KubeCon | CloudNativeCon Europe 2019

# Building images efficiently and securely on Kubernetes with BuildKit

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# Raise your hand if you have heard of BuildKit?

# Raise your hand if you are already using BuildKit?

# Raise your hand if you are already running BuildKit on Kubernetes?

# Part 1
# Introduction to BuildKit

# BuildKit: next-generation docker build



- Concurrent multi-stage build
- Efficient caching
- Secure access to private assets
- Flexible syntax for build definition
- Does not require root privileges

# BuildKit: next-generation docker build



- BuildKit is included in Docker since v18.06

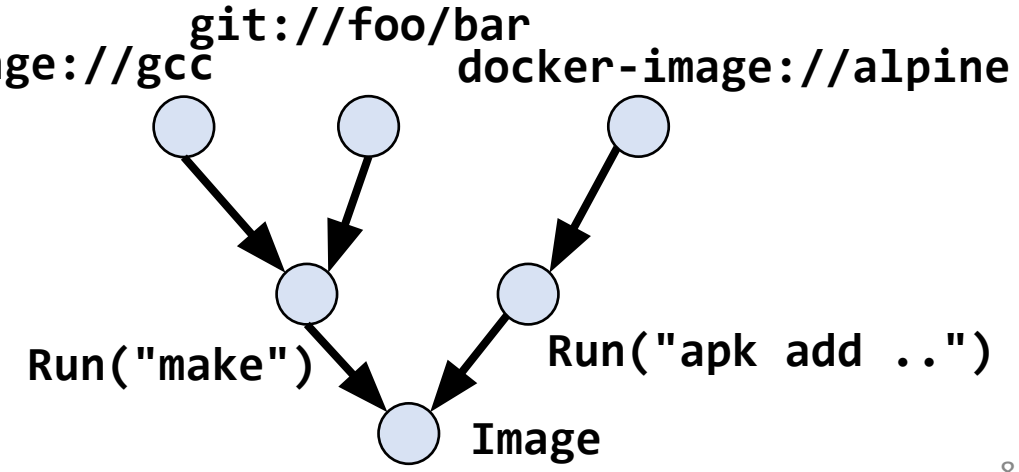
```
$ export DOCKER_BUILDKIT=1
$ docker build ...
```

- But this talk will focus on the standalone version of BuildKit (`buildkitd` & `buildctl`)
  - No dependency on Docker

# LLB DAG



- LLB is to Dockerfile what LLVM IR is to C
- Typically compiled from Dockerfile
- Accurate dependency expression with DAG structure
  - Efficient caching
  - Concurrent execution



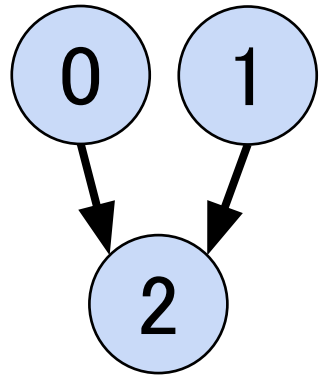
# LLB DAG



```
FROM golang AS stage0
...
RUN go build –o /foo ...

FROM clang AS stage1
...
RUN clang –o /bar ...

FROM debian AS stage2
COPY --from=stage0 /foo /usr/local/bin/foo
COPY --from=stage1 /bar /usr/local/bin/bar
```



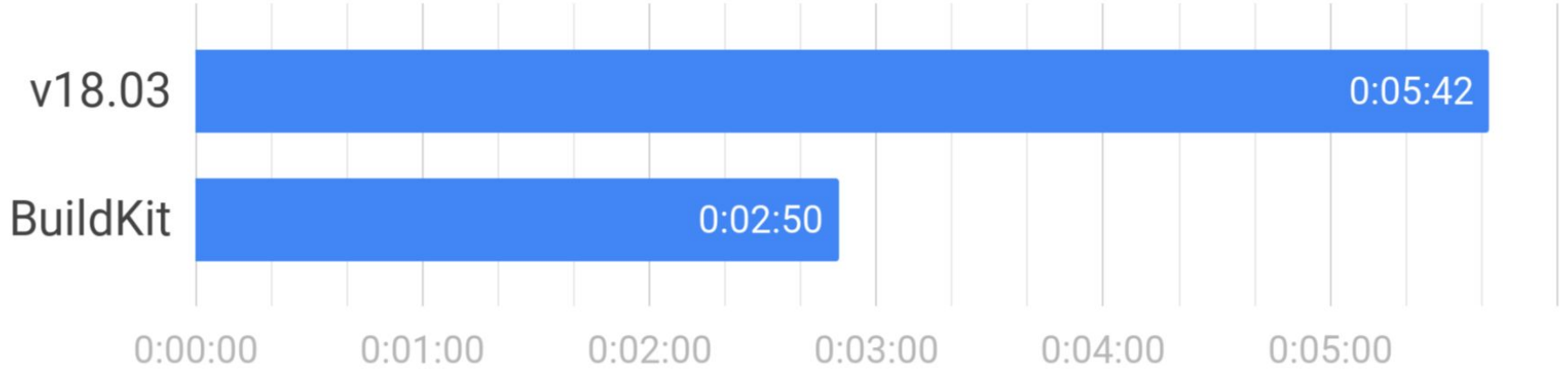
https://t.co/aUKqQCVmXa

## BuildKit

# Performance example

Based on **github.com/moby/moby** Dockerfile, master branch. **Smaller** is better.

## Time for full build from empty state




**2.0x faster**

*Measured on DO 4vcpu droplet*

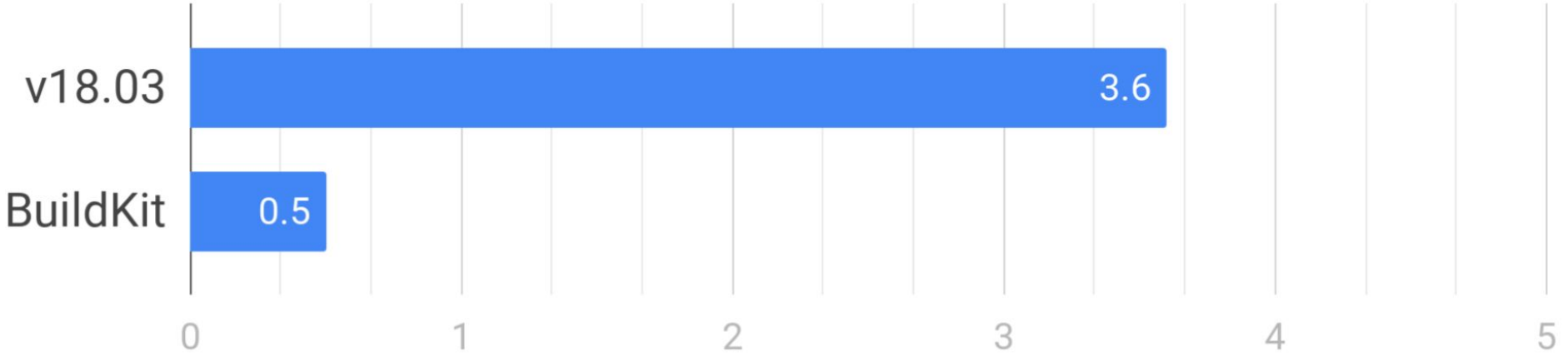
https://t.co/aUKqQCVmXa

## BuildKit

# Performance example

Based on **github.com/moby/moby** Dockerfile, master branch. **Smaller** is better.

