SPROBE: Enforcing Kernel Code Integrity on the TrustZone Architecture

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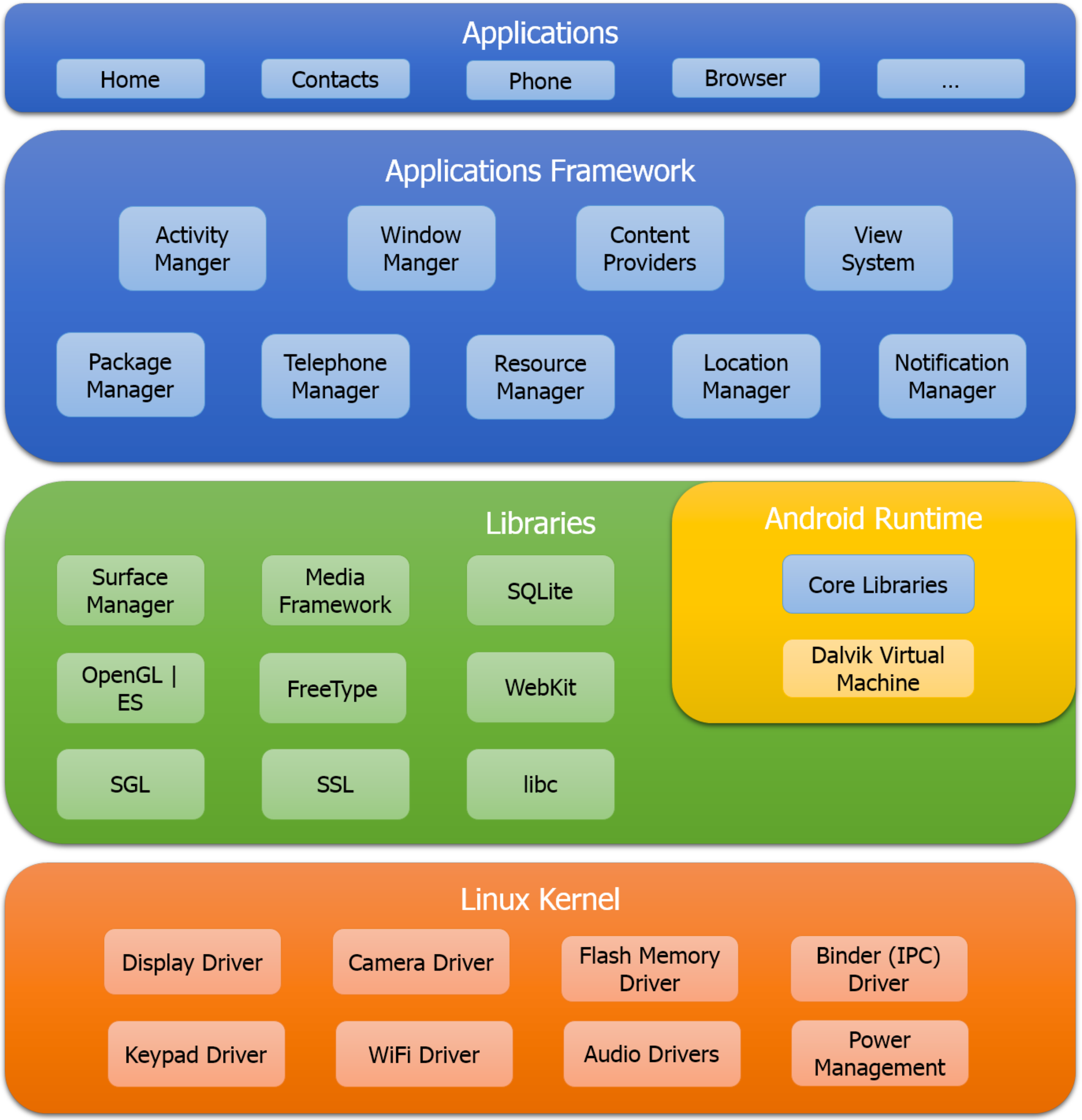
Problem


Applications
Home
Contacts
Phone
Browser
...
Applications Framework
Activity Manger
Window Manger
Content Providers
View System
Package Manager
Telephone Manager
Resource Manager
Location Manager
Notification Manager
Libraries
Surface Manager
Media Framework
SQLite
OpenGL | ES
FreeType
WebKit
SGL
SSL
libc
Android Runtime
Core Libraries
Dalvik Virtual Machine
Linux Kernel
Display Driver
Camera Driver
Flash Memory Driver
Binder (IPC) Driver
Keypad Driver
WiFi Driver
Audio Drivers
Power Management

