Painless Transposition of Reproducible Distributed Environments with NixOS Compose

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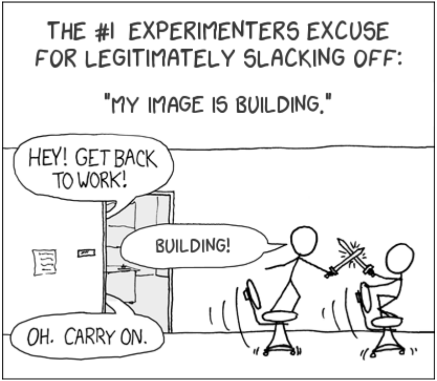
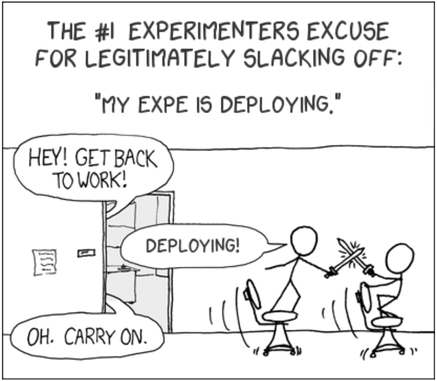
Motivation

Setting up Distributed Environments for Distributed Experiments
↪ **Difficult**, **Time-consuming** and **Iterative** process





⟹ **Does not encourage good reproducibility practices**

The Reproducibility Problem

Different Levels of Reproducibility

1. **Repetition**: Run exact same experiment
2. **Replication**: Run experiment with different parameters
3. **Variation**: Run experiment with different environment

↪ **Share the experimental environment and how to build/modify it**

How to share a Software Environment in HPC?

- Containers? ⇝ need `Dockerfile` to rebuild/modify.
  ↪ might not be repro (e.g., `apt update`, `curl`, commit)
- Modules? ⇝ cluster dependent. how to modify?
- Spack? ⇝ share through modules...

Nix and NixOS

The Nix Package Manager

- Functional Package Manager
- Packages are functions
    - Inputs = dependencies
    - Body of function = how to build
- No side-effect
- ($\simeq$) Solves Dependencies Hell
- Reproducible by design

The NixOS Linux Distribution

- Based on Nix
- Declarative approach
- Complete description of the system (kernel, services, pkgs)

How to store the packages?

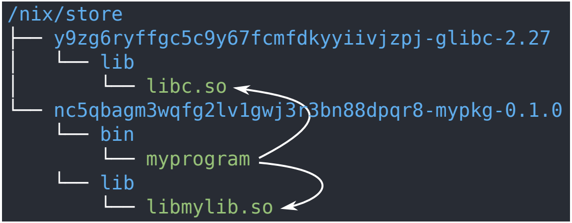
Usual approach: **Merge them all**

- Conflicts
- PATH=/usr/bin

```
/usr
├── bin
│   └── myprogram
└── lib
    ├── libc.so
    └── libmylib.so
```

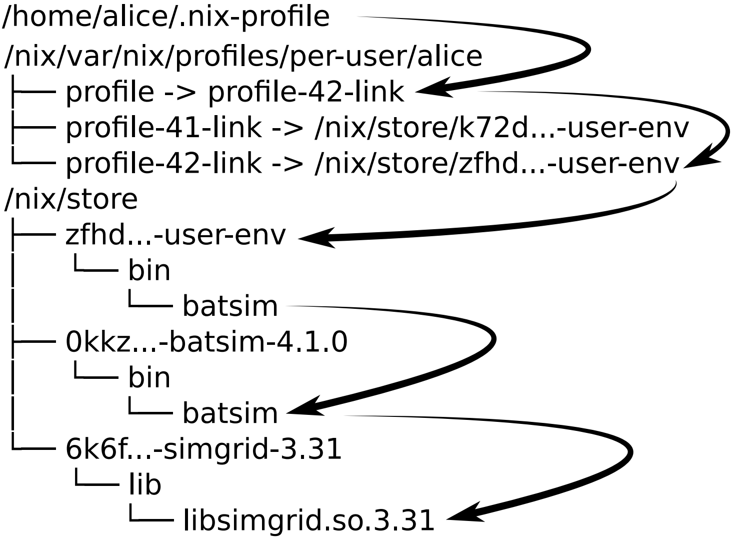
Nix approach: **Keep them separated**

+ Pkg variation
+ Isolated
+ Well def. PATH
+ Read-only



```
/nix/store
├── y9zg6ryffgc5c9y67fcmfdkyyiivjzpj-glibc-2.27
│   └── lib
│       └── libc.so
└── nc5qbagm3wqfg2lv1gwj3r3bn88dpqr8-mypkg-0.1.0
    └── bin
        └── myprogram
    └── lib
        └── libmylib.so
```