## Repeated build with matching cache




**7.2x faster**

*Measured on DO 4vcpu droplet*

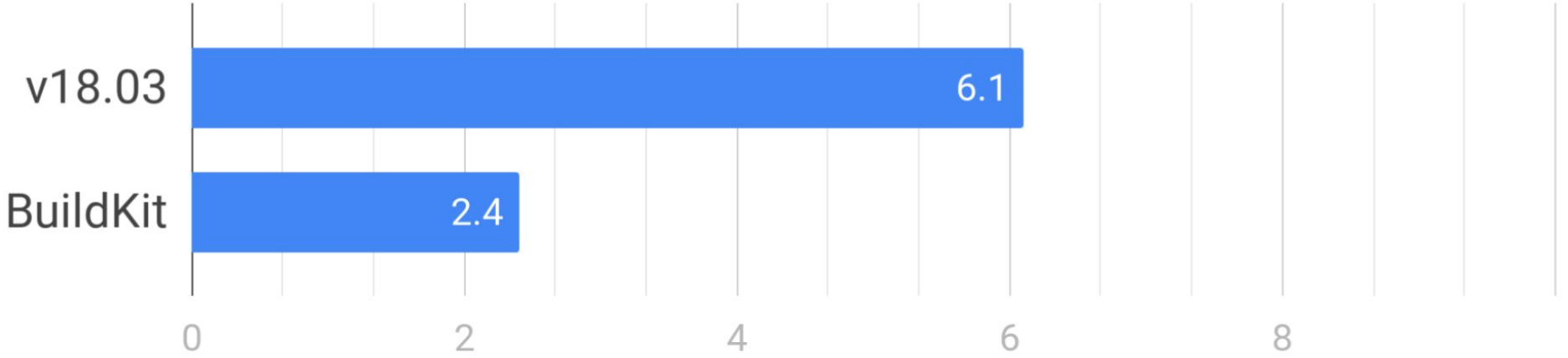
https://t.co/aUKqQCVmXa

## BuildKit

# Performance example

Based on **github.com/moby/moby** Dockerfile, master branch. **Smaller** is better.

## Repeated build with new source code




**2.5x faster**

*Measured on DO 4vcpu droplet*

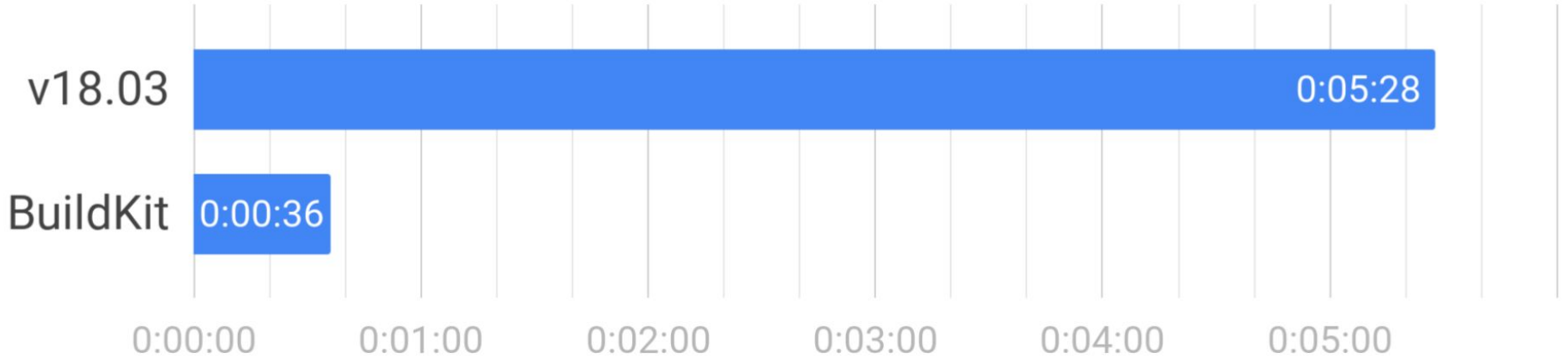
https://t.co/aUKqQCVmXa

## BuildKit

# Performance example

Based on **github.com/moby/moby** Dockerfile, master branch. **Smaller** is better.

## Fresh build with --cache-from from remote source




**9.1x faster**

*Measured on DO 4vcpu droplet*

# RUN --mount=type=cache



- Allows preserving caches of compilers and package managers

```
# syntax = docker/dockerfile:1.1-experimental
...
RUN --mount=type=cache,target=/root/.cache go build
...
```

# RUN --mount=type=cache



- Allows preserving caches of compilers and package managers

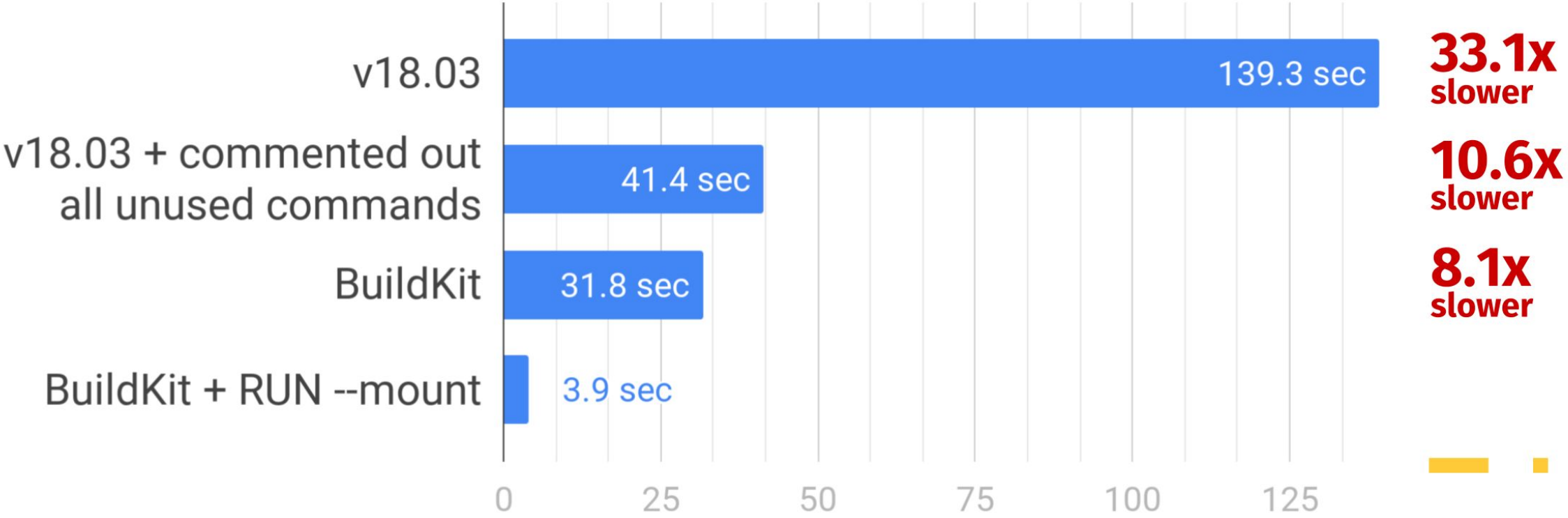
```
# syntax = docker/dockerfile:1.1-experimental
FROM ubuntu
RUN rm -f /etc/apt/apt.conf.d/docker-clean; \
  echo 'Binary::apt::APT::Keep-Downloaded-Packages "true";' > \
  /etc/apt/apt.conf.d/keep-cache
RUN \
  --mount=type=cache,target=/var/cache/apt \
  --mount=type=cache,target=/var/lib/apt \
  apt update && apt install -y gcc
```

https://t.co/aUKqQCVmXa

## Dockerfile syntax directive

# Example: RUN --mount

moby/buildkit Dockerfile: time to binary rebuild after code change




*Measured on DO 4vcpu droplet*

# RUN --mount=type=secret



- Allows accessing private assets without leaking credential in the image

```
# syntax = docker/dockerfile:1.1-experimental
...
RUN --mount=type=secret,id=aws,target=/root/.aws/credentials \
    aws s3 cp s3://... ...
```

```
$ buildctl build --secret id=aws,src=~/.aws/credentials ...
```