Problem

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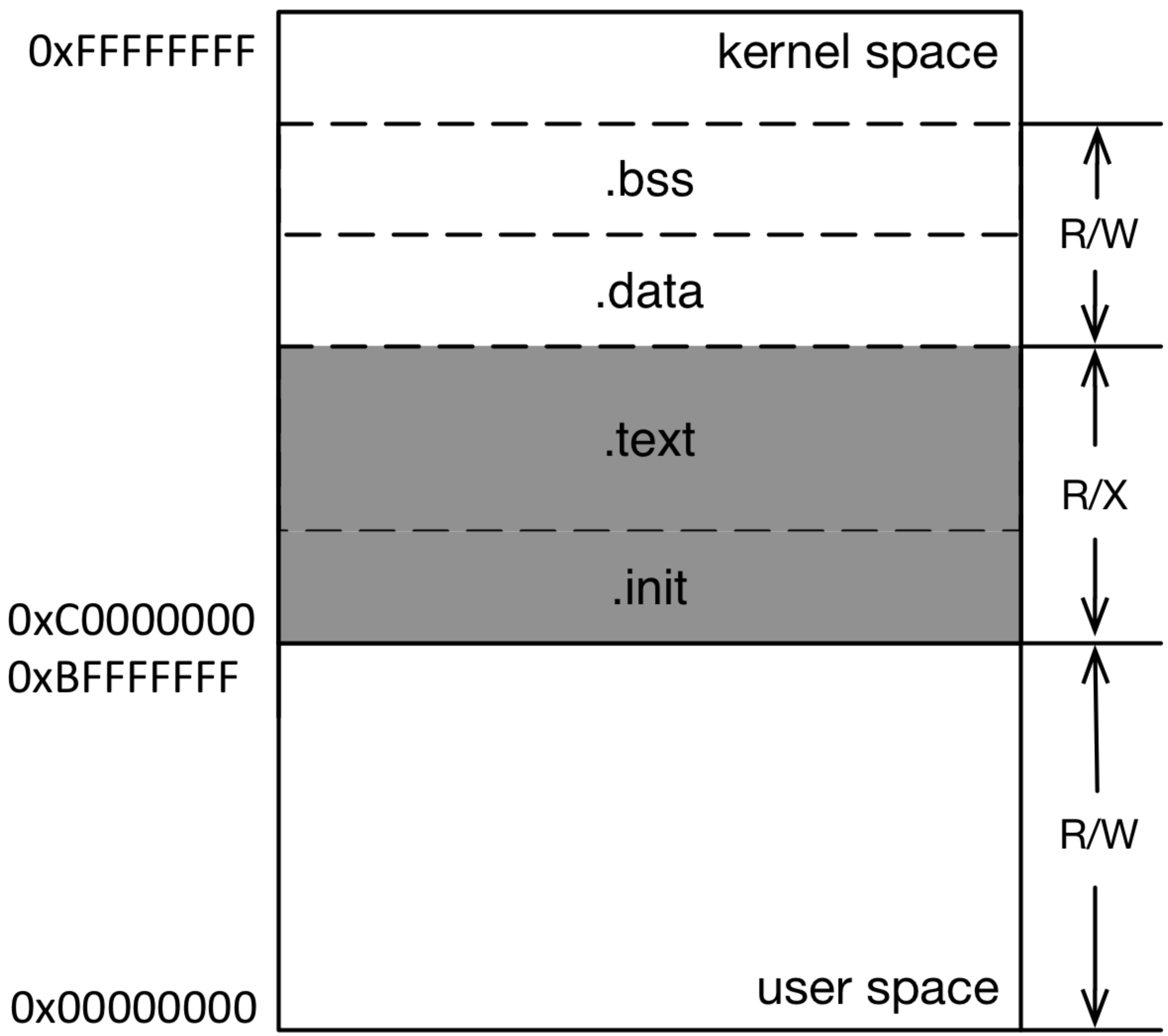
- Kernel rootkits are now becoming a serious threat to smartphone operating systems (e.g., Android)
  - CVE-2011-1823: an integer overflow bug in a daemon process on Android 3.0 enables an adversary to gain root privilege and install a kernel rootkit
  - Motivation: Protect the kernel code integrity despite of the presence of kernel rootkits

Preliminary Defenses

- W⊕X Protection
  - Background: eXecute-Never (XN) bit
  - A virtual memory page cannot be set as writable and executable at the same time
- Privileged eXecute-Never
  - Prohibit user code from executing in the kernel

