GNURadio ecosystem management with Nix

Tom Bereknyei

Intro

- Defense Digital Service: "SWAT team of nerds."
- Me: Technical lead for several projects using GNU Radio in DoD.
- Assumptions: Intermediate-level user of GNU Radio and *nix systems.
- Why: Because this vastly improved confidence in our software and improved our time to delivery

Ask questions!

- If something isn't clear. Interrupt me
- No really... Interrupt me

Build problems - current state of affairs

- It compiles on *my* machine
- I installed `SOMETHING` into `/usr/{bin,lib}`, but now interferes with stuff in `/usr/local/{bin,lib}`
- I have both versions X and Y, but I can't seem to get things to link to version Y
- My package manager has version X, but I need version Y or patch it
- My component uses Boost version X, but another part of the my application uses version Y
- GNU Radio Companion can't find ...
- Pip, virtualenv, setup.py, SWIG, PYTHONPATH, etc.
- Now cross-compile everything above
- Now do all of the above with RFNoC
- **Insert story from the audience here**

Solutions

- Use a VM and snapshots.
- Docker scripts
- "Just use this install script on a fresh OS installation."
- Custom solutions: once it works, don't touch it.

Challenge

- Take a random commit from 5 years ago along with all the changes in libraries, compilers, operating systems, etc.
- Can you get the commit to build from scratch?

What do we want?

- Reliable builds
- If it builds on my machine, it should build on any machine, always
- If I build it today, I should be able to build it in 10 years
- Isolation
- Multiple versions of the same software should be able to run next to each other
- Atomic updates
- You either install something completely, or you do not install it at all
- Experimentation without fear

Idea

Lets make package managers work like git!

Eelco Dolstra. The Purely Functional Software Deployment Model. PhD thesis, Faculty of Science, Utrecht, The Netherlands. January 2006. ISBN 90-393-4130-3.

https://nixos.org/~eelco/pubs/phd-thesis.pdf

Idea

Lets make package managers work like git!

```
PREFIX= sha256(sha256(deps(package)) + sha256(src(package)) + sha256(options(package))

$PREFIX/bin , $PREFIX/lib  $PREFIX/share
instead of:
/usr/bin, /usr/lib/, /usr/share
```

- Dependencies change? => Installed in different prefix
- Source code change? => Installed in different prefix
- Build options change? => Installed in different prefix

Nix

- Package manager
- Declarative lanuage to describe package builds
- Isolated build environments
- Over 10000 packages and counting
- Mac OS X / GNU/Linux / BSD and Soon Windows Subsystem for Linux*
- Source-based package manager (Like Gentoo)
- But don't worry; also has a build cache

DEMO 0: Basic install of hello

Two styles

- Imperative, similar to apt, brew, dpkg, etc.
  - *`nix-env -i hello`* *or* *`nix-env -iA nixpkgs.hello`*
  - *`nix-env -e hello`*
- Declarative, similar to Dockerfile, package.json, etc. `default.nix` or `shell.nix`

DEMO 1: Basic install of gnuradio

- To install a package, we build it from source, given a package description
- Nixpkgs is a set of expressions currated by the community.
- Observation: It was instant? It didn't build anything from source?
- Not very user-friendly to type in the large /nix/store/bLAHBLAH/ when I want to run a program

Important takeaways

- Each package is installed in its own unique path (think git commit hash)
- Software is installed into profiles, which are symlinks to packages (think `HEAD`)
- You can rollback to previous profiles, by changing a symlink (think `git checkout`)
- This allows for atomic updates, because symlink changes are atomic
- As an end user, not very different from `homebrew` or `apt`, except for rollbacks