# RUN --mount=type=secret



- Note: DON’T do this!

```
...
COPY my_aws_credentials /root/.aws/credentials
RUN aws s3 cp s3://... …
RUN rm -f /root/.aws/credentials
...
```

# RUN --mount=type=secret



- Note: DON’T do this either!

```
$ docker build \
  --build-arg \
  MY_AWS_CREDENTIALS=$(cat ~/.aws/credentials)
```

# RUN --mount=type=ssh



- Akin to `--mount=type=secret` but specific to SSH
- Supports passphrase

```
# syntax = docker/dockerfile:1.1-experimental
...
RUN --mount=type=ssh git clone ssh://github.com/...
```

```
$ eval $(ssh-agent)
$ ssh-add ~/.ssh/id_rsa
(Enter your passphrase)
$ buildctl build --ssh default=$SSH_AUTH_SOCK ...
```

# Non-Dockerfiles



- LLB can be also compiled from non-Dockerfiles

- Several languages are being proposed
  - Buildpacks
  - Mockerfile
  - Gockerfile

- You can also create your own language

# Buildpacks



- Ported from Heroku/CloudFoundry Buildpacks
- No support for Cloud Native Buildpacks yet

```
# syntax = tonistiigi/pack
---
applications:
- name: myapp
  memory: 128MB
  disk_quota: 256MB
  random-route: true
  buildpack: python_buildpack
  command: python hello.py
```

# Mockerfile



- `apt-get` in highly declarative YAML

```
# syntax = r2d4/mocker
apiVersion: v1alpha1
images:
- name: demo
  from: ubuntu:16.04
  package:
    repo:
    - deb [arch=amd64] http://storage.googleapis.com/bazel-apt stable jdk1.8
    gpg:
    - https://bazel.build/bazel-release.pub.gpg
    install:
    - bazel
```

# Gockerfile



- Really simple
- Specific to Golang

```
# syntax = po3rin/gocker
repo: github.com/foo/bar
path: ./cmd/baz
version: v0.0.1
```

# Part 2
# Deploying BuildKit on Kubernetes

# Why build images on Kube?



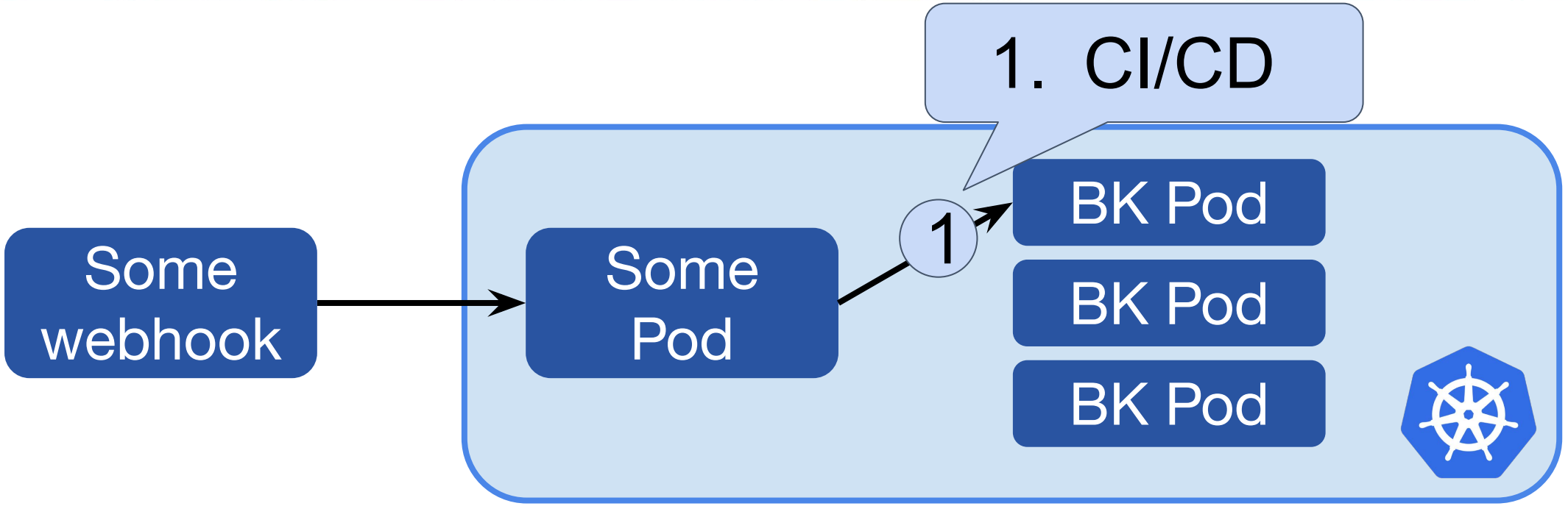
Two kinds of motivation:

1. CI/CD

2. Developer Experience

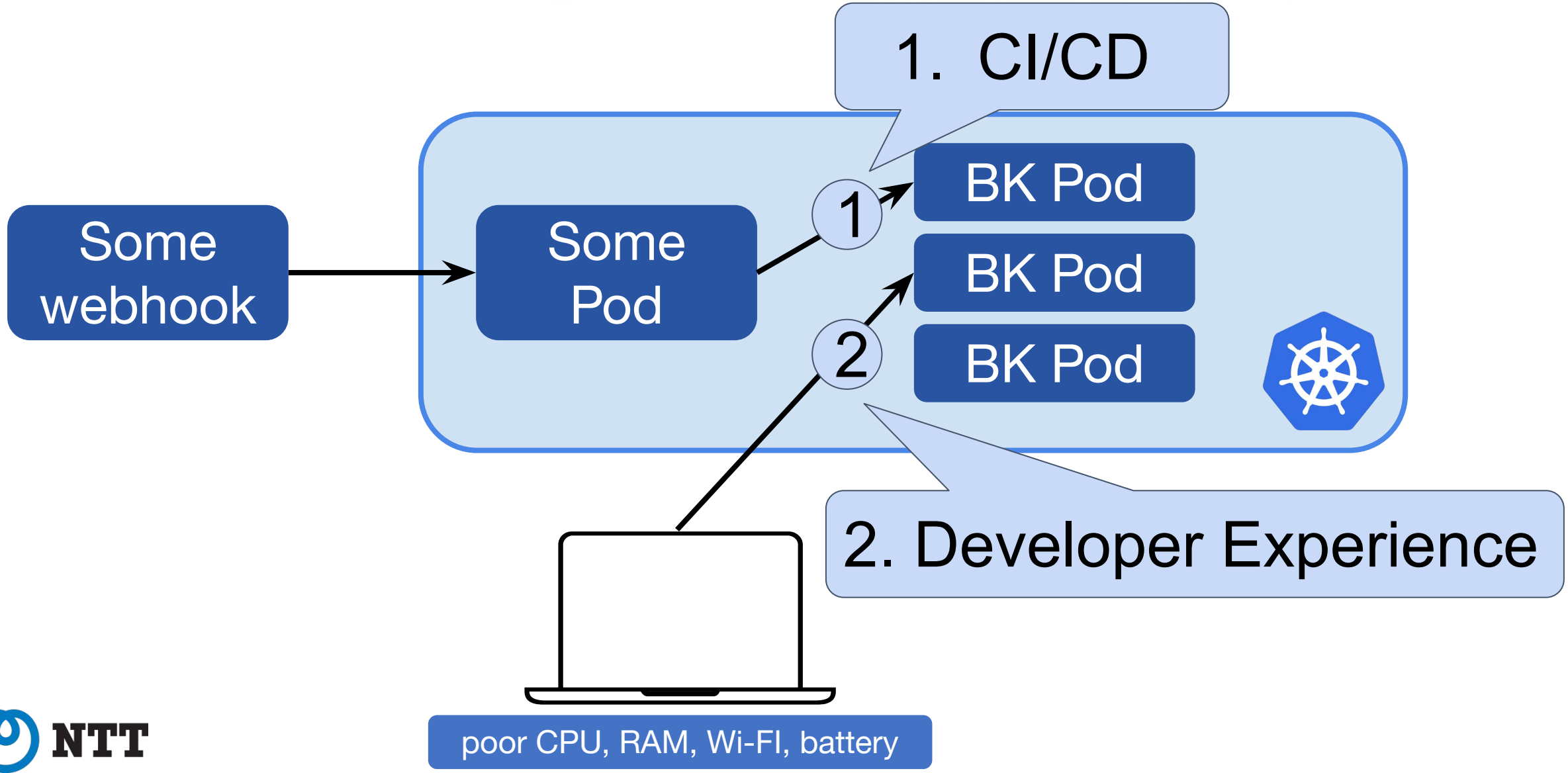
# Why build images on Kube?





