Protecting Kernels from Untrusted Modules using Dynamic Binary Instrumentation

Akshay Kumar
ak.kumar@mail.utoronto.ca

Peter Goodman
pag@cs.toronto.edu

Angela Demke Brown
demke@cs.toronto.edu

Ashvin Goel
ashvin@eecg.toronto.edu

University of Toronto

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 (HUKO, Gateway, etc.)
  - ✘ Many native modules cannot be run under virtualization
- Secure only modules whose source code is available (BGI, LXFI, 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

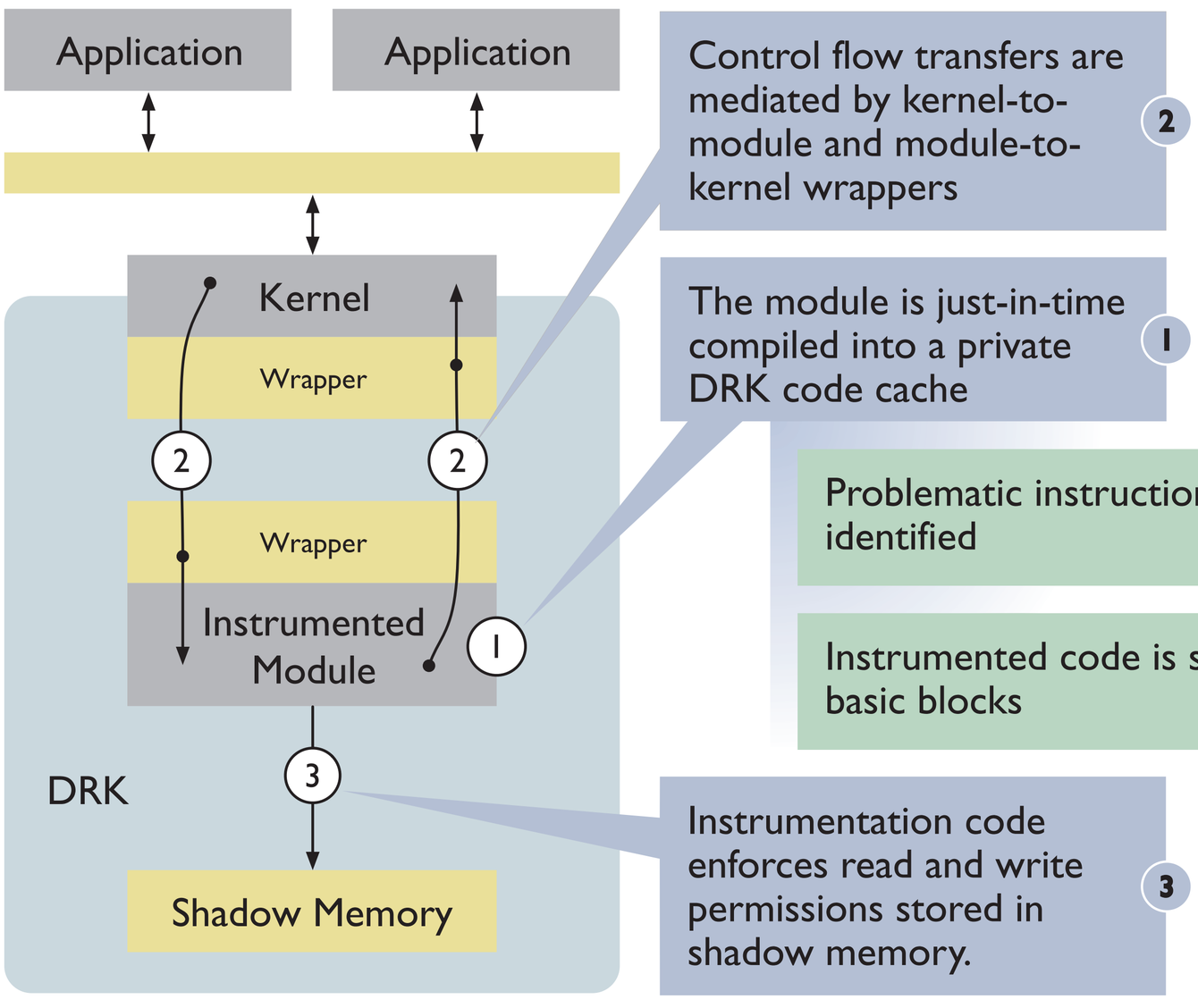
Challenges

Securing kernel modules is challenging:
- ✔ Interrupt handling
- ✔ Complex kernel interface

