Application Containers

Introdução Engenharia Informática

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A Deep Dive into AppImage, Snap, and Flatpak

The Core Problem: “Linux Dependency Hell” 👹

Traditional Linux apps rely on **shared system libraries** (`.so` files).

- **The Conflict:**
  - App A needs `libXYZ v1.0`
  - App B needs `libXYZ v2.0`
- **The Result:**
  - Your package manager (`apt`, `dnf`) can often only install one version.
  - Installing App B breaks App A (or vice-versa).

The Need for Isolation & Portability

- **Portability:** An app packaged with its dependencies will "run anywhere" on any Linux distro, regardless of its system libraries.
- **Stability:** Apps can't conflict with each other's dependencies.
- **Security:** If an app is isolated (sandboxed), it can't read your SSH keys, browser history, or other sensitive data.

How Other OSes Handle This

This isn't just a Linux problem.

- **Windows:** Apps bundle almost *all* their `.dll` files in their installation folder (e.g., `C:\Program Files\App`).
  - **Pro:** Prevents conflicts.
  - **Con:** Lots of duplication; inefficient.
- **macOS:** `.app` "bundles" are just folders that contain the app's binary and all its libraries.
  - **Pro:** Self-contained and portable.
  - **Con:** Also duplicates libraries.

“Natural” Isolation: VMs & Runtimes

Some technologies provide isolation by their very nature.

- **Java Virtual Machine (JVM):**
  - The OS runs the `java` process, not your app directly.
  - The JVM runs the Java bytecode in a managed, sandboxed environment.

- **Python Virtual Environments (`venv`):**
  - This is **dependency isolation**, not security sandboxing.
  - Creates a local folder (`.venv`) with its own Python interpreter and packages (like `pygame`).
  - A `requirements.txt` file lists all dependencies, allowing `pip install -r requirements.txt` to create a reproducible environment, just as we did in our exercise.
  - This solves the “App A vs. App B” problem on our local machine but doesn’t stop the app from reading our files.

The Modern Linux Solutions

Three major technologies emerged to solve this for *any* application, aiming to bundle the app *and* its dependencies.

1. **AppImage** 📦
    - **Philosophy:** “One app = one file.” No installation needed.
2. **Snap** 🧩
    - **Philosophy:** “A secure, universal package.” Backed by Canonical (Ubuntu).
3. **Flatpak** 🎁
    - **Philosophy:** “The future of desktop apps.” Backed by Red Hat & the GNOME community.

Deep Dive: AppImage 📦

- **Isolation: None by default.** It's about portability, not security. The app runs as a normal user process.
  - *(Can be sandboxed by optional, external tools like `firejail`).*
- **Dependencies: "Bundle Everything."** The app bundles all libraries it needs, assuming only a minimal base system.
- **Host Access: Full User Access.** The app can see and modify anything the user who ran it can.

Deep Dive: Snap 🧩

- **Isolation: Strong Sandbox.** Uses Linux kernel features like **cgroups**, **namespaces**, and **AppArmor** to strictly confine the app.
- **Dependencies: Bundled + Core Snaps.** Apps bundle their specific libraries but also depend on a shared `core` snap (e.g., `core22`) that provides a base Ubuntu runtime.
- **Host Access: "Interfaces."** Denied by default. The app must declare what it needs (e.g., `network`, `home`, `camera`).

Deep Dive: Flatpak 🎁

- **Isolation: Strong Sandbox.** Uses kernel **namespaces** and a tool called **Bubblewrap (`bwrap`)** to create a private environment for the app.
- **Dependencies: Shared Runtimes.** An app requests a "Runtime" (e.g., `org.gnome.Platform`). This is downloaded *once* and shared by all apps that need it. Very efficient.
- **Host Access: "Portals."** Denied by default. When an app needs a file, it asks a Portal, which opens a file-picker *outside* the sandbox. The user picks a file, and *only* that file is given to the app.

Comparison: Sandboxing & Dependencies

Feature	AppImage	Snap	Flatpak
Sandboxing	❌ None (by default)	✅ Strong (AppArmor)	✅ Strong (Bubblewrap)
Permissions	Full user access	Interfaces (Declarative)	Portals (Interactive)
Dependency Model	All bundled in file	Bundled + Core snaps	Shared Runtimes

Comparison: Distribution & Backing

Feature	AppImage	Snap	Flatpak
Distribution	Decentralized (any URL)	Centralized (Snap Store)	Decentralized (Repos)
Central Backer	Community	Canonical (Ubuntu)	Red Hat / GNOME
Needs a Daemon?	❌ No	✅ Yes (`snapd`)	✅ Yes (`flatpak-daemon`)
Desktop Integration	Optional (`appimaged`)	Automatic	Automatic

Limitations: The Trade-Offs

- **Disk Space:**
  - **AppImage/Snap:** Bundling can be inefficient. A 10MB app might become a 150MB package.
  - **Flatpak:** Runtimes are large (often 500MB+), but this is a **one-time** download.
- **Startup Time:**
  - **AppImage:** Must mount the compressed file system on every launch (can be slow).
  - **Snap:** Notoriously slow *first launch* as it sets up the sandbox.