# Why build images on Kube?





# Issue with docker build on Kube



- The common pattern was to run `docker` Pod with `/var/run/docker.sock` hostPath
- Or run `docker:dind` Pod with `securityContext.privileged`
- Both are insecure

# Part 2.1
# Rootless mode

# Rootless mode



- BuildKit can be executed as a non-root user
- No extra `securityContext` configuration needed
- Protect the host from potential BuildKit vulns

# Demo

# myth 1: requires securityContext.privileged



- Not true since BuildKit v0.4.0
- But you need to disable “Process Sandbox”:

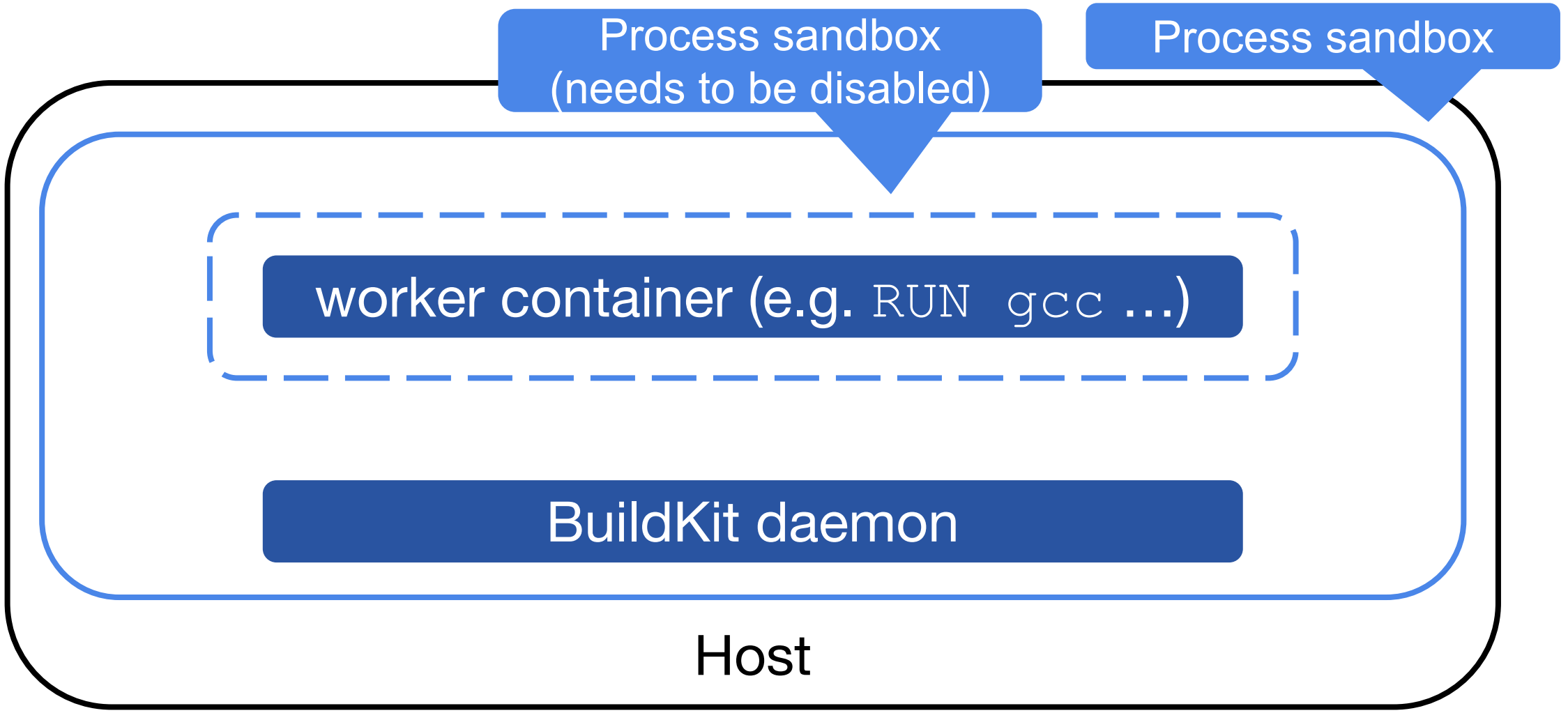
  launch `buildkitd` with

  `--oci-worker-no-process-sandbox`

  - Disable unsharing PIDNS and mounting `/proc`

