Towards Adaptive Process Confinement Mechanisms

COMP5900I Literature Review

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Abstract

[Come back hither when done.]

1 Introduction

Restricting unprivileged access to system resources has been a key focus of operating systems security research since the inception of the earliest timesharing computers in the late 1960s and early 1970s [cite]. In its earliest and simplest form, access control in operating systems meant preventing one user from interfering with or reading the data of another user. The natural choice for these early multi-user systems, such as Unix [29], was to build access control solutions centred around the user model—a design choice which has persisted in modern Unix-like operating systems such as Linux, OpenBSD, FreeBSD, and MacOS. Unfortunately, while user-centric permissions offer at least some protection from other users, they fail entirely to protect users from *themselves* or from their own *processes*. It was long ago recognized that finer granularity of protection is required to truly restrict a process to its desired functionality [26]. This is often referred to as *the process confinement problem* or *the sandboxing problem*.

Despite decades of work since Lampson's first proposal of the process confinement problem in 1973 [26], it remains largely unsolved to date [8]. This begs the question as to whether our current techniques for process confinement are simply inadequate for dealing with an evolving technical and adversarial landscape. [Rework the commented part]

The rest of this paper proceeds as follows. Section 2 presents the process confinement threat model and examines the motivation for considering process confinement from an adaptive security perspective. Section 3 discusses traditional approaches to process confinement, both historical and state-of-the-art. Section 4 and Section 5 discuss automatic and semi-automatic approaches for policy generation and policy audit respectively. Section 6 discusses moving toward truly adaptive process confinement mechanisms and argues that new operating system technologies coupled with well-known techniques from the anomaly detection literature may enable a paradigm shift in this direction. Section 7 concludes.

2 Motivation

2.1 The Process Confinement Threat Model

To understand why process confinement is a desirable goal in operating system security, we must first identify the credible threats to system stability and security that process confinement addresses. To that end, I first describe three attack vectors (items A1 to A3), followed by three attack goals (items G1 to G3) which highlight just a few of the credible threats posed by unconfined processes running on a given host.

A1. Compromised processes. Unconfined running processes have classically presented a valuable target for attacker exploitation. With the advent of the Internet, web-facing processes which handle untrusted user input are especially vulnerable, particularly as they often run with heightened privileges [7]. The attacker may send specially crafted input to the target application, hoping to compromise its control flow integrity via a classic buffer overflow, return-oriented programming [31], or some other means. The venerable Morris Worm, regarded as the first computer worm on the Internet, exploited a classic buffer overflow vulnerability in the `fingerd` service for Unix, as well as a development backdoor left in the `sendmail` daemon [37]. In both cases, proper process confinement would have eliminated the threat entirely by preventing the compromised programs from impacting the rest of the system.

A2. Semi-honest software. Here, I define semi-honest software as that which appears to perform its desired functionality, but which additionally may perform some set of unwanted actions without the user's knowledge. Without putting a proper, external confinement mechanism in place to restrict the behaviour of such an application, it may continue to perform the undesired actions ad infinitum, so long as it remains installed on the host. As a topical example, an `strace` of the popular Discord [10] voice communication client on Linux reveals that it repeatedly scans the process tree and reports a list of *all applications* running on the system, even when the "display active game" feature is turned **off**. This represents a clear violation of the user's privacy expectations.

A3. Malicious software. In contrast to semi-honest software, malicious software is that which is expressly designed and distributed with malicious intent. Typically this software would be downloaded by an unsuspecting user either through social engineering (e.g. fake antivirus scams) or without the user's knowledge (e.g. a drive-by download attack). It would be useful to provide the user with a means of running such potentially untrustworthy applications in a sandbox so that they cannot damage the rest of the system.

G1. Installation of backdoors/rootkits. Potentially the most dangerous attack goal in the exploitation of unconfined processes is the establishment of a backdoor on the target system. A backdoor needn't be sophisticated—for example, installing the attacker's RSA public key in `ssh`'s list of authorized keys would be sufficient—however the most sophisticated backdoors may result in permanent and virtually undetectable escalation of privilege. For instance, a sophisticated attacker with sufficient privileges may load a *rootkit* [3] into the operating system kernel, at which point she has free reign over the system in perpetuity (unless the rootkit is somehow removed or the operating system is reinstalled).

