture

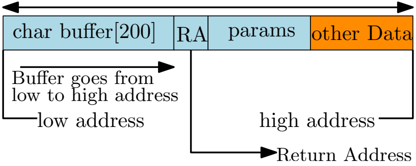
5 Conclusion

What is a Stack Smashing Attack ?

Listing 1 : Vulnerable Function

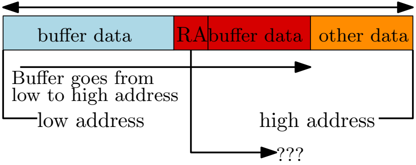
```
void vulnerableFunction(char *string){
    char buffer[200];
    //BAD!
    //No size check!
    strcpy(buffer,string);
}
```

What is a Stack Smashing Attack ?



- The stack contains the buffer, the return address and the parameters of the function.

What is a Stack Smashing Attack ?



- With injected code, data gets overwritten.

Stack Overflow Attack

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  - Most CPUs have a NOP instruction (**no operation**): the instruction does nothing but increasing the Instruction Pointer by one.
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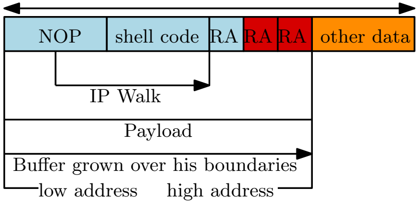
  - Finally we set the RA (Return Address) back to a NOP instruction (guess the jump distance).

Stack Overflow Attack



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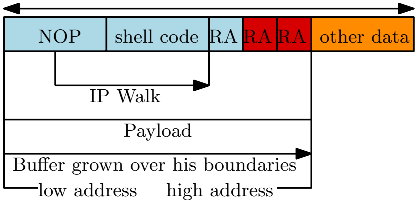

- The stack contains the NOP instructions, our payload and the altered return address.
- We insert a bunch of NOP instructions to increase the chance of finding the right position.

Prevent the attack with GCC

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- Now I will show you how to prevent such attacks with GCC and the -**fstack-protector** flag.

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- Normally our subroutine would look like this:

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    - Initialization: The preparation of space on the stack for local variables.
    - Subroutine body: The subroutine's implemented algorithm.
    - Clean-up: Removing local variables from the stack.
    - Return: Jump back to the original address before the branch.

Prevent the attack with GCC

- Subroutine code with SSP:
    - SSP's prolog
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    - SSP's epilog
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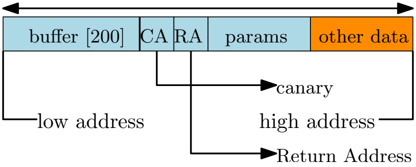

- The canary got saved before the Return Address.

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Prevent the attack with GCC

- The canary is a randomly generated number.
- GCC adds code at compile time, the code generates a random canary which will be checked after strcpy.
- It's almost impossible to guess the actual canary, so there is no way to overwrite the canary in the payload with the right value.

Prevent the attack with GCC

Listing 4 : -fno-stack-protector

```
vulnerableFunction:
.LFB2:
;Reserve Space on the stack

leaq -4352(%rsp), %rsp
orq $0, (%rsp)
leaq 4128(%rsp), %rsp

;Arguments from Register onto Stack
movq %rdi, -216(%rbp)   ;1st arg from rdi to stack
;Params for strcpy
movq -216(%rbp), %rdx   ;1st arg to rdx
leaq -208(%rbp), %rax   ;2nd arg to rax
;Call Strcpy
movq %rdx, %rsi       ;src address from rdx to rsi
movq %rax, %rdi       ;dest address from rax to rdi
call strcpy@PLT       ;call strcpy() @PLT
```

Listing 5 : -fstack-protector

```
vulnerableFunction:
leaq  -4352(%rsp), %rsp     ;Reserve space on stack
orq  $0, (%rsp)
leaq  4128(%rsp), %rsp
                           ; Args from register onto stack
movq %rdi, -216(%rbp)      ; 1st arg from rdi to stack
                           ; SSP prolog, put canary to
                               stack
movq %fs:40, %rax          ; canary from %fs:40 to ras
movq %rax, -8(%rbp)        ; canary from rax to stack
xorl %eax, %eax            ; set rax to zero
                            ; Params for strcpy
movq  -216(%rbp), %rdx     ; 1st argument to rdx
leaq  -208(%rbp), %rax     ; 2nd argument to rax
                           ; Call strcpy
movq %rdx, %rsi            ; src addres from rdx to rsi
movq %rax, %rdi            ; dest address from rax to rdi
call  strcpy@PLT           ; call strcpy()
                           ; SSP epilog
movq  -8(%rbp), %rax       ; canery from stack to rax
xorq %fs:40, %rax          ; original canary XOR rax
je  .L2                    ; no overflow > xor == 0, jump
call  __stack_chk_fail@PLT  ; overflow > xor != 0, kill
```

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- An example of Process Virtual Machines is Java virtual machine (JVM), Microsoft Common Language Runtime (CLR) and Dalvik

Security in Virtual machines

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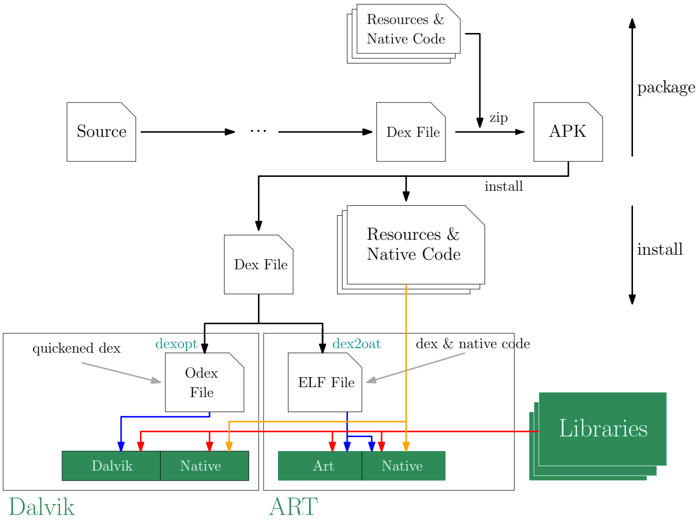
Dalvik


Resources &
Native Code
Source
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Dex File
zip
APK
package
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Dex File
Resources &
Native Code
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dexopt
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- ART uses the same input bytecode as Dalvik.

System and kernel security

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- in AndroidManifest.xml, add one or more uses-permissions tags

How to implement Security

Listing 6 : AndroidManifest.xml

```
<permissions>
<permission name=”android.permission.CAMERA” >
<group gid=”camera” />
</permission>
<permission name=”android.permission.BLUETOOTH” >
<group gid=”net bt” />
</permission>
</permissions>
```

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- Nevertheless, it's much harder to break into a computer system with all those fancy security features
- It's difficult to find a good path between all those conflicting goals: **comfort**, **security**, **performance**, **clean** and **simple implementation**...