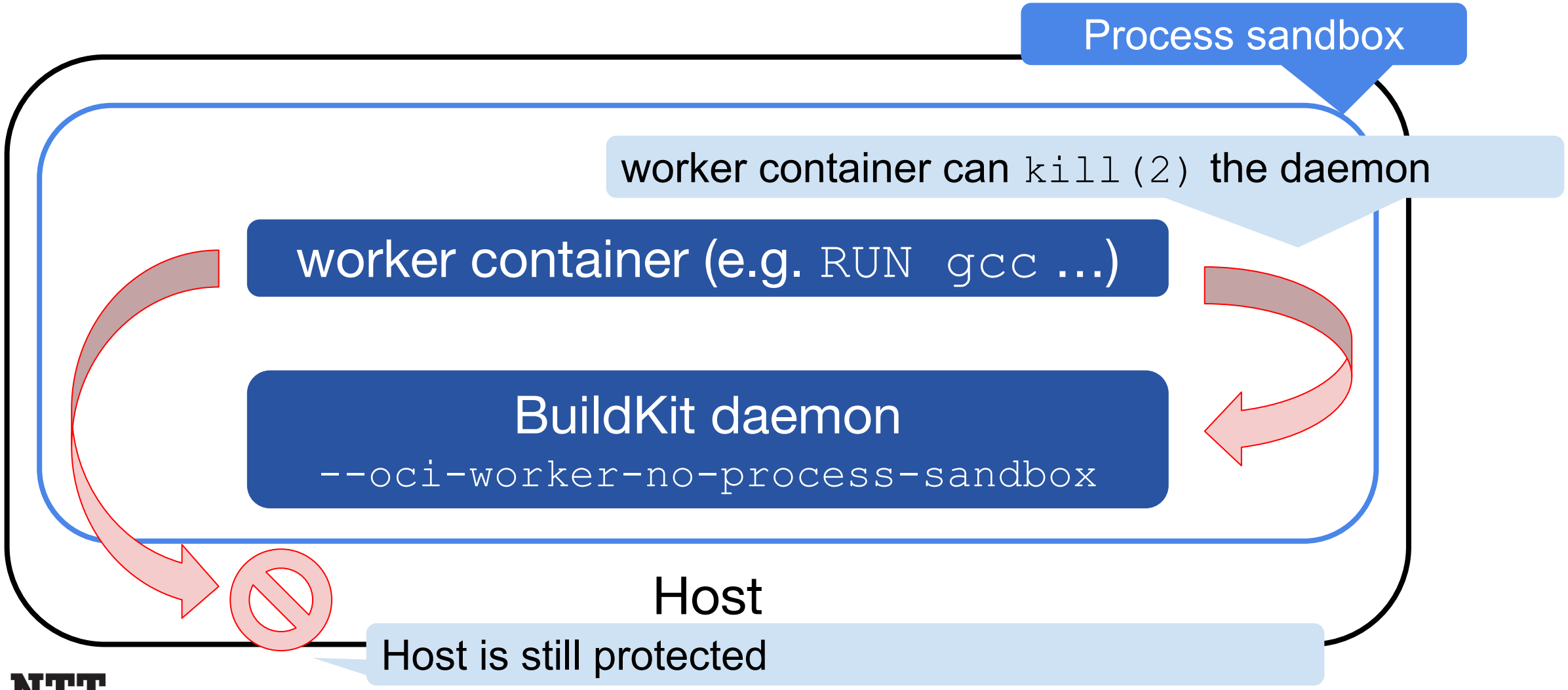
# myth 1: requires securityContext.privileged





# myth 1: requires securityContext.privileged





# myth 1: requires securityContext.privileged



- To enable Process Sandbox, `securityContext.procMount` needs to be set to `Unmasked`
  - Requires Kubernetes v1.12+ with Docker v18.06+ / containerd v1.2+ / CRI-O v1.12

# myth 2: seccomp and AppArmor need to be disabled

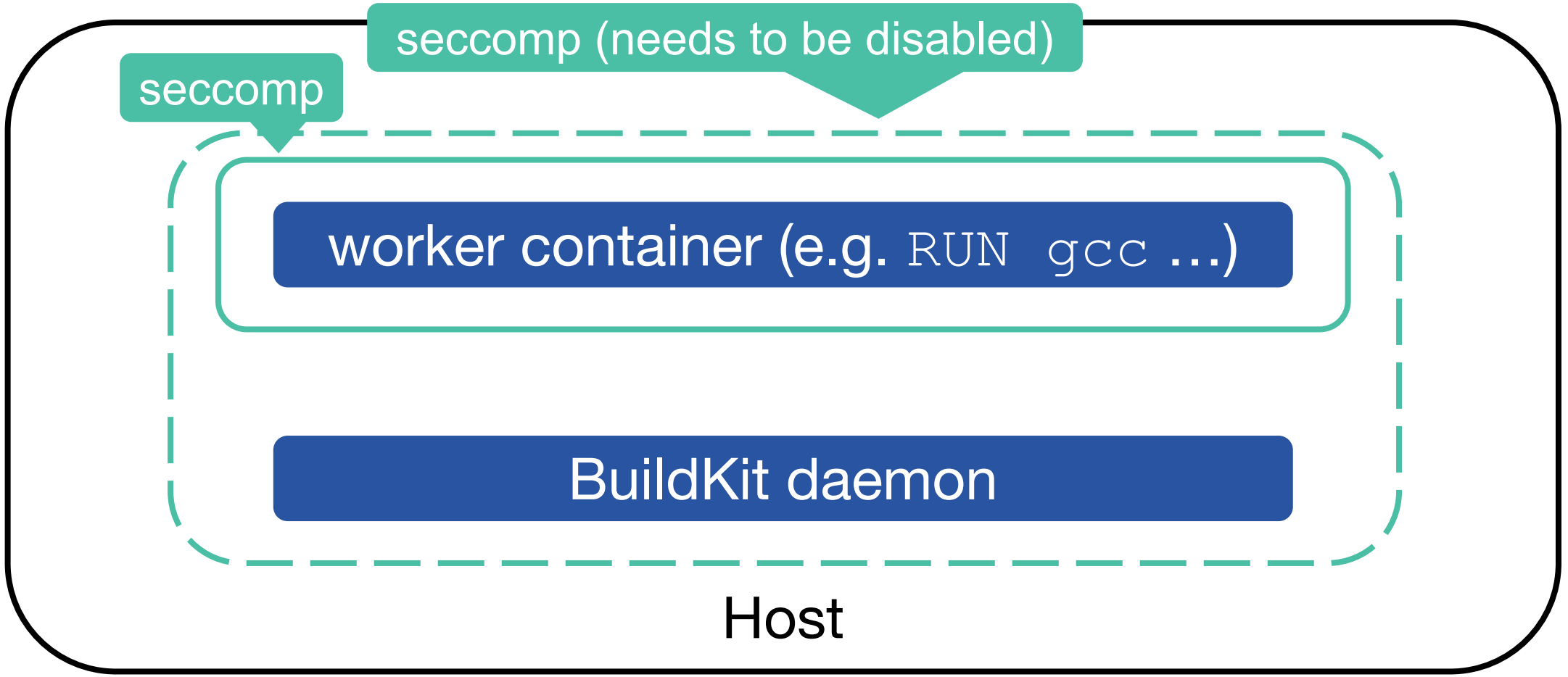
# ~~myth 2~~: seccomp and AppArmor need to be disabled



- Not a myth :P
- seccomp (and AppArmor) is typically disabled by default on Kubernetes anyway
  - In Kubernetes world, seccomp is still in alpha status and AppArmor is in beta