Limitations: The “Jail” Problem

- **Security vs. Usability:**
  - The sandbox is a “jail.” This is great for security but can be frustrating.
  - “Why can’t my app see my home folder?” This is a **feature**, not a bug, but it requires apps to be written to use Portals correctly.
- **Not for Everything:**
  - Poorly suited for command-line tools that need deep system integration (e.g., `docker`, `htop`, system drivers).

Practical: The AppImage `AppDir` Structure

An AppImage is just a compressed directory. This directory is called the `AppDir`.

`MyGame.AppDir/` (The root folder)

- `AppRun` **(Required):** The entrypoint script. This is what runs when you double-click the AppImage. It's our job to write this script to set up the environment (like `PYTHONPATH` for Pygame) and launch the main binary.

- `my-game.desktop` **(Required):** The desktop integration file. It tells the system's app menu:
  - `Name=My Game`
  - `Exec=AppRun` (Always `AppRun`)
  - `Icon=my-game` (The name of the icon, without extension)
- `my-game.png` **(Required):** The icon file named in the `.desktop` file.
- `usr/...`: A standard Linux structure containing your binaries, libraries, and the portable Python interpreter.

Practical: AppImage “Hello World”

Here, we create the *minimal* `AppDir` structure.

1. **Create the directory, script, and metadata:**

```
mkdir -p HelloWorld.AppDir
cd HelloWorld.AppDir

# Create the AppRun entrypoint
echo '#!/bin/bash' > AppRun
echo 'echo "Hello from an AppImage!"' >> AppRun
chmod +x AppRun

# Create the desktop file
echo '[Desktop Entry]' > hello.desktop
echo 'Name=Hello' >> hello.desktop
echo 'Exec=AppRun' >> hello.desktop
echo 'Icon=hello' >> hello.desktop
echo 'Type=Application' >> hello.desktop

# Add a dummy icon
touch hello.png
```

Practical: Bundling the AppImage

1. **Bundle it!**

```
# Go back to parent dir
cd ..

# Download appimagetool (only need to do this once)
wget https://github.com/AppImage/AppImageKit/releases/download/continuous/appimagetool
chmod +x appimagetool-x86_64.AppImage

# Run the tool on your directory
# We must set ARCH for script-based apps
ARCH=x86_64 ./appimagetool-x86_64.AppImage HelloWorld.AppDir
```

Result: You now have `Hello-x86_64.AppImage`. Run it: `./Hello-x86_64.AppImage`

Practical: The Flatpak Manifest (`.yml`)

A Flatpak is built from a “manifest” file that acts as a “recipe.”

- `app-id`: The unique name (e.g., `com.example.HelloWorld`).
- `runtime` / `sdk`: The base system to build upon (e.g., `org.gnome.Platform`). We don’t bundle Python; we use the one from the runtime.
- `command`: The executable to run.
- `modules`: The list of “parts” to build. This is where we list our app’s code and its dependencies (like `pygame` from PyPI or our game from a `git` URL).

Practical: Flatpak “Hello World”

1. **Create the script:**

```
# Create a file named hello.sh
echo '#!/bin/sh' > hello.sh
echo 'echo "Hello from a Flatpak Sandbox!"' >> hello.sh
```

2. **Create the manifest (`com.example.HelloWorld.yml`):**

```
app-id: com.example.HelloWorld
runtime: org.freedesktop.Platform
runtime-version: '25.08'
sdk: org.freedesktop.Sdk
command: hello.sh
modules:
  - name: hello-module
    buildsystem: simple
    build-commands:
      # Install the script into the sandbox
      - install -Dm755 hello.sh /app/bin/hello.sh
    sources:
      - type: file
        path: hello.sh
```

Practical: The `flatpak-builder` Tool

The `flatpak-builder` command reads your `.yml` manifest and performs the build inside a clean, sandboxed environment.

```
# 1. Build and install the app
flatpak-builder --user --install --force-clean \
  build-dir com.example.HelloWorld.yml
```

- `--user`: Installs for the current user (no `sudo`).
- `--install`: Installs the app as soon as it's built.
- `--force-clean`: Deletes the old build directory for a fresh start.
- `build-dir`: A temporary folder for the build process.

```
# 2. Run your new app!
flatpak run com.example.HelloWorld
```

Practical: Flatpak Repositories

Flatpak is decentralized, like `git`. There is no single "store."

- **What is a Repository?**
  - A server (or local folder) that hosts apps, managed by `ostree`.
  - You can have multiple "remotes" (repositories) configured.
- **Flathub: The "Main" Repo**
  - `flathub.org` is the *de facto* central repository for most desktop apps (Spotify, VS Code, GIMP, Steam).
  - `flatpak remote-add --if-not-exists flathub https://flathub.org/repo/flathub.flatpakrepo`

- **How to Publish:**
  - To get your app on Flathub, you submit your `.yml` manifest file to their GitHub repository as a pull request.
  - Their build system automatically builds, signs, and publishes your app for you.

Conclusion

- **Isolation** solves “Dependency Hell” and adds **security**.
- **AppImage:** Best for simple **portability**.
  - *Focus:* Manually creating a file structure (`AppDir`) and an AppRun script.
- **Snap:** Strong in **IoT/Server** and on Ubuntu.
  - *Focus:* Central store, strong security.
- **Flatpak:** The leader in the **desktop** space.
  - *Focus:* Writing a declarative “recipe” (`.yml` manifest) and letting `flatpak-builder` and shared runtimes do the heavy lifting.