Container IMA using eBPF

Avery Blanchard and Lily Sturmann
Red Hat Emerging Technologies

March 22, 2023 Container Plumbing Days 2023

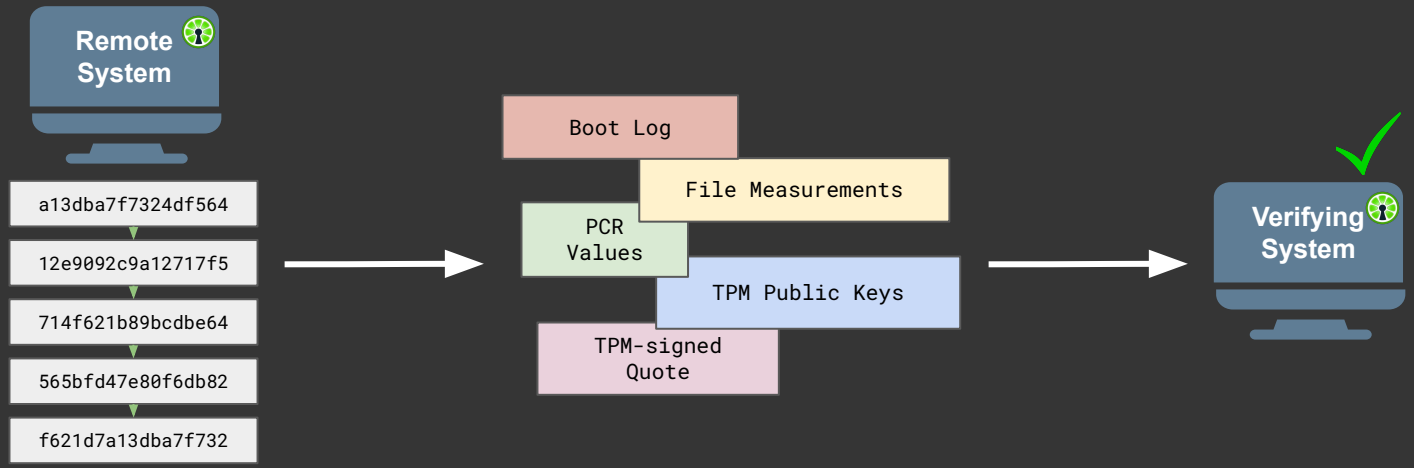
Red Hat

Overview

- Motivation
- Background
- Threat Model
- Implementation Details
- Future Work

Motivation

Extending Keylime remote attestation framework to individual containers



Using eBPF provides visibility for IMA while requiring no changes to the Linux kernel

Linux Integrity Measurement Architecture IMA

- Linux kernel's integrity subsystem
- IMA implementation
  - Measurement
  - Attestation
  - Appraisal
- Individual container integrity cannot be monitored by IMA as it measures the system as a whole

Zohar, M. An overview of the linux integrity subsystem. [LWN.net] . https://lwn.net/Articles/420001/
Red Hat on IMA: https://www.redhat.com/en/blog/how-use-linux-kernels-integrity-measurement-architecture

Trusted Platform Module TPM

- Microcontroller that can securely store artifacts used to authenticate the platform
- Components of a TPM
  - Non-volatile secure storage
  - Platform Configuration Registers PCR
  - Cryptographic functions (key generation, random number generation, hashing)
  - Platform Identity Keys
- Uses: remote attestation, secure boot, encrypted devices

Trusted platform module (TPM) summary. Trusted Computing Group. (2018, March 7). Retrieved October 27, 2022, from https://trustedcomputinggroup.org/resource/trusted-platform-module-tpm-summary/

TPM: chain of trust

Each measurement in the chain incorporates the ones before it to form an immutable record.

hash (event1) = h1

hash (h1 : hash(event2)) = h2

hash (h2 : hash(event3)) = h3

Measurements signed by TPM's private key

eBPF

- Mechanism to provide a sandboxed runtime environment inside the kernel
- Programs can be attached in various places in the kernel including in system call and various kernel subsystems