Preliminary Defenses



Possible Attacks

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- Code-Reuse Attacks
  - ret2libc attack
  - return-oriented programming
- Attack Vectors
  1. Attacks that modify the initial VM layout
  2. Attacks that remain the initial VM layout

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  - Disable the MMU

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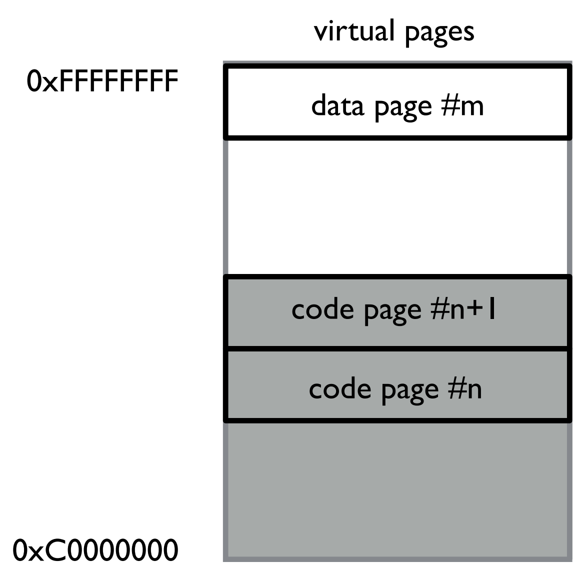

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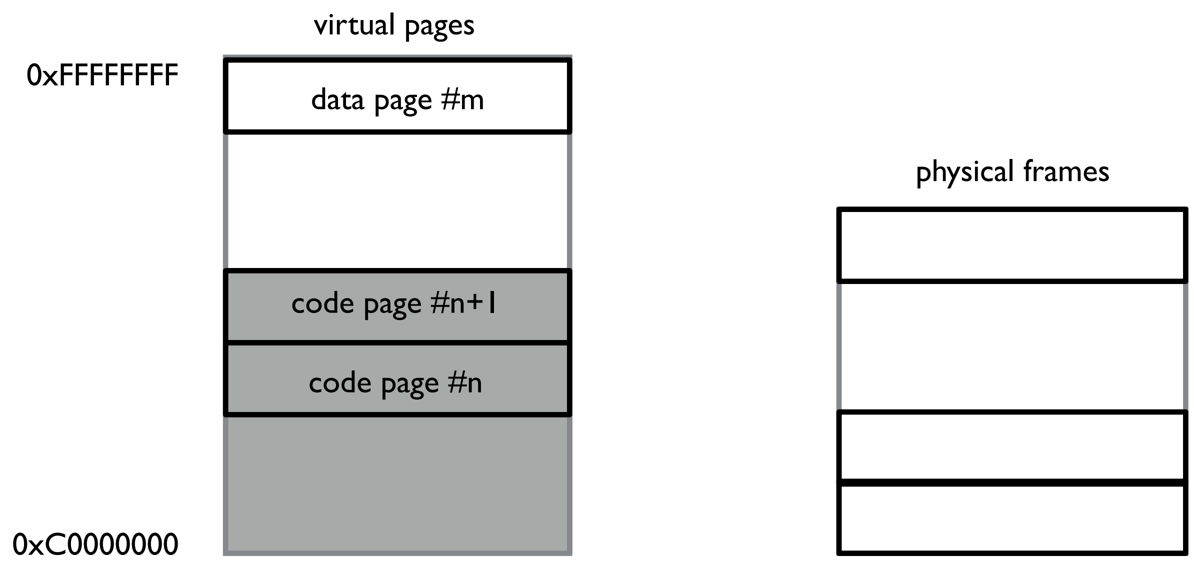