G2. Information leakage. An obvious goal for attacks on unconfined processes (and indeed the focus of the earliest literature on process confinement [26]) is information leakage. An adversary may attempt to gain access personal information or other sensitive data such as private keys, password hashes, or bank credentials. Depending on the type of information, an unauthorized party may not even necessarily require elevated privileges to access it—for instance, no special privileges are required to leak the list of processes running on a Linux system, as in the case of Discord [10] highlighted above.

G3. Tampering and denial of service. **[Write this]**

[Talk about how the internet has exacerbated this problem]

2.2 Defining Adaptive Process Confinement

Here, I define adaptive process confinement mechanisms as those which greatly help defenders confine their processes and are robust in the presence of attacker innovation. Roughly, this definition can be broken down into the following properties:

P1. Robustness to attacker innovation. An adaptive process confinement mechanism should continue to protect the host system, even in the presence of attacker innovation. That is, it should be resistant to an adaptive adversary.

P2. Low adoption effort. An adaptive process confinement mechanism should require minimal effort to adopt on a variety of system configurations.

P3. High reconfigurability. An adaptive process confinement mechanism should be highly reconfigurable based on the needs of the end user and the environment in which it is running. This reconfiguration could either be automated, semi-automated, or manual, but should not impose significant adoptability barriers (c.f. P2).

P4. Transparency. An adaptive process confinement mechanism should be as transparent to the end user as possible. It should not get in the way of ordinary system functionality.

P5. Usability. An adaptive process confinement mechanism should maximize its usability such that it is usable by largest and most diverse set of defenders possible. In particular, it should not require significant computer security expertise from its users.

Ideally, an adaptive process confinement mechanism should have most—if not all—of the above properties.

3 Traditional Process Confinement Approaches

4 Automating Policy Generation

5 Automating Policy Audit

6 Towards Truly Adaptive Process Confinement

6.1 Anomaly Detection Techniques

6.2 Extended BPF

7 Conclusion

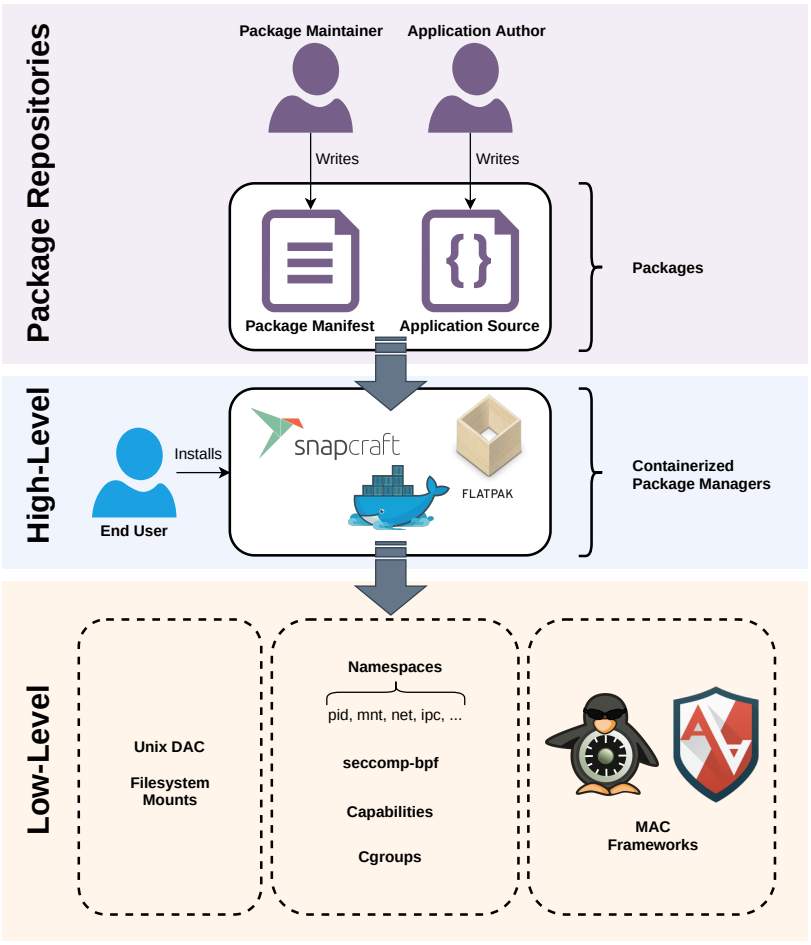

Figure 3.1: The basic architecture of containerized package management solutions for Linux, such as Snapcraft [33], Flatpak [15], and Docker [11]. Package maintainers write high-level, coarse-grained package manifests, which are then compiled into policy for lower-level process confinement mechanisms to enforce.

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