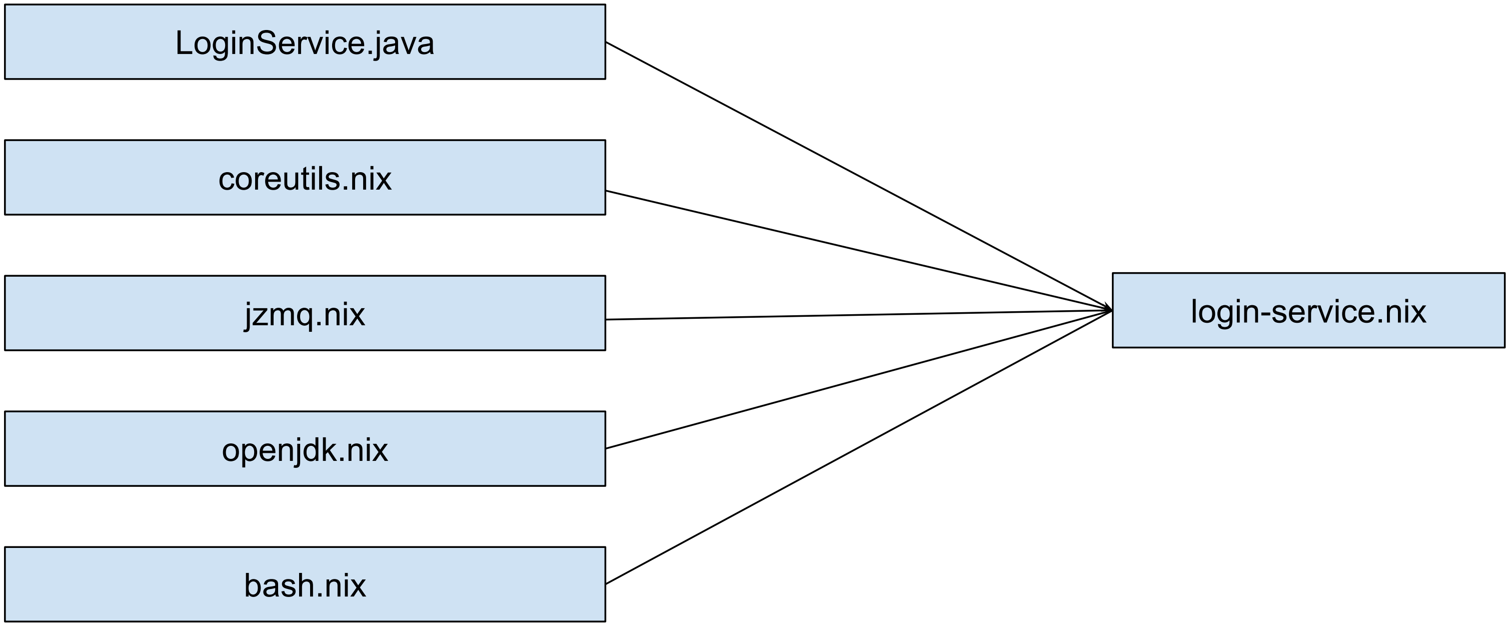
The Nix Language in 1 minute

- Language of Nixfiles, which describes how to build packages
- Think `Dockerfile` or `debinfo` file
- Actually a proper programming language
- JSON-like with templating, functions and variables
- Side-effects only allowed *but* only if we know the *output* beforehand

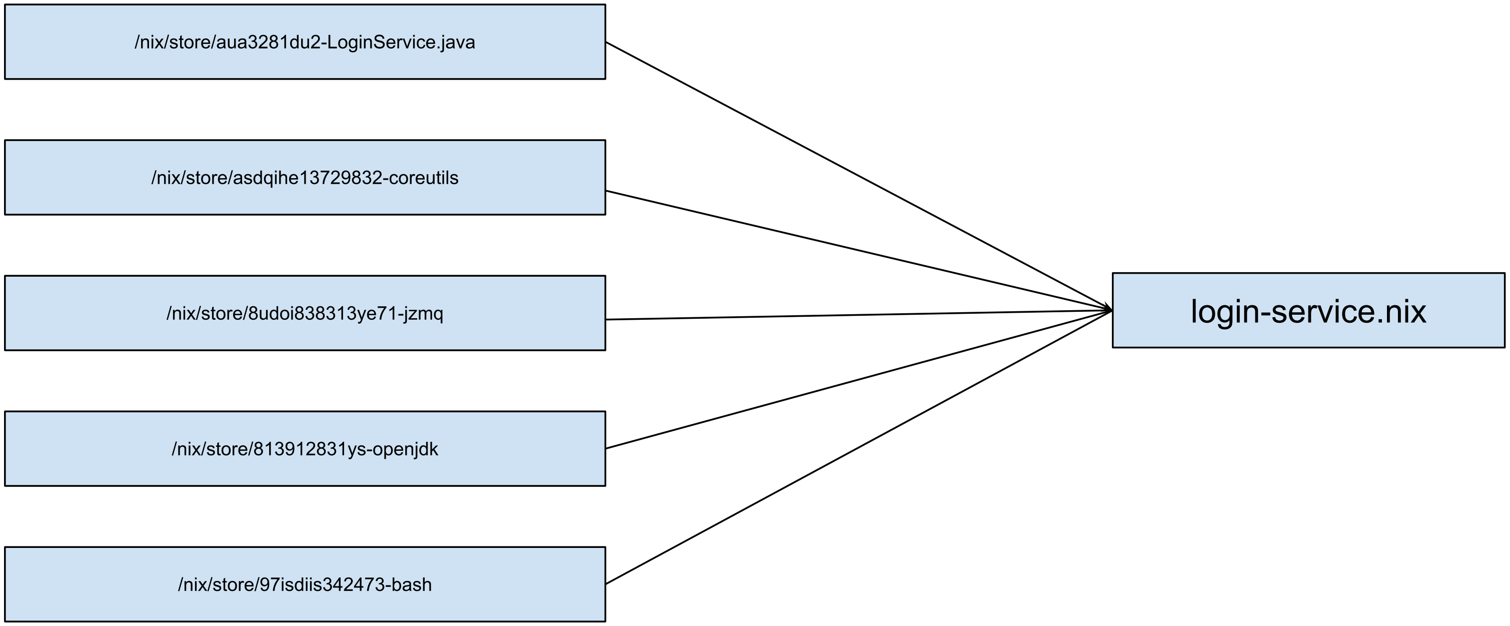
```
"hello"
1 + 3
./a/path
[ "i" 3 5 ]
{ x = "Hello"; y=42;}
```

```
a = 3
b = 4
thing = { x = a;, y = b;}
add_struct = {x, y}:  x + y
add_struct thing  # Results in 7
```