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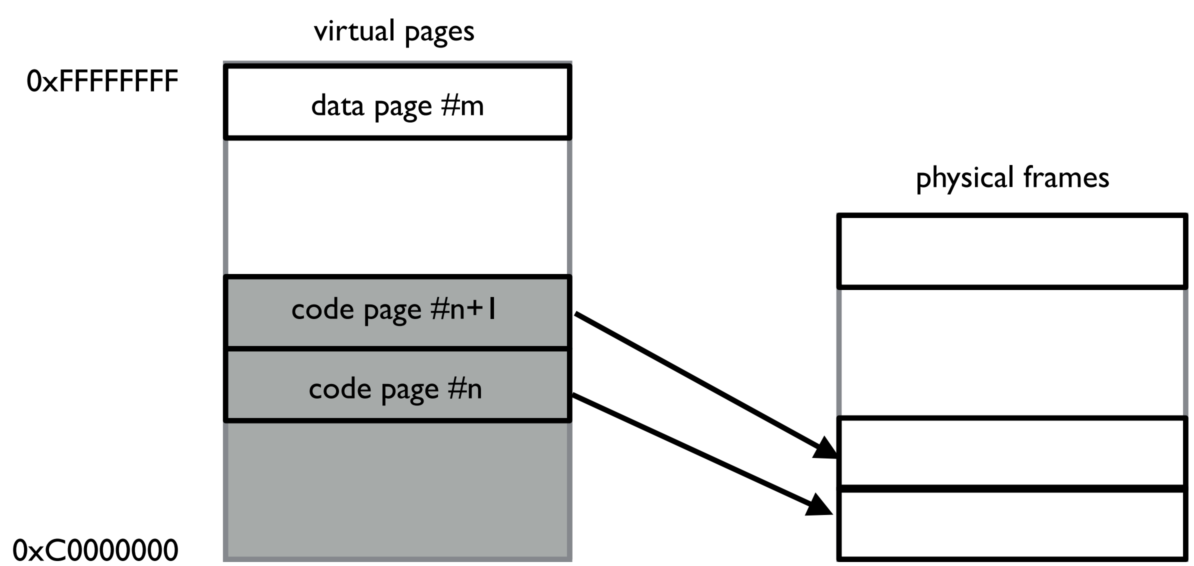

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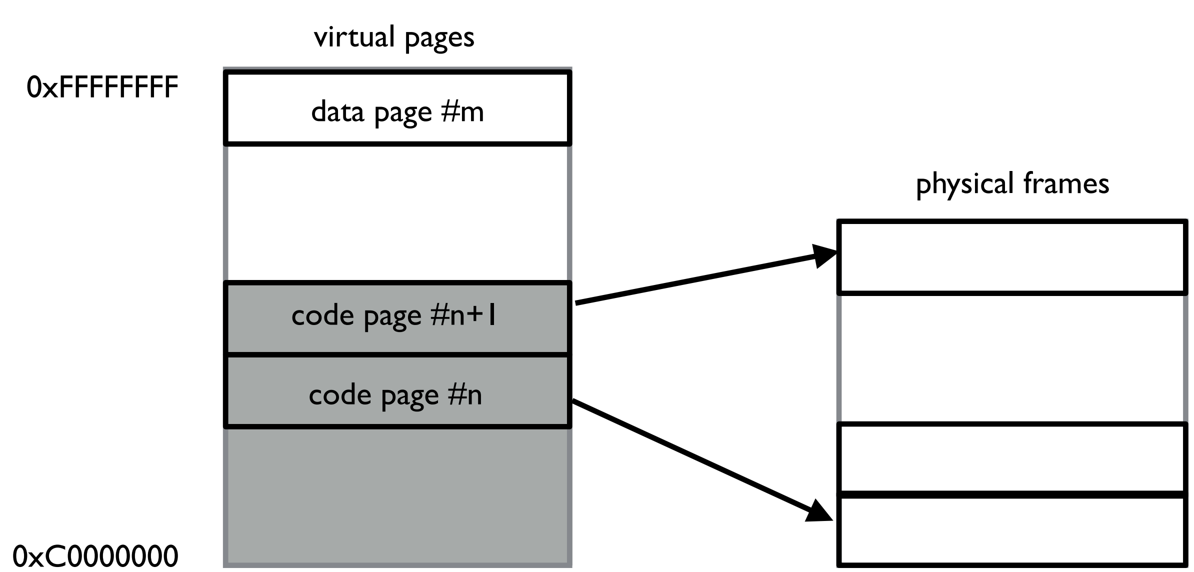

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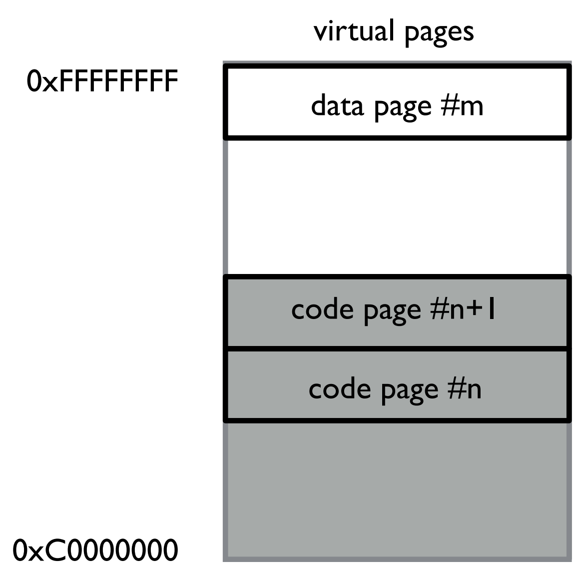