Nix Profiles



```
/home/alice/.nix-profile
/nix/var/nix/profiles/per-user/alice
├── profile -> profile-42-link
├── profile-41-link -> /nix/store/k72d...-user-env
└── profile-42-link -> /nix/store/zfhd...-user-env
/nix/store
├── zfhd...-user-env
│   └── bin
│       └── batsim
├── 0kkz...-batsim-4.1.0
│   └── bin
│       └── batsim
└── 6k6f...-simgrid-3.31
    └── lib
        └── libsimgrid.so.3.31
```

1 Introduction & Concepts

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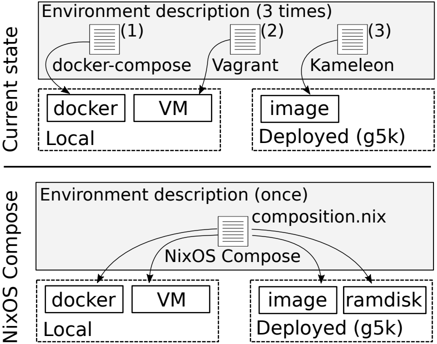
NixOS Compose - Introduction

Goal

Use Nix(OS) to reduce friction for the development of **reproducible distributed environments**

The Tool

- Python + Nix ($\simeq$ 4000 l.o.c.)
- One Definition
  $\hookrightarrow$ Multiple Platforms
- Build and Deploy
- **Reproducible by design**



NixOS Compose - Terminology

Transposition

Capacity to deploy a **uniquely defined environment** on several platforms of different natures (flavours, see later).

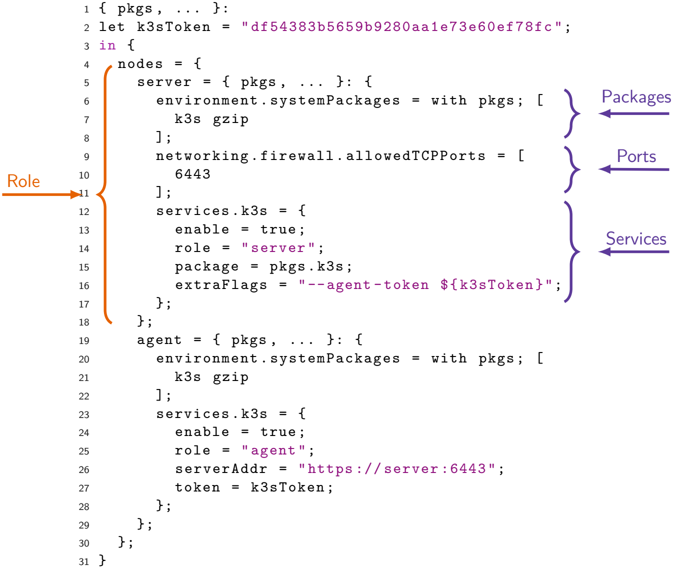
Role

Type of configuration associated with the mission of a node.
Example: One Server and several Clients.

Composition

Nix expression describing the NixOS **configuration of every role** in the environment.

NixOS Compose - Composition Example: K3S



```
{ pkgs, ... }:
let k3sToken = "df54383b5659b9280aa1e73e60ef78fc";
in {
  nodes = {
    server = { pkgs, ... }: {
      environment.systemPackages = with pkgs; [
        k3s gzip
      ];
      networking.firewall.allowedTCPPorts = [
        6443
      ];
      services.k3s = {
        enable = true;
        role = "server";
        package = pkgs.k3s;
        extraFlags = "--agent-token ${k3sToken}";
      };
    };
    agent = { pkgs, ... }: {
      environment.systemPackages = with pkgs; [
        k3s gzip
      ];
      services.k3s = {
        enable = true;
        role = "agent";
        serverAddr = "https://server:6443";
        token = k3sToken;
      };
    };
  };
}
```

Role

Packages

Ports

Services

NixOS Compose - Flavours = Target Platform + Variant

`docker` - local and virtual

Generate a `docker-compose` configuration.