Graphical representation of our Derivation



Evaluated derivation



/nix/store/aua3281du2-LoginService.java

/nix/store/asdqihe13729832-coreutils

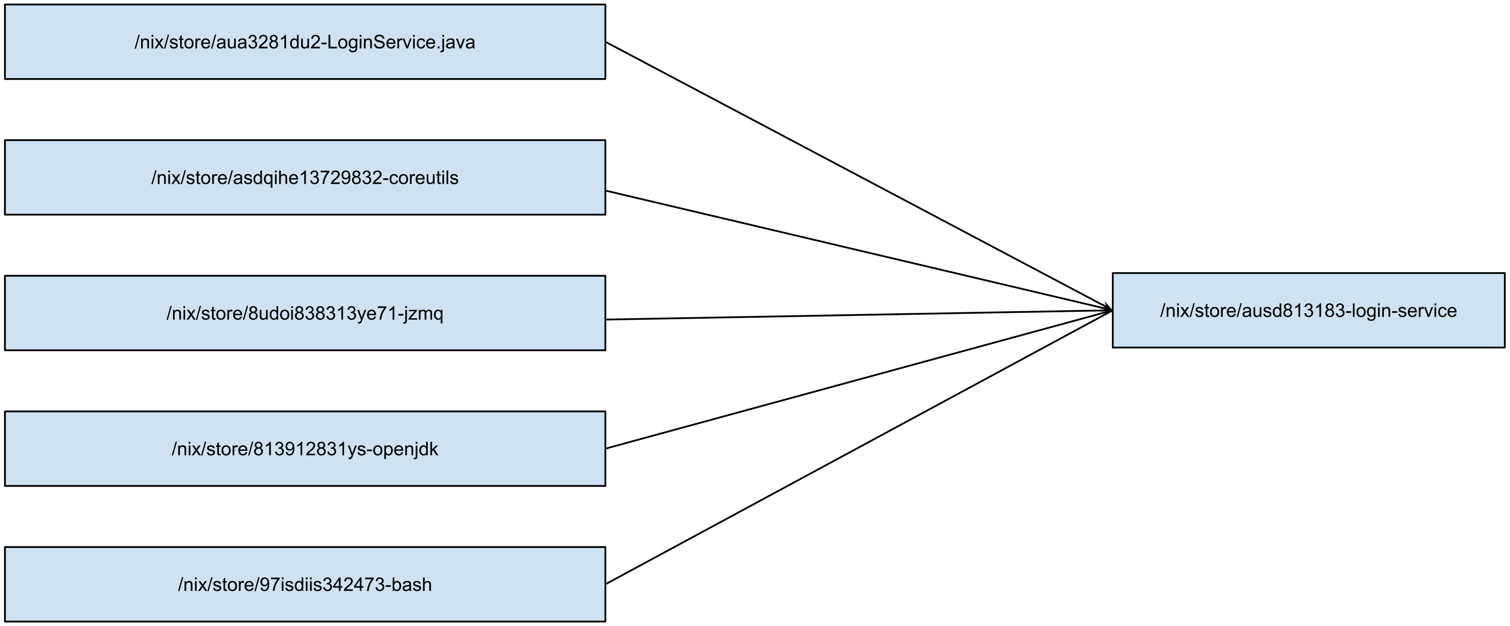
/nix/store/8udoi838313ye71-jzmq

/nix/store/813912831ys-openjdk

/nix/store/97isdiis342473-bash

login-service.nix

Evaluated derivation



/nix/store/aua3281du2-LoginService.java