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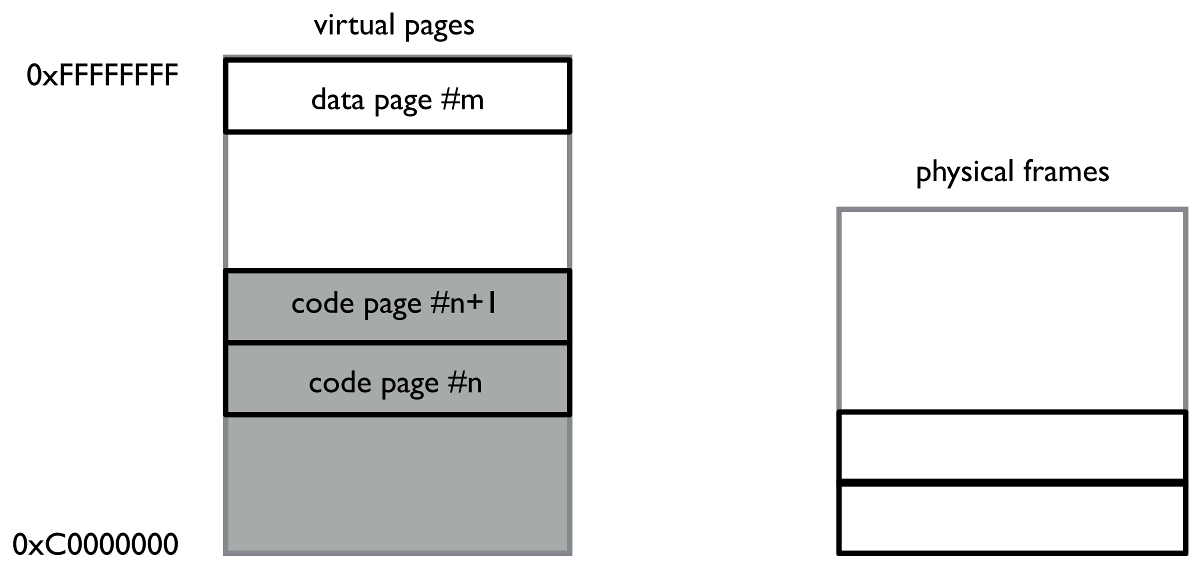

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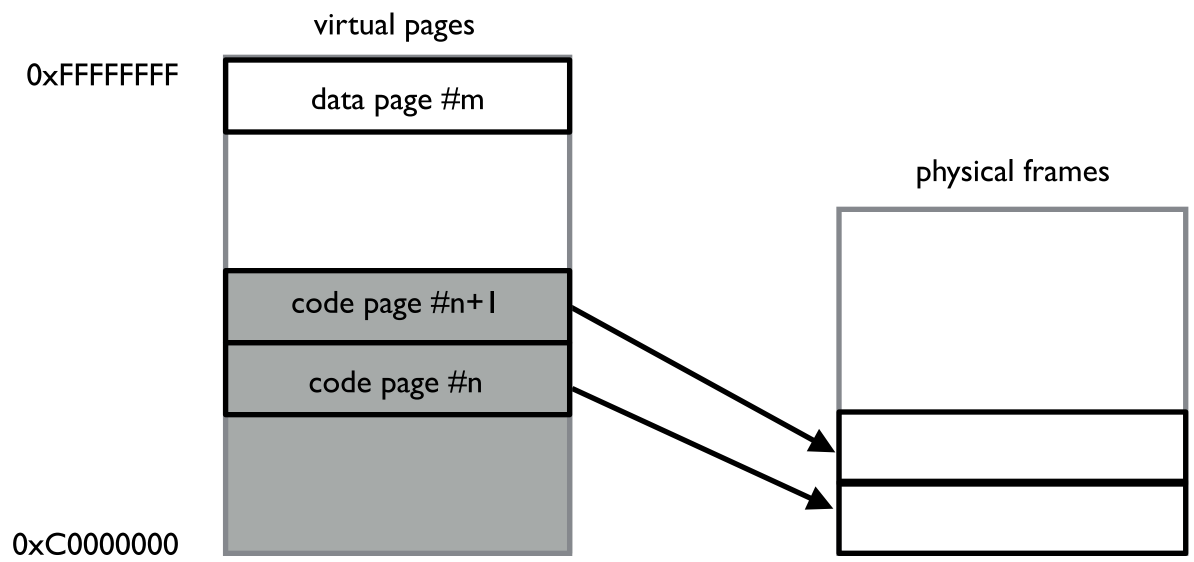