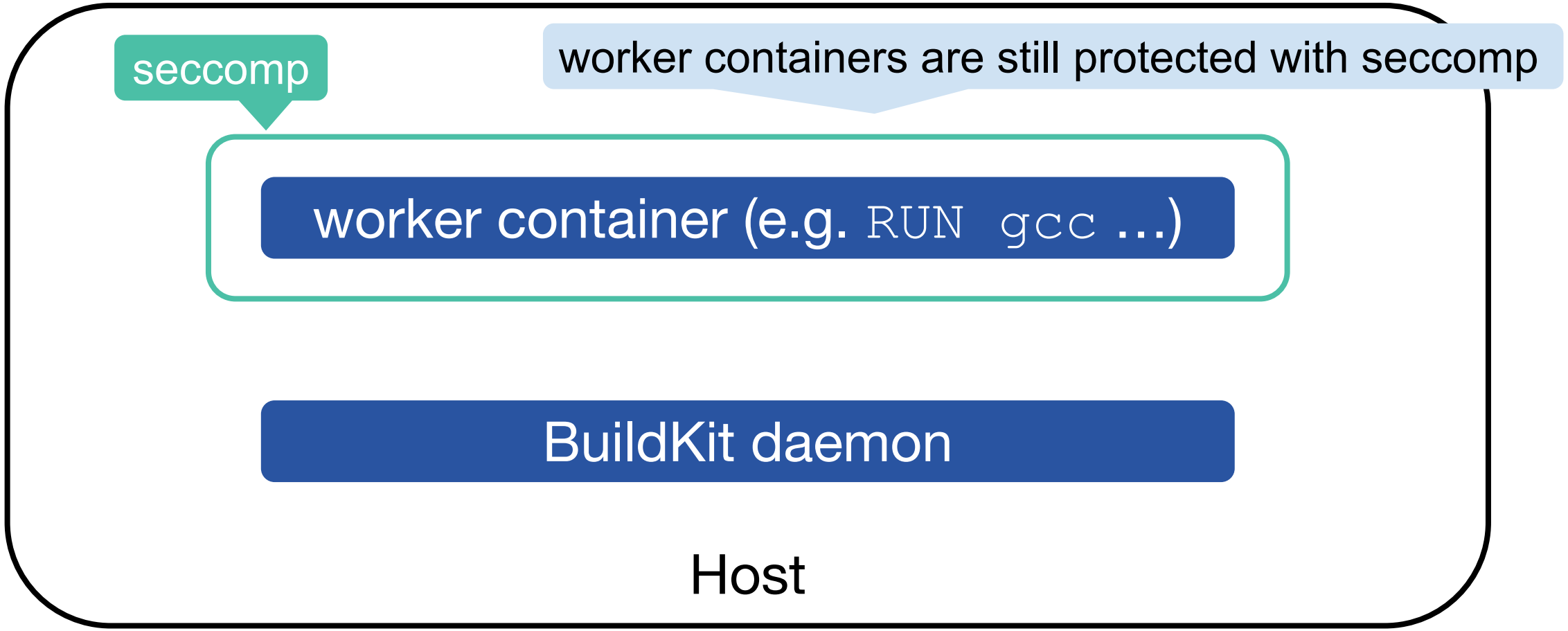
# ~~myth 2~~: seccomp and AppArmor need to be disabled





# ~~myth 2~~: seccomp and AppArmor need to be disabled



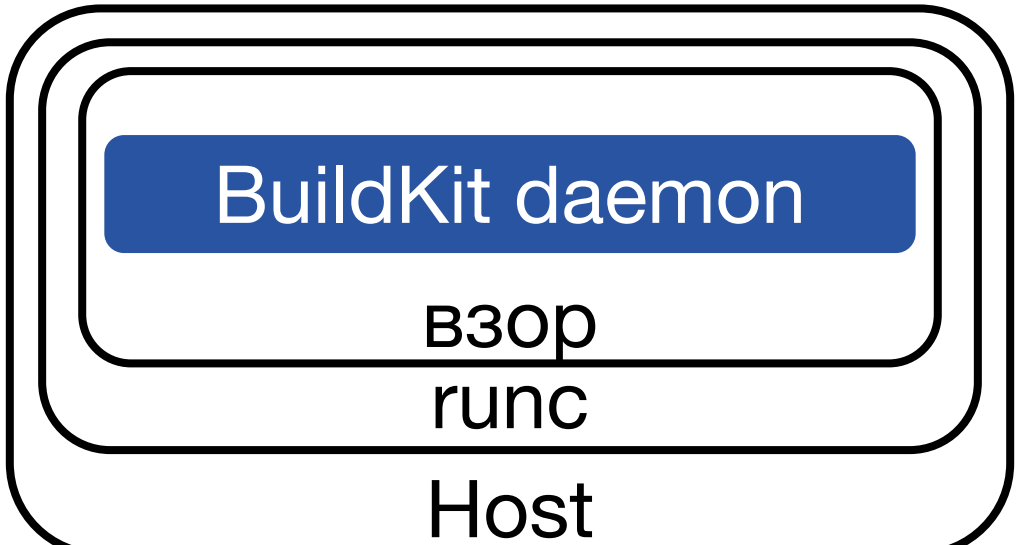


# Future work: gVisor integration?



- gVisor: Yet another Linux kernel implementation in userspace
- вzор (*vzor*): gVisor-based sandbox for runc containers

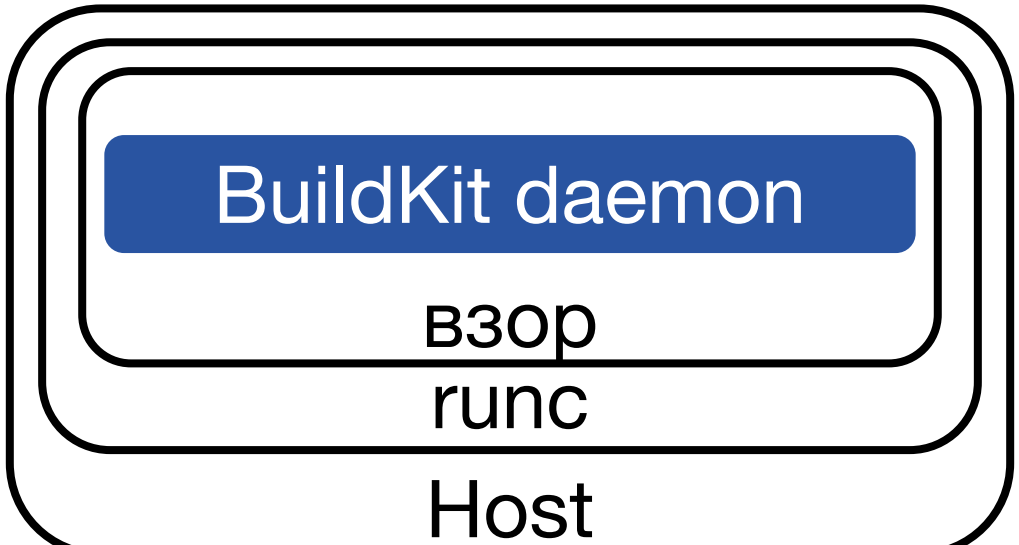
  https://github.com/tonistiigi/vzor



# Future work: gVisor integration?



- No need to disable seccomp/AppArmor for runc
- Can also mitigate kernel vulns



# Future work: gVisor integration?



- Currently BuildKit fails with `EINVAL` due to syscall incompatibility
- Or User-Mode Linux?
  - Full Linux compatibility
  - 20 yo, still alive :)

# Rootless BuildKit vs Kaniko



- Kaniko runs as the root but “unprivileged”
  - No need to disable seccomp and AppArmor
- Kaniko might be able to mitigate some vuln that Rootless BuildKit cannot mitigate - and vice versa
  - Rootless BuildKit might be weak against kernel vulns
  - Kaniko might be weak against runc vulns

# Part 2.2
# Deployment strategy

# Deployment strategy



Deployment?

DaemonSet?

StatefulSet?

Job?