/nix/store/asdqihe13729832-coreutils

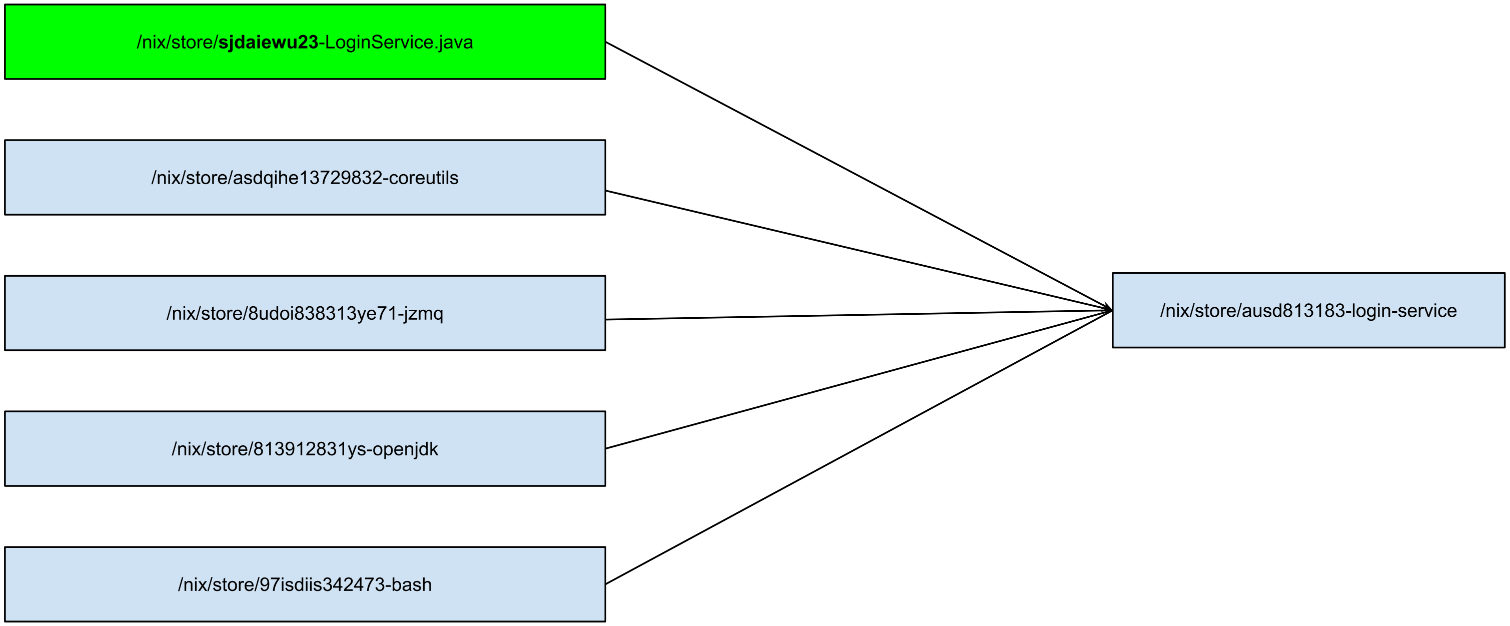
/nix/store/8udoi838313ye71-jzmq

/nix/store/813912831ys-openjdk

/nix/store/97isdiis342473-bash

/nix/store/ausd813183-login-service

If I update the source code



/nix/store/**sjdaiewu23**-LoginService.java

/nix/store/asdqihe13729832-coreutils

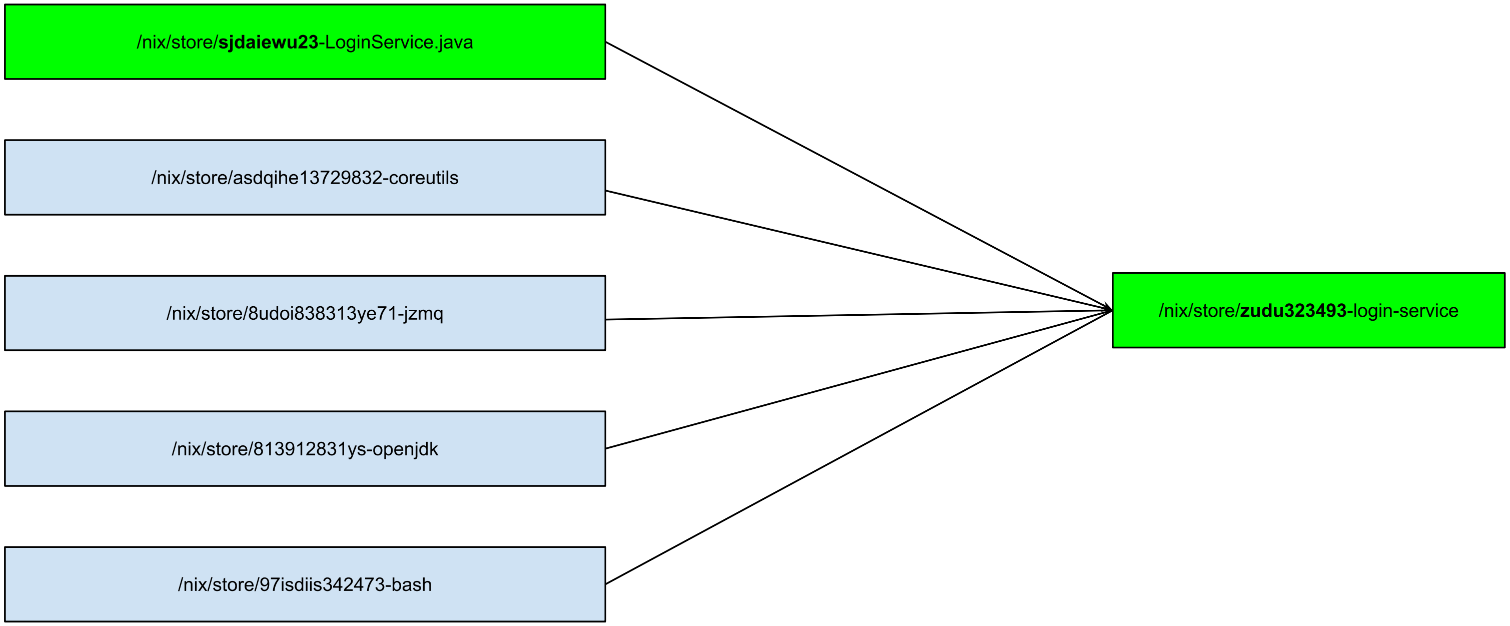
/nix/store/8udoi838313ye71-jzmq