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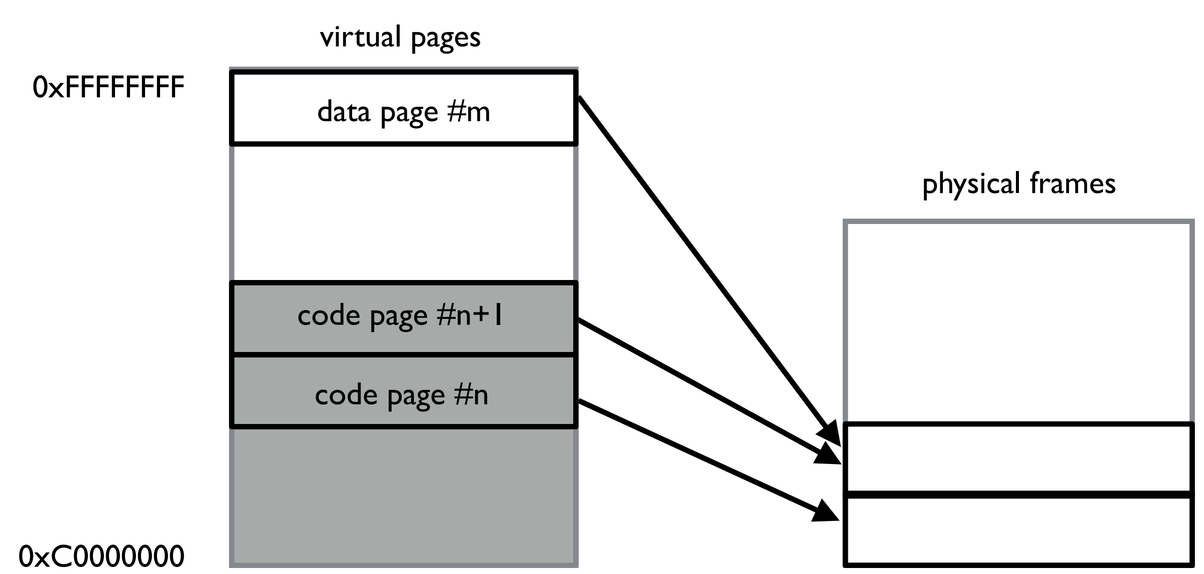

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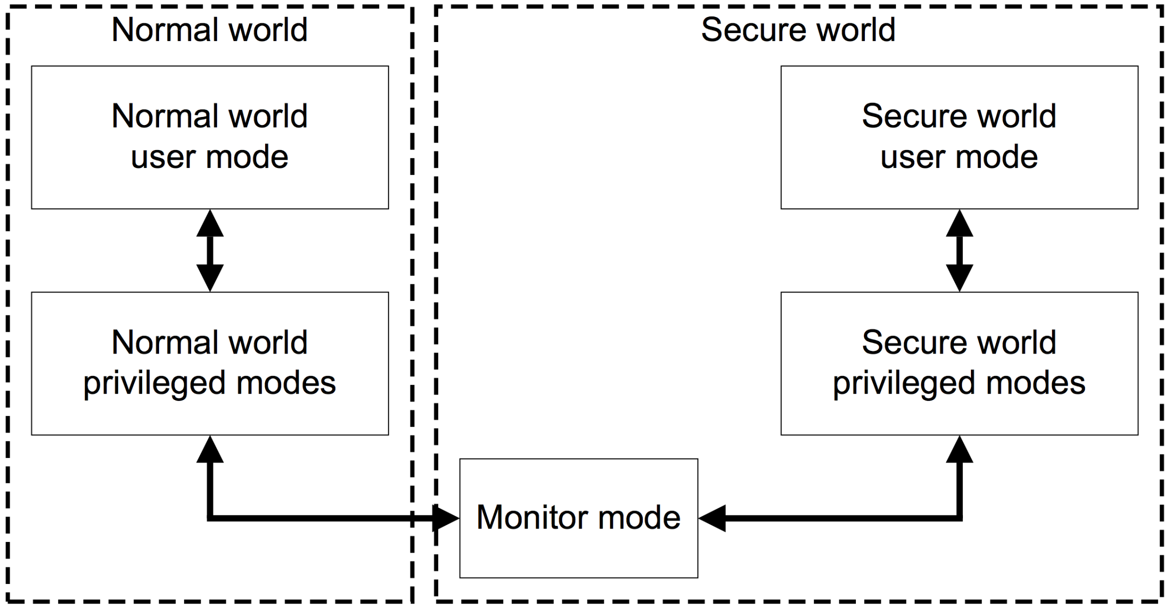
Goal