# Deployment strategy



- `Deployment`
  - Most typical deployment

- `DaemonSet`
  - Better `Pod` placement
  - But unlikely to hit daemon-local cache if you have a bunch of replicas
  - So might be not always optimal for large clusters w/ complex Dockerfiles

# Deployment strategy



- `StatefulSet`
  - Consistent `Pod` names
  - Good for Consistent Hashing (discussed later)

# Deployment strategy



- `Job` ("Daemonless")
  - `buildctl` and ephemeral `buildkitd` in a single ephemeral `Pod`
  - No need to manage the life cycles of the daemons
  - Needs PR: moby/buildkit#979
    - or github.com/genuinetools/img (lacks some upstream features)

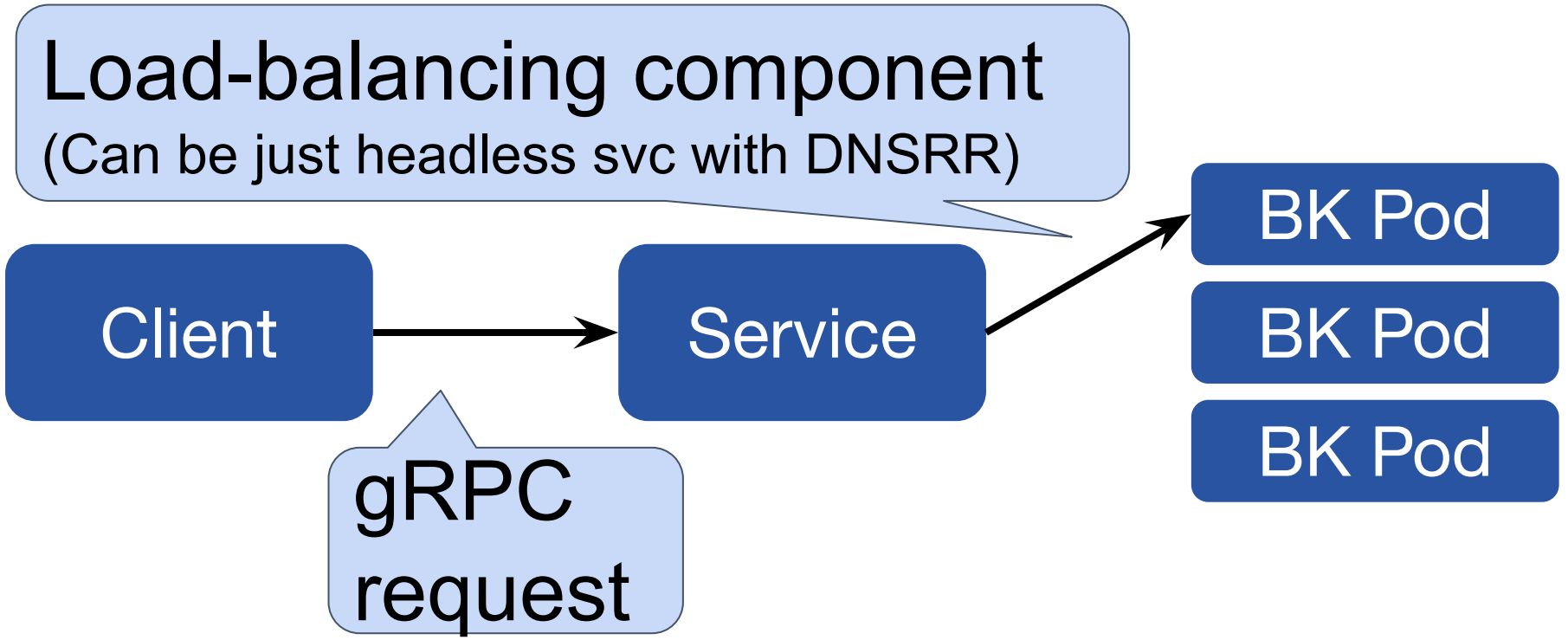
# How to connect to BuildKit?



- BuildKit daemon can listen on TCP (with TLS)
- The entire operation (build & push) just needs a single gRPC connection
- So you can create Kubernetes `Service` for connecting to BuildKit `Deployment` / `DaemonSet` / `StatefulSet`

# How to connect to BuildKit?





# How to connect to BuildKit?



- But you don't need to necessarily create `Service`
- `buildctl` CLI can directly connect to a daemon in a `Pod` without `Service`
  - Internally invokes `kubectl exec`

# How to connect to BuildKit?



```
$ kubectl run \
  --generator=run-pod/v1 \
  --image=moby/buildkit:master-rootless \
  bk -- --oci-worker-no-process-sandbox
```

```
$ export BUILDKIT_HOST=kube-pod://bk
$ buildctl build ...
```

# Coming soon: docker buildx for Kube



- `docker buildx` is the next generation CLI for integrating BuildKit to Docker
  - Supports building multi-arch image with remote ARM machines
  - “Bake”: compose-like build

- `docker buildx` will support connecting to BuildKit on Kubernetes in the same UX

# Part 2.3
# Caching

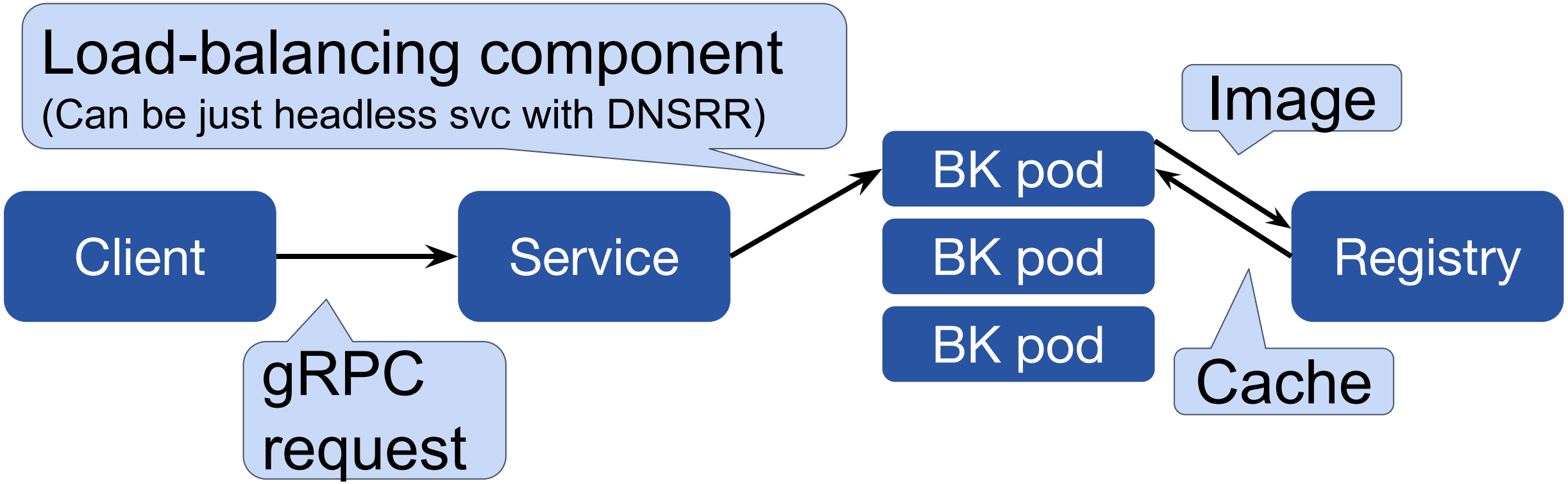
# Remote cache



- Cache can be shared via either registry or shared FS
- Similar to classic `docker build --cache-from` but more chance of hitting cache
- For building non-container artifacts (it's a valid use-case), FS cache might be useful

# Remote cache





# Remote cache



- Remote cache might be slow compared to the daemon-local cache

- Example from Part 1 slides:
  - No cache: 2m50s
  - Remote cache: : 36s
  - Daemon-local cache: 0.5s