/nix/store/813912831ys-openjdk

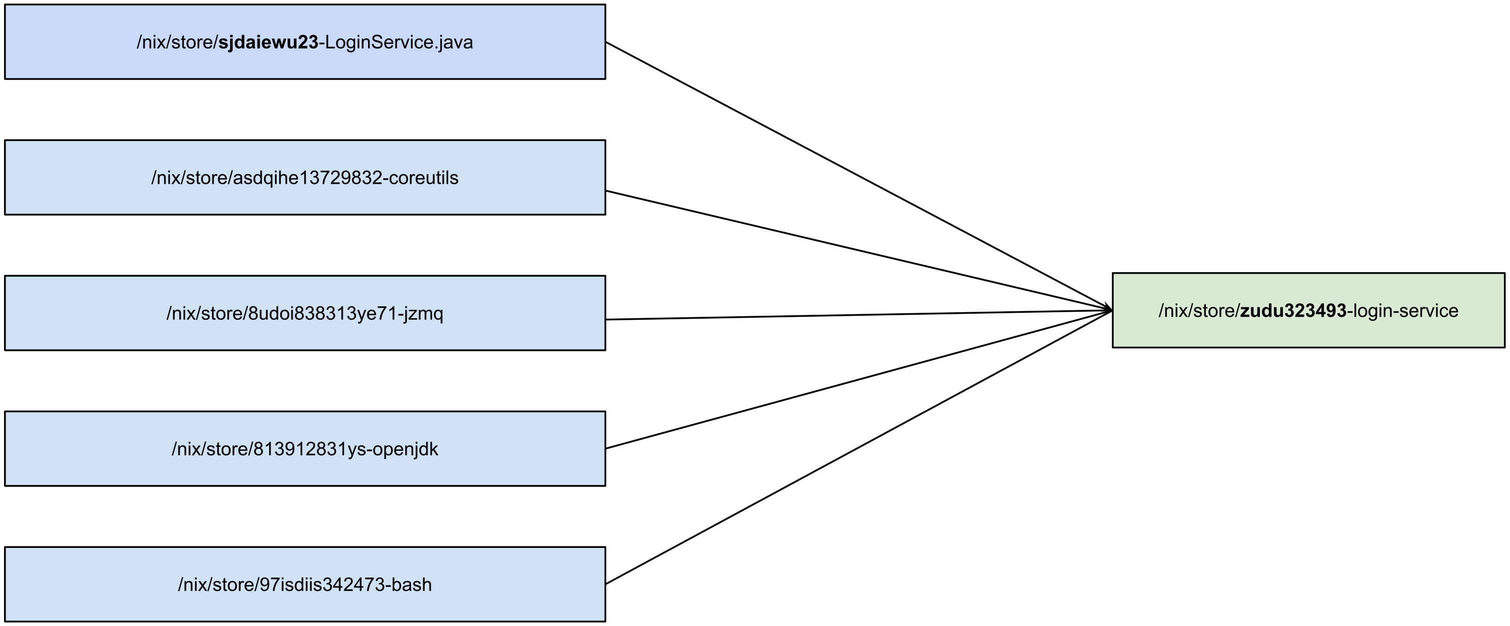
/nix/store/97isdiis342473-bash

/nix/store/ausd813183-login-service

If I update the source code


/nix/store/**sjdaiewu23**-LoginService.java
/nix/store/asdqihe13729832-coreutils
/nix/store/8udoi838313ye71-jzmq
/nix/store/813912831ys-openjdk
/nix/store/97isdiis342473-bash
/nix/store/**zudu323493**-login-service

...