`vm-ramdisk` - local and virtual

In memory QEMU Virtual Machines.

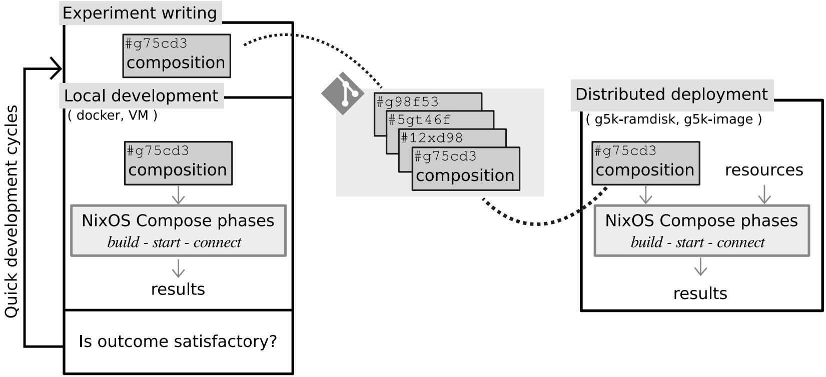
`g5k-ramdisk` - distributed and physical

`initrds` deployed in memory without reboot on G5K (via `kexec`).

`g5k-image` - distributed and physical

Full system tarball images on G5K via Kadeploy.

NixOS Compose - Workflow



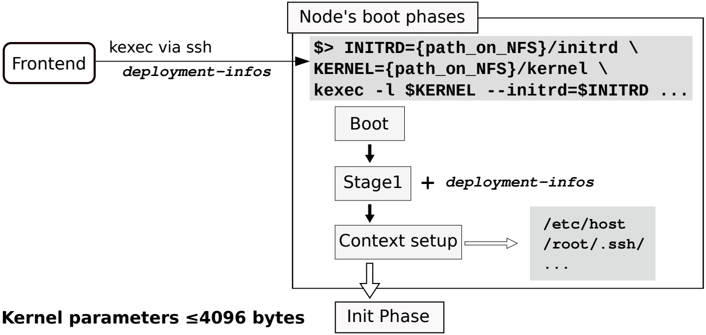
NixOS Compose - Technical Details (g5k-ramdisk)

Building

1. Eval. of the NixOS configuration (+firmware)
2. Generation of the kernel, image, initrd (in the store)

Deploying

1. Get the addresses of the nodes
2. Run `kexec` on the nodes
3. Setup the info for the nodes (hostname, ssh keys, role)



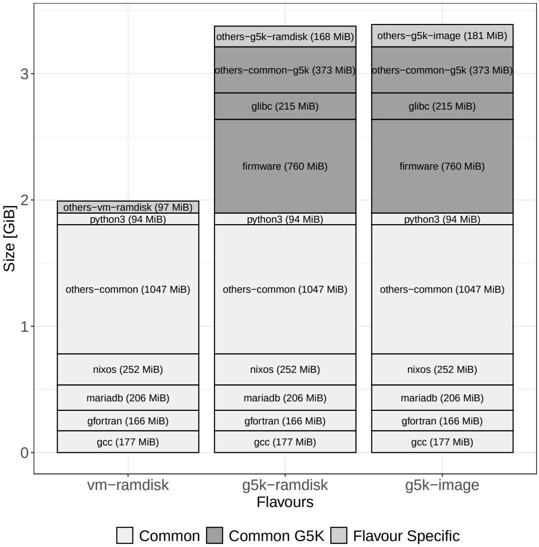
```
$> INITRD={path_on_NFS}/initrd \
KERNEL={path_on_NFS}/kernel \
kexec -l $KERNEL --initrd=$INITRD ...
```

```
/etc/host
/root/.ssh/
...
```

Kernel parameters ≤4096 bytes

NixOS Compose - Difference per Flavours

Content of the Nix Store of the Melissa Image for each Flavour



Example: Melissa

- Distributed Runner for Data Assimiliation
- Slurm, DB, ...
- Several roles

Common base for all flavours

↪ then variations based on platform/flavour (e.g., firmwares, boot loader)

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Experimental Evaluation

Experimental Setup

- Grid'5000: dahu cluster
- 192 GiB of RAM
- Intel Xeon Gold 6130 (2 × 16 cores)
- 240 GB SSD SATA Samsung

Goal of Experiments

- Evaluate the (re)construction times of images **vs. Kameleon**
- Evaluate the size of the images generated **vs. Kameleon**
- Evaluate the deployment cycle **vs. EnOSlib**

$\hookrightarrow$ Will not evaluate the deployment times as we use third party tools.