# Consistent hashing

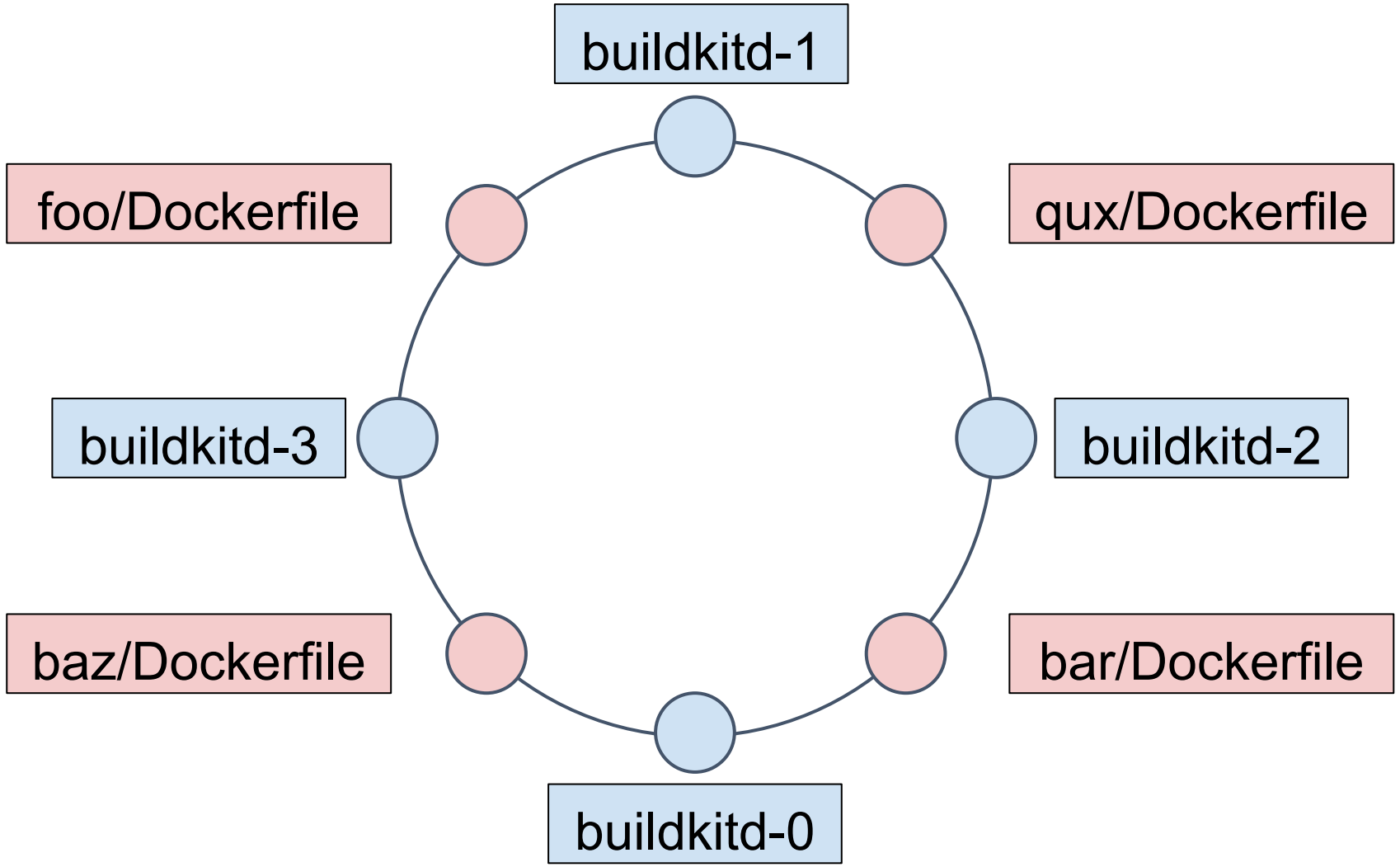


- Consistent hashing allows sticking a build request to a specific `Pod` in `StatefulSet`

- So the build request can always hit the daemon-local cache in the `Pod`

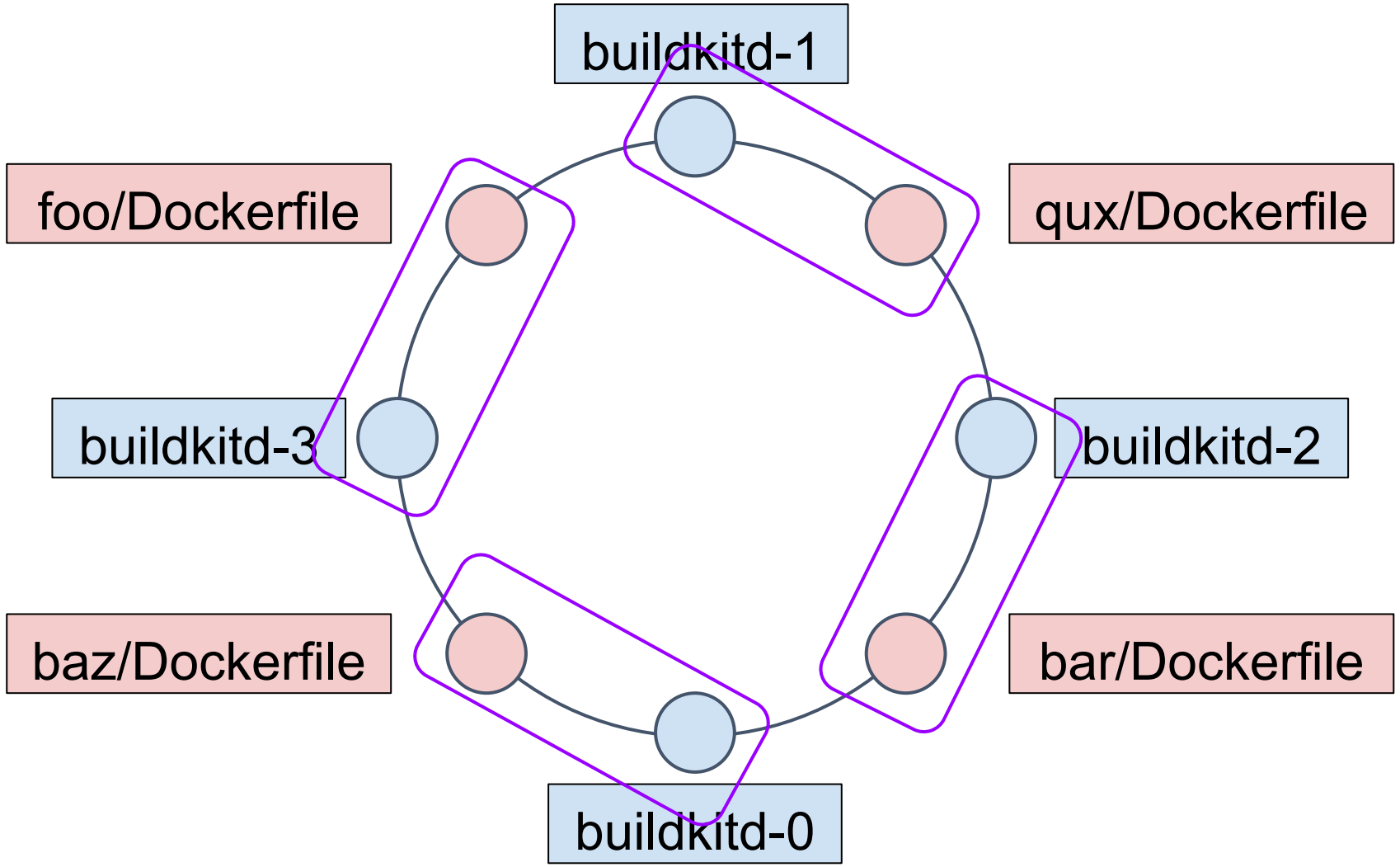
# Consistent hashing