/nix/store/**sjdaiewu23**-LoginService.java

/nix/store/asdqihe13729832-coreutils

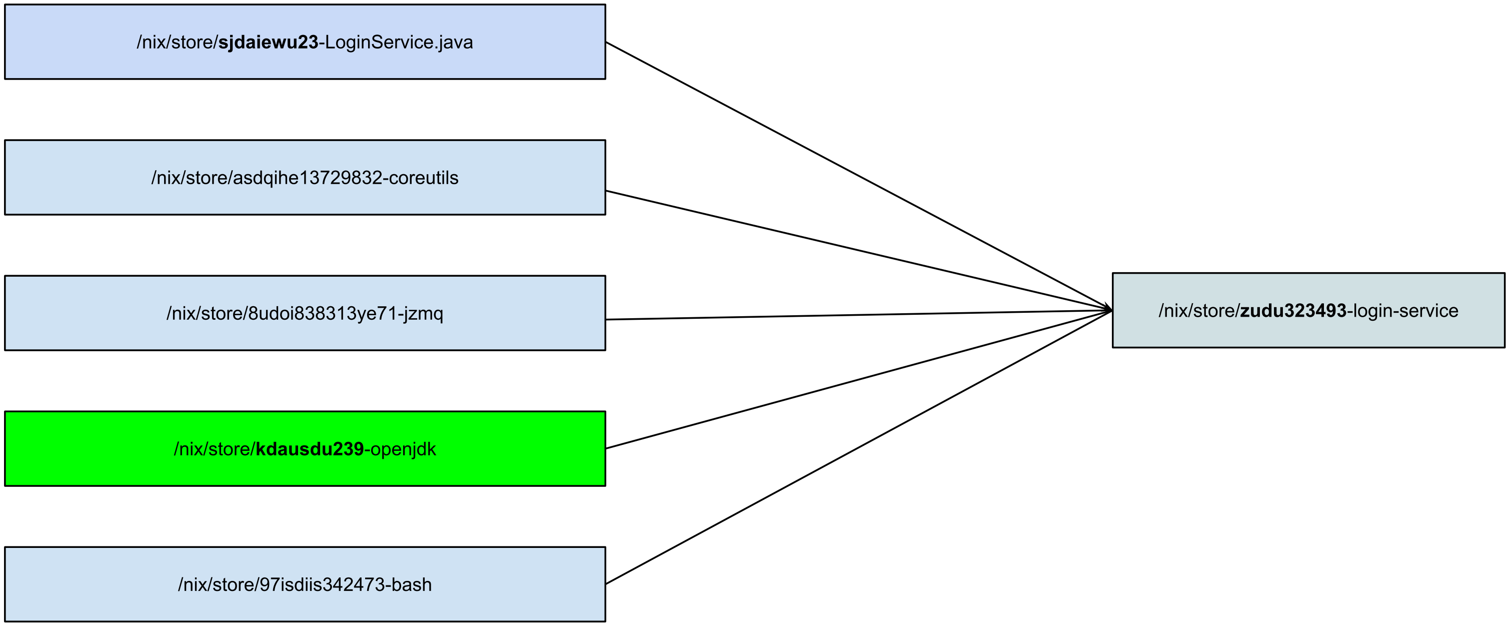
/nix/store/8udoi838313ye71-jzmq

/nix/store/813912831ys-openjdk

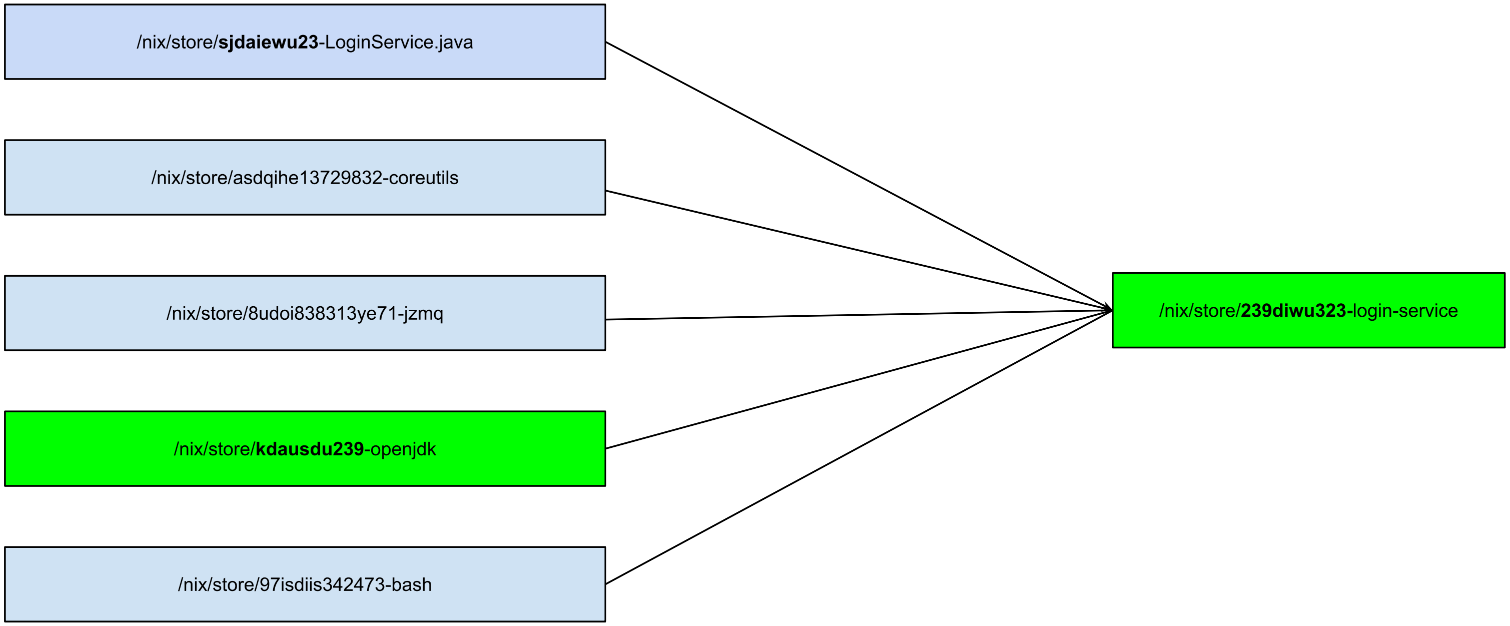
/nix/store/97isdiis342473-bash

/nix/store/**zudu323493**-login-service

If I update one of the dependencies ...