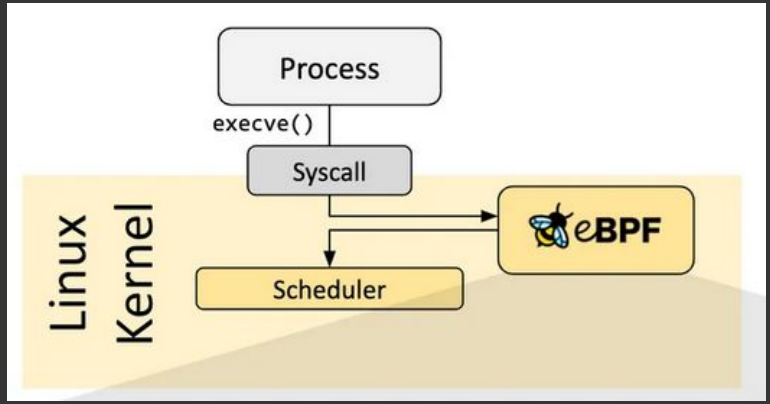


Image credit: https://ebpf.io/what-is-ebpf/

Threat Model

- Host is trusted and local attacker cannot gain ownership of the TPM
- Focus: local and remote adversaries
- Various attacks on file integrity, authenticity, confidentiality (ie. attempting to run malicious code, offline attacks)
- Detect if container integrity has been compromised, not protect against such compromise

Requirements

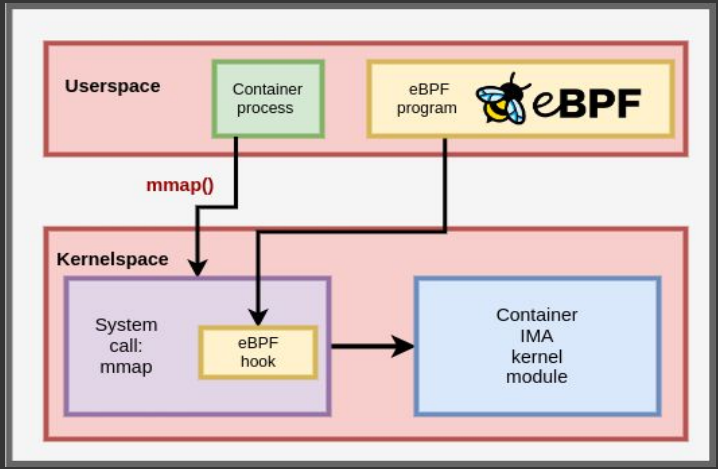
- Must provide the same functionality and interface for remote attestation as IMA
- Should not affect host IMA processes
- Architecture should not impeded the host’s ability to scale
- Each container should be strongly associated with its IMA resources

Implementation

- Probe attests to the kernel module
- Kernel module is signed and signature is checked at boot by the OS
- Measurements are invoked by the probe
- IMA resources are namespaced
- Measurements are extended to a container's SWTPM

Architecture

- eBPF probe: **visibility** into a container's executable content **without changes to the kernel**
- Kernel Module: signed and included into a secure boot kernel to **extend trust**



Probe Design

- eBPF program inserted into mmap system call implementation
- Invoke integrity measurement for executable content mapped by a container
- Parameters passed by probe to kernel module: namespace, address pointer, file descriptor, offset, flags, protocol

Kernel Module Design

- Measures and stores file integrity information
- Measurements are extend to PCR
- The value of the PCR is signed for per container attestation
- Container IMA data is separated by their namespace
- Signed to be included in a secure boot system

Future Work

- Allow for multiple policies (differing between container / host)
- Reduce complexity and overhead for scale
- Benchmarking
- Implement IMA appraisal

Thank you!

Keylime https://keylime.dev/

- Remote attestation and runtime integrity monitoring tool
- Utilizes IMA and TPM

Red Hat