Evaluation vs. Kameleon

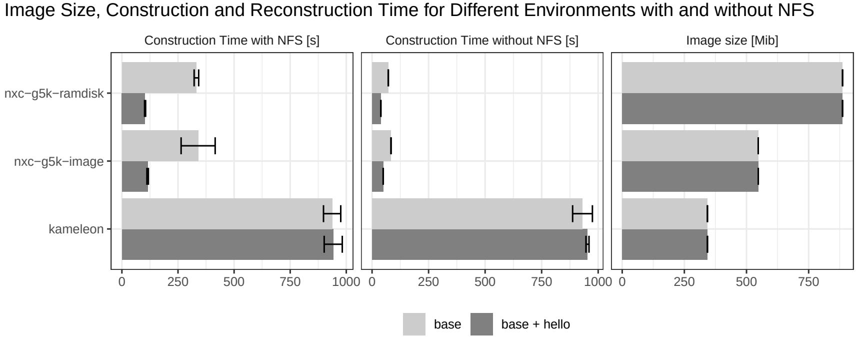
Experiment Goals

Eval. Images **Construction** and **Reconstruction** Times + Images **Sizes**

Protocol

1. Empty the `nix store` (no cache for Kameleon)
2. Create a `base` recipe with NXC and Kameleon
3. Build and measure the building time and the size of the image
4. Add the `hello` package to the recipe (`base + hello`)
5. Build the `base + hello` image and measure time and size

Evaluation vs. Kameleon - Results



- NXC **faster to build and even faster to rebuild** (> 10x)
- NXC produces larger images than Kameleon
- NFS introduces a overhead due to many reads/writes of Nix

Evaluation vs. EnOSlib

Experiment Goals

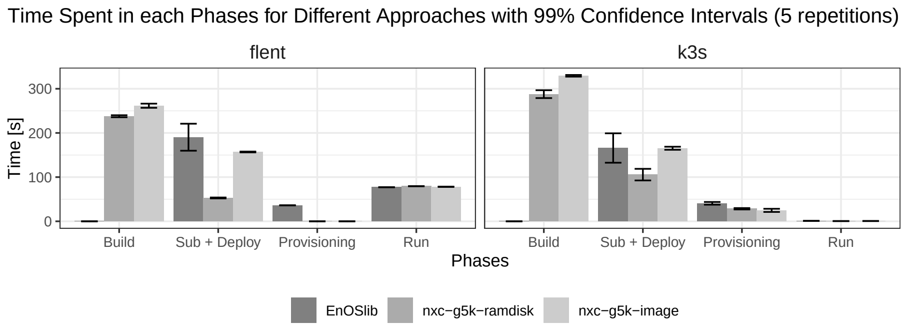
Eval. Deployment Cycles vs. EnOSlib **with Reproducibility considerations**

4 Phases: Build ⇝ Deploy ⇝ Provisioning ⇝ Run.

Protocol

1. Write an experiment with EnOSlib and NXC (+ Execo)
2. Build the image if needed (EnOSlib uses a prebuilt G5K image)
3. Deploy the image
4. Do the Provisioning phase (i.e., installing pkgs + config)
5. Run the actual experiment
6. Measure the time spent in each phase

Evaluation vs. EnOSlib - Results



- No building for EnOSlib (might need it if image no longer available)
- **Fast Deploy with `g5k-ramdisk`** (via `kexec`)
- Manage to **reduce provisioning phase** with NXC in the image

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Conclusion & Perspectives

Reminder

Objective: Reduce the friction for dvp of reproducible distributed envs

Approach: used Nix(OS) to build NXC: a tool for transposing envs defs

Takeaway

- Fast development cycles (containers, VM, ramdisk)
- NXC builds faster (but larger) images than Kameleon

Perspectives

- Target others platforms
- Hybrid deployment
- Integration w/ EnOSlib
- Doc & Tuto

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