健康資訊交換系統中之容器安全

The Container Security in Healthcare Data Exchange System

國立中山大學資訊工程學系

Department of Computer Science and Engineering

National Sun-Yet-San University, Taiwan

110 學年度大學部專題製作競賽

Bachelor's degree graduation project in 2021

Author: Chih-Hsuan Yang (B073040047)

Advisor: Chun-I Fan

October 12, 2021

Abstract

This research proposes a mechanism to enforce the system call a specific policy in the container, which is deployed in runtime. This policy is designed for the FHIR healthcare data exchange standard's container, which could guarantee the FHIR server does not have unsupported behavior and takes almost zero overhead. Recently, many companies use containers to run their microservices since containers could make their hardware resources be used efficiently. And the newest healthcare data exchange standard FHIR (Fast Healthcare Interoperability Resources) [1] has been implemented in a container by IBM, Microsoft, and Firebase. The deployment of FHIR in a container is a trend in the digital world [1]. However, containers are not sandboxes [2] . Containers are just isolated processes [2]. Therefore, if hackers or malicious software could sneak into the container that would be a new cyber attacking surface in nearly future.

[1] FHIR official: https://www.hl7.org/fhir/

[2] gVisor GitHub: `https://github.com/google/gvisor`

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Chapter 1

Introduction

1.1 Container and Linux Kernel

The container is a secondary product of the operating system in the past 20 years. The FreeBSD develops ‘Jails’ in 1999, and the Solaris develops ‘Zones’ in 2004. Linux also took this idea into the Linux kernel, which is named cgroups (2007), the capabilities (2003), and seccomp (2005). However, why the Linux breaks this technology into many parts? This is because they had discussed: ”Why Should a System Administrator Upgrade?” in 2001 [1]. The Linux kernel almost entered the development path of ”upgrade for demand” like Microsoft Windows, and deviated from the original path of ”providing a mechanism but not a strategy” of the original Linux kernel.

While Linux were spreading in various server or distributed system, the Linux community got more pull requests to solved the scalability and virtualization issues [3]. However, they avoided confusion caused by multiple meanings of the term ”container” in the Linux kernel context. In kernel version 2.6.24 (2007) [2], control groups functionality was merged into the mainline, which is designed for an administrator (or administrative daemon) to organize processes into hierarchies of containers; each hierarchy is managed by a subsystem. Moreover, the cgroups was rewrote into cgroups-v2 in Linux kernel 4.5 (2015) [3].

The first and most complete implementation of the Linux container manager was LXC (Linux Containers). It was implemented in 2008 using cgroups and namespaces, and it runs on a single Linux

[1] Version 2.4 of the LINUX KERNEL–Why Should a System Administrator Upgrade? https://www.informit.com/articles/article.aspx?p=20667

[2] Notes from a container: https://lwn.net/Articles/256389/

[3] Control Group v2: https://www.kernel.org/doc/Documentation/cgroup-v2.txt

kernel without requiring any patches. LXC provides a new view and imagination of virtualized services without any hypervisor. In 2016, Docker replaced LXC with ”libcontainer”, which was written in the Go programming language. Docker combined features in a new, more attractive way and made Linux containers popular.

The secondary product of the operating system, containers, offering many advantages: they enable you to ”build once, run anywhere.” Docker does this by bundling applications with all their dependencies into one package and isolating applications from the rest of the machine on which they’re running. Therefore, this research is based on docker container to propose a scheme of healthcare data exchange system’s security.

1.2 FHIR

FHIR is a standard for healthcare data exchange. The FHIR standard will be used in Taiwan in the near future. FHIR will be used to provide PHR (Personal Healthcare Records) in Taiwan. Therefore, we choose the most popular standard ”FHIR” for the target of the healthcare data exchange system.

1.2.1 RESTful API and Data Structure

REST (Representational State Transfer) is a stateless reliable web API, which is based on HTTP methods to access resources or data via URL parameters and the use of JSON or XML format to transmit queries. Because the RESTful is stateless, the client should keep their information (i.e. cookies) by themself.

FHIR has features: RESTful and data structure, make our research and benchmarks more accurate and reliable. Statelessness is a developer-friendly feature, the developer and the tester would not to design a complex state machine on the server-side or generating test files. And the FHIR takes RESTful as standard. Moreover, FHIR standard declared the ‘StructureDefinition’ [4]. These structure definitions are used to describe both the content defined in the FHIR specification itself - Resources, data types, the underlying infrastructural types, and also are used to describe how these structures are used in implementations.

[4] FHIR Resource Structure Definition: http://www.hl7.org/fhir/structuredefinition.html

1.2.2 Why IBM FHIR server

There are many applications using IBM's FHIR server as the base component of the EHR (Electronic Health Records) system to communicate with the other various databases. Take it for example that the NextCloud's EHR service, Taipei Veterans General Hospital, and AWS Cloud are using the FHIR server in a container for subroutine service.

NextCloud is an open-source and self-hosted productivity platform for users. Many people caring about their privacy issues distrust the FAANG (Facebook, Amazon, Apple, Netflix, Google), so they are using NextCloud to keep their privacy on their own. Therefore, they are eager to have a secure EHR system for their PHR [5].

1.3 Data and Privacy

TBD.