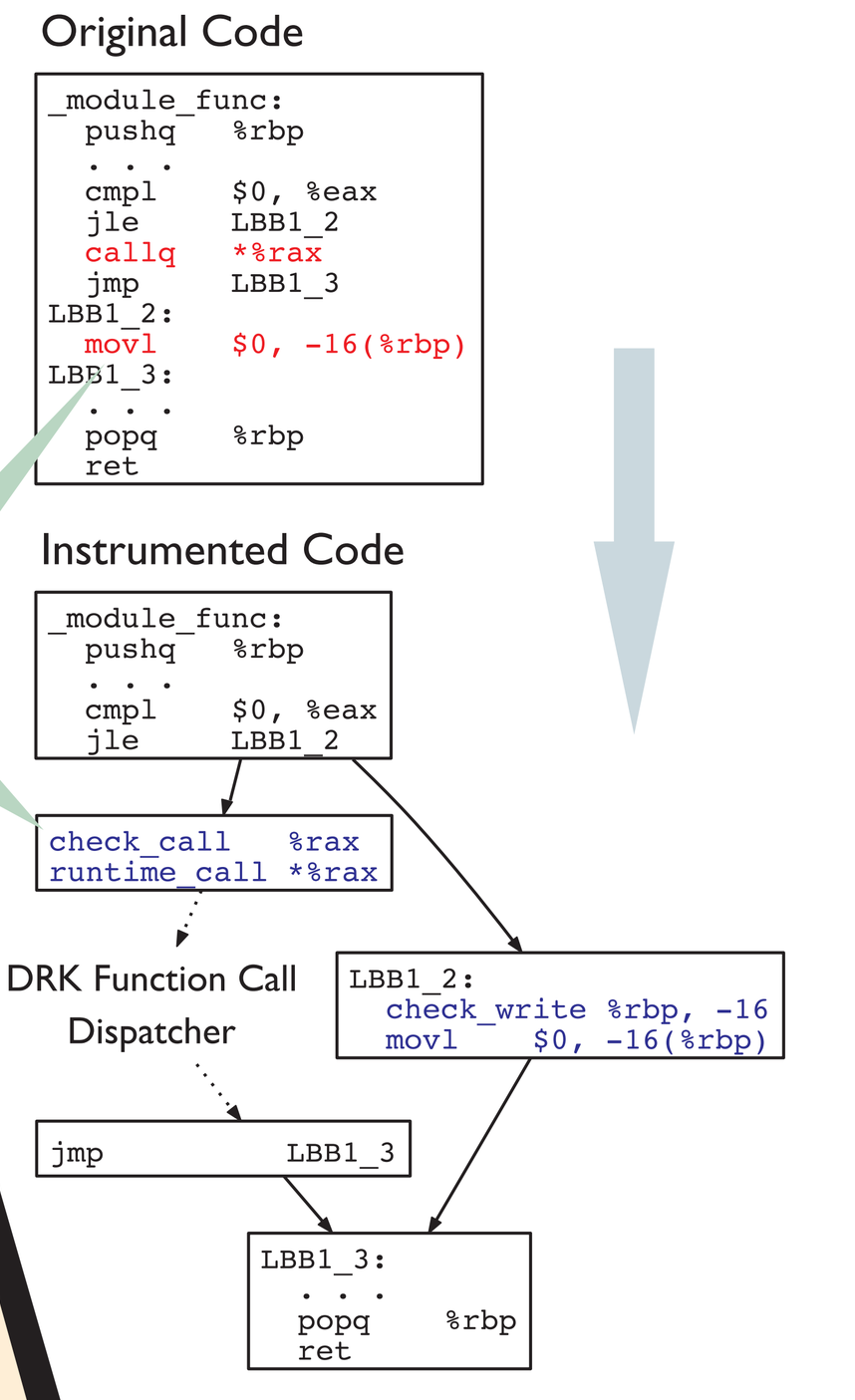
- ✘ Sensitive kernel data exposed through shared data, macros, etc.
  - BGI and LXFI lead the way

- ✘ Difficult to maintain integrity of kernel stack
  - Call/return consistency is manageable
  - Data consistency is challenging

Architecture



Dynamic Binary Instrumentation



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