Prevent both types of attacks and limit the adversary to approved kernel code on the TrustZone

Background: TrustZone

- Resources are partitioned into two distinct worlds
  - physical memory, interrupts, peripherals, etc.
- Each world has its own autonomy over its own resources
- Secure world can access normal world resources, but *not* vice versa
- Run in time-sliced fashion



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    - write-protect the whole page tables and instrument the first instruction in page fault handler

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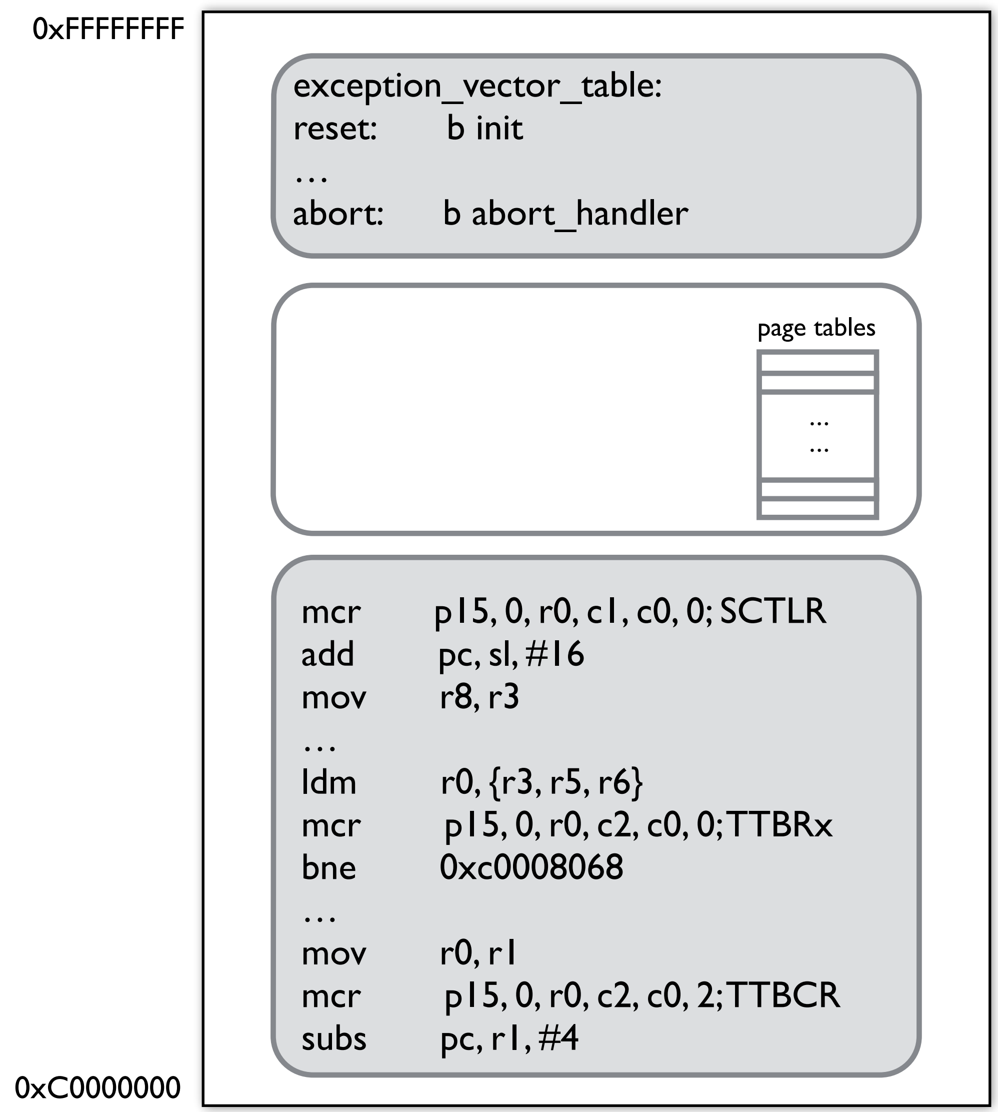