/nix/store/**sjdaiewu23**-LoginService.java
/nix/store/asdqihe13729832-coreutils
/nix/store/8udoi838313ye71-jzmq
/nix/store/**kdausdu239**-openjdk
/nix/store/97isdiis342473-bash
/nix/store/**zudu323493**-login-service

If I update one of the dependencies ...


/nix/store/**sjdaiewu23**-LoginService.java
/nix/store/asdqihe13729832-coreutils
/nix/store/8udoi838313ye71-jzmq
/nix/store/**kdausdu239**-openjdk
/nix/store/97isdiis342473-bash
/nix/store/**239diwu323-**login-service

DEMO2: Reliable builds

- I am confident, that if I check out the Nix file of `gnuradio` from five years ago, it will build
- It will build all old versions of dependencies from source, and then build `gnuradio` from source
- Takes a long time. But **it *will* work**

DEMO 2:

```
commit 993dadd2136ffca9a6f81d7e4d6acd5116da83a0 (HEAD)
Author: Franz Pletz <fpletz@fnordicwalking.de>
Date:   Fri May 13 02:31:33 2016 +0200

    gnuradio: 3.7.9.1 -> 3.7.9.2
```

How is a derivation built

- Source code is downloaded, fetched, obtained.
- Code is **checked against hash, otherwise abort**
- A chroot (container) is setup, containing *just* the build dependencies and source
- No network access
- All environment variables are *Cleared*
- No access to `$HOME`. No access to anything on disk..
- Time is set to 1970
- **The package build can only depend directly on the dependencies specified, and NOTHING else**
- The `builder` argument is executed, and its output copied to the Nix store

How is a derivation built

- Now, if a collegue forgets to write down what libraries *exactly* you need to install
- ... Or if uses library that is available by default on Ubuntu but not On Redhat
- ... The build is guarenteed to fail
- We explicitly state the hash of sources we download from the internet
- If the internet changes, then the build fails. No implicit changes!
- **Reliable builds**

Build Cache

- Remember, our build instructions uniquely determine where we install the package

```
nix-repl> "${gnuradio}"
"/nix/store/sqxmwvn33x39sjfr47spib74gi3cqffv-gnuradio-3.7.11"
```

- **We know *beforehand* where our build is going to be put!**
- Simply *ask* if someone else already built it, and download it from there!
- Trust?

Build Cache

- Can also be used privately, for internal packages
- `nix build --store https://cache.nixos.org` (Default)
- `nix build --store s3://my-company-bucket`
- `nix build --store ssh://collegue-machine`
- `nix build --store file:///nfs/company-fileshare/`
- BuildCache As A Service : https://cachix.org/
- If a collegue already built some project
- ... and you checkout the same git commit
- Then you don't have to rebuild everything! You just download it from the cache!

DEMO 3:

GNURadio OOT

- Reproducibly build a module
- Create a wrapped version of GNURadio

DEMO 4:

GNURadio OOT with integration

Same as demo3, but

- remove GTK errors
- allow for inspectability in nix-shell

DEMO 5: RFNoC

- Use provided toolchain
- Build UHD
- Build GNURadio
- Build gr-ettus
- All dependencies down to USRP images and glibc are pinned.
- Cross-compile libraries and produce a bundle ready for installation, testing, and deployment

Continuous integration script

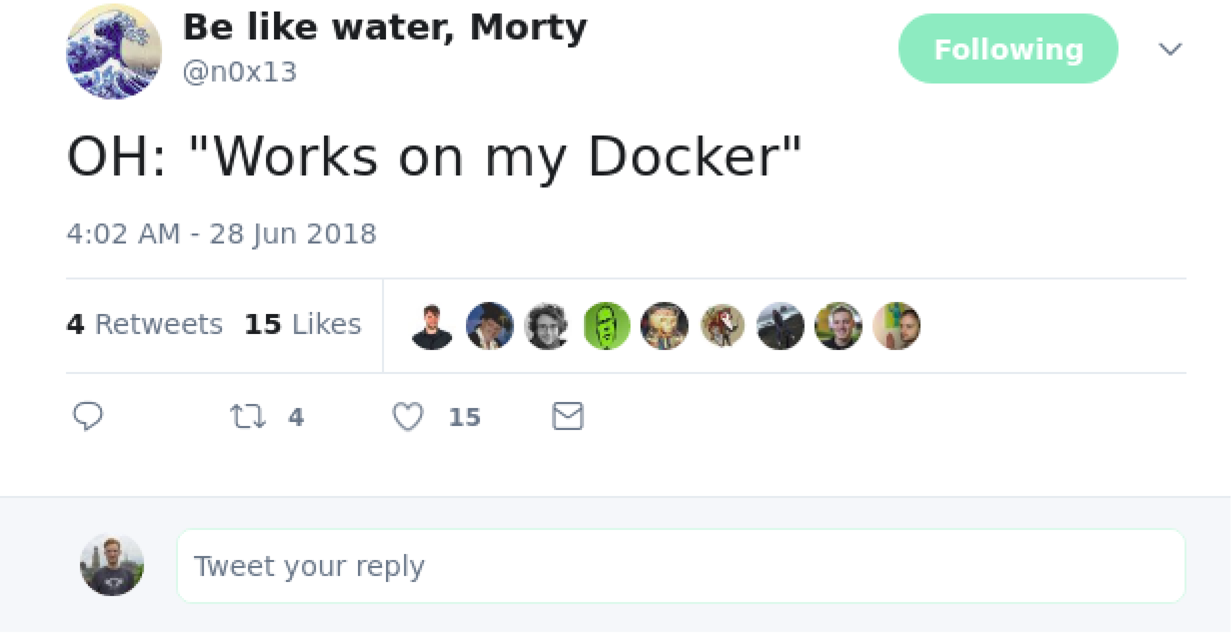
- Typical Nix CI script

```
# .travis.yml
language: nix
script:
  - nix build . --store s3://company-bucket
after_success:
  - nix copy . --to s3://company-bucket
```