[5] Richard Stallman talks about IoT

Chapter 2

Related Work

2.1 Collecting System Calls

There are several pieces of research to detect intrusions or unexpected behaviors by collecting the system calls methods in runtime [4, 5, 6, 7]. Amr S. Abed et al.[4] proposed a real-time host-based intrusion detection system in a container, which is based on system call monitoring. They use the ‘strace’ command to collect a behavior log to a system call parser. Then use the BoSC (Bag of System Calls) [8] to classify is it a normal behavior in the database.

The BoSC technique is a frequency-based detection tip. Kang et al.[8] defined those distinct system calls in $\{c_1, c_2, \ldots, c_n\}$, $\forall$ system call s_i had been called in c_i times. And they use Naïve Bayes classification to deduce if it is unexpected behavior. Then the Amr S. Abed et al. give the false positive rate around 2% in $O(S + n_k)$ epochs to the MySQL database [4].

- Epoch Size (S): The total number of system calls in one epoch.
- n_k: It is the size of the database after epoch k.

However, the BoSC is running in user space, even though it is a background service running on the same host kernel. It might have heavy constant time costs of copying data from user to kernel and kernel to user by the ‘copy_to_user()’ and ‘copy_from_user()’ calls.

Mohamed Azab et al.[6, 7] takes a mathematical model to simulate the smart moving target defense for Linux container resiliency. Considering an ‘ESCAPE’ model is the interaction between attackers and their target containers as a “predator searching for a prey” search game. This search game has 3 modules: behavior monitoring, the checkpoint/restore, and the live migration modules. This model is running on the same host and the same attacking surface because they considered the containers (prey) are running on the same machine with some migration probability.

They show the survival rate in Amr S. Abed et al.[4] model for some zero-day vulnerabilities in different types and numbers machines. Mohamed Azab et al. [6, 7] concluded that an IDS could detect and avoid mobile continually-growing attacks efficiently by the 'ESCAPE' model with collecting system calls.

2.2 Fine-grained Permission Control

2.2.1 Capabilities

There are 49 different capabilities in todays Linux kernel 5.13 [1]. A capability can be assign to a task (i.e thread or process) to determine if the task can use the fine-granted system calls. For example, we give a thread CAP_SYS_BOOT, then the thread can use the reboot [2] and the kexec_load [3] system call.

Xin Lin et al.[9] collected 27 CVE vulnerabilities could cause the privilege escalation attacks. There are only 3 vulnerabilities could bypass the capabilities protection of Linux kernel. And the other 24 escalation vulnerabilities, could be filtered by the fine-grained permission control with capabilities. Those 3 (CVE-2016-8655, CVE-2017-5123, CVE-2017-7308) bypassed capabilities vulnerabilities are attacking kernel level race conditions.

The CVE-2016-8655[4] is a bug in net/packet/af_packet.c. We often use the CAP_NET_RAW namespace in the container to make unprivileged user be able to use some privileged net-util commands. The bug is that there exists a race condition probability to race the unauthorized data inside packet_set_ring() and packet_setsockopt()[5] such that there is a chance to modify the socket version to TPACKET_V_1 before the packet_set_ring function. However, it would be 'kfree' the timer in the TPACKET_V_1. Then we can take the timer, which is used after free, to control the SLAB adopter to write the st_uid by itself [6].

[1] https://man7.org/linux/man-pages/man7/capabilities.7.html

[2] https://man7.org/linux/man-pages/man2/reboot.2.html

[3] https://man7.org/linux/man-pages/man2/kexec_load.2.html

[4] https://cve.mitre.org/cgi-bin/cvename.cgi?name=CVE-2016-8655

[5] Linux af_packet.c race condition (local root) https://lwn.net/Articles/708319/

[6] CVE-2016-8655 PoC: https://www.exploit-db.com/exploits/40871

2.2.2 Linux Secure Module

There were many researches designing great rules of the LSM (Linux secure module). LSM is a mandatory access control framework in kernel, which supported from Linux 2.6 (2004). The AppArmor[7] and SELinux[8] are common LSM in the kernel. All the Android devices are fully enforced the SELinux after Android 5.0. [9]

The SIDs (Security IDs) and permissions, which are the identifiers for access control policies, make up the security policy of SELinux or AppArmor. Files and directories, which are the actual protected objects for the SID, are mapped to the SELinux or AppArmor of each system [10, 11, 12]. The SELinux is much more incredibly complex then AppArmor, but with this complexity you have more control over how tasks are isolated. However, the AppArmor is so straight forward that peoples can write the configuration profile by themself.

SUNG-HWA HAN et al.[13] had proposed an architecture to enforce the access control of image's layers. Because the docker engine does not guarantee the layers could not be modified by the host environment. Therefore, if we give a container privileged permission, it could modify the layers of images. The research [13] is using the LSM's policy table to enforce the access control of file system in kernel.

This paper [13] shows that the performance is almost same as raw SELinux, and the branch costs of indexing the policy table could be a constant value in the CPU rate measurement. However, the research is only be measured in overlay2 file system. SUNG-HWA HAN et al. said if it have same performance in AUFS or the other file systems, the above results could be more reliable.

Yuqiong Sun et al.[14] proposed separate the security namespace. Each container can route their operation to different security namespaces for their ”comment”. Each involved the security namespace independently makes a security decision, and the operation is allowed only if all the secure namespaces allow.

The policy engine and the security namespace are implemented in . . .

[7] https://apparmor.net/

[8] https://github.com/SELinuxProject/selinux

[9] https://source.android.com/security/selinux#supporting_documentation

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