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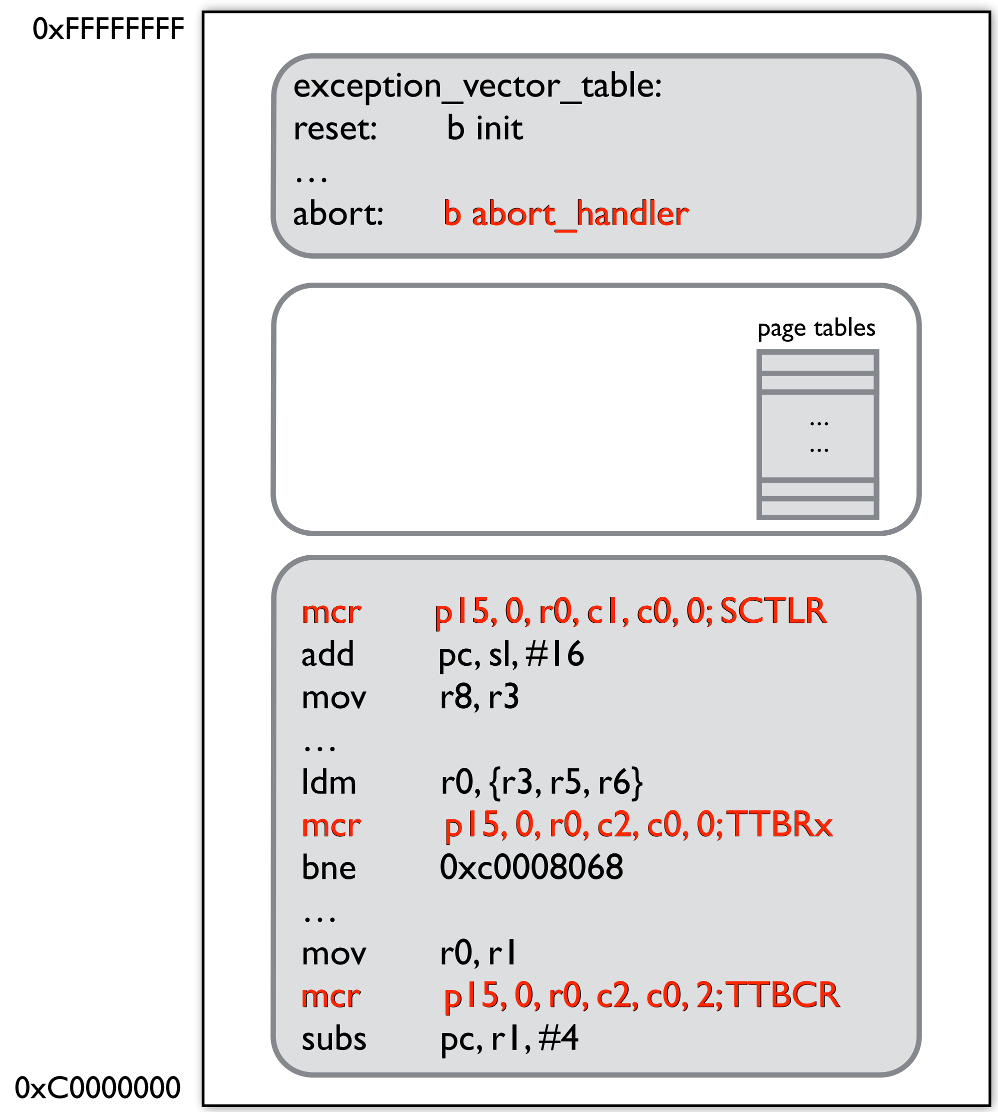

Evaluation

- Environment setup
  - Linux 2.6.38 in the normal world
  - Fast Models 8.1 for emulation
- Types of SPROBES
  - Type #1: 6 SPROBES for enforcing W⊕X protection
  - Type #2: 4 SPROBES for monitoring page table root
  - Type #3: 1 SPROBE for monitoring page table configuration
  - Type #4: 1 SPROBE for monitoring page table entries

Evaluation

- Def. Hit Frequency: the average number of instructions elapsed between two contiguous SPROBE hits

SPROBE Type	1	2	3	4
Hit Frequency	N/A	313,836	N/A	85,982
Overhead	0	1.8%	0	6.5%

Q & A