DEMO: Hydra

Solution? Docker

- Docker is an ubiquitous distribution format.
- Once it builds.. send it to the registry
- Solves the "runs on my machine" problem
- Does *not* solve the "builds on my machine" problem



Be like water, Morty
@n0x13

OH: "Works on my Docker"

4:02 AM - 28 Jun 2018

4 Retweets 15 Likes

Best of both worlds

- Nix has support for building docker containers
- Copies your package + all its dependencies in a docker image
- **Bare image**, no `FROM blah`
- Super small (not quite as small as Alpine)
- You can easily integrate Nix in existing docker-compose or Kubernetes projects!

```
let
  pkgs = import ../nixpkgs.nix;
  some-service = import ./some-service.nix;
in
  pkgs.dockerTools.buildImage {
    name = "some-service";
    config = {
      Cmd = [ "${login-service}/bin/login-service" ];
      Expose = [ 8080 ];
    };
  }
```

Possibiliites

- Reproducible builds on local machines.
- Reproducible builds on CI with testing.
- Cross-compile to other architectures.
- Distributed builds. Build natively on other architectures.
- Testing.

End state

- Each push to testing/staging/master compiles all dependencies (cached).
- Manages Python 2 and 3 applications, C, C++, GNURadio OOT, Javascript (npm/yarn).
- Flowgraph tested in QEMU VM on recorded data.
- Distributed ARM builders connected via VPN.
- Single fat binary bundled for OS agnostic deployment to GNU/Linux
- .deb packages created bundling all dependecies, systemd service configurations, udev rules, nginx, raster tiles for maps etc.
- .deb installation tested on fresh Ubuntu VM
- Docker containers built, tested, cached.
- Nix binary package cached on build server.
- Flowgraph tested on specific builders with SDR and other hardware attached.

Other thoughts:

- NixOS - OS based on simliar mechanisms to also track OS, configs, services, etc.
- Everything including kernel, kernel patches, DTBs, GRUB/U-Boot, etc all managed.
- NixOps - infrastructure management tool
- Deploy NixOS to cloud/local virtualization/environment declaratively. VPC, routes, security rules, key distribution, etc. (Terraform-ish)
- The build system, pipeline, and testing from previous slide are declaratively defined.
- Check out commit from 5 years ago, get production environment from 5 years ago
- Experimental
- Disnix - Nix for services, but can be on Windows, non-NixOS, etc.
  - *Dydisnix - Distributed service deployment*
  - *Dysnomia - Automated deployment of mutable components*

Downsides

- Steep learning curve. Thinking functionally is something to get used to
- You *can not* do dirty hacks. You can't go monkeypatch some python package in `/usr/lib/python`, or update `/etc/hosts` manually
- Unforgiving, enforces discipline
- Closure can get large, all dependencies included, nothing is used from host system other than POSIX `sh`.
- Documentation is ... not always great. "Read the source code" is a common philosophy among Nix'ers
- Hardcoded paths and functionality in GRC, UHD, etc requires some manipulation and patching. *Potential for improvement, PRs on the way*.

Recap

- Nix is a package manager, and build system coordinator.
- Build OOT modules in isolation with reliable dependency tracking.
- Test flowgraphs on a predicatble system.
- Easily share build environments with collegues.
- Is not docker, but works well with docker!
- Can be set up on 100% internal infrastructure.

Thanks! Questions?

- [https://github.com/tomberek/nixtalk
- [https://github.com/tomberek/gnuradio-demo
- https://nixos.org/nixos/nix-pills - Tutorial to get up to speed quickly with how nix works
- https://nixos.org/nix
- Credits: presentation adopted from Arian van Putten
- Before Ben asks, yes we have upstreamed bug-fixes, generic libraries not tied to the original mission, and this entire presentation plus demos are available on GitHub.

Bonus: Hey did gnuradio compile?