Protecting Kernels from Untrusted Modules using Dynamic Binary Instrumentation

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Kernel modules cannot be trusted

Two thirds of all kernel vulnerabilities reside in kernel modules [CVE 2010].

Kernel modules can be:
- Malicious
- Buggy
- Exploited

Modules can compromise:
- Control-flow integrity
- Data integrity
- Both (e.g. stack integrity)

Existing kernel protection methods

Existing solutions cannot secure against all native kernel modules. They either:
- Secure only virtualized modules (HURO, Gateway, etc.)
  - Many native modules cannot be run under virtualization
- Secure only modules whose source code is available (BGI, LXFl, etc.)
  - Many modules are provided as pre-compiled binaries by third-party vendors

Goals and Approach

Goals:
- Secure all kernel modules
- Secure pre-compiled binary modules
- No overhead when running in the kernel

Approach:
- Secure modules by modifying their binary code at runtime using DynamoRIO Kernel (DRK)
- Instrument only while the module code is running

Kernel modules will be secured in three steps:
1. Isolate modules in separate protection domains
2. Mediate all control transfers between the kernel and its modules
3. Verify all memory accesses by modules

Challenges

Securing kernel modules is challenging:
- ✓ Interrupt handling
- ✓ Complex kernel interface
- X Sensitive kernel data exposed through shared data, macros, etc.
  - BGI and LXFl lead the way
- X Difficult to maintain integrity of kernel stack
  - Call/return consistency is manageable
  - Data consistency is challenging

Architecture

Dynamic Binary Instrumentation

Control flow transfers are mediated by kernel-to-module and module-to-kernel wrappers

The module is just-in-time compiled into a private DRK code cache

Problematic instructions are identified

Instrumented code is stored as basic blocks

Instrumentation code enforces read and write permissions stored in shadow memory.

Original Code

```
_module_func:
    pushq %rbp
    ...
    cmp $0, %eax
    jle LABEL_2
    callq *(%rax)
    jmp LABEL_3

LABEL_2:
    mov $0, -16(%rbp)
    ...
    popq %rbp
    ret
```

Instrumented Code

```
_instrumented_func:
    pushq %rbp
    ...
    cmp $0, %eax
    jle LABEL_2
    ...
    pushq %rax
    ...
    popq %rbp
    ret
```

Summary

- Protect the kernel from malicious or misbehaving modules
- Use DynamoRIO Kernel to secure pre-compiled binary modules
- Run non-module kernel code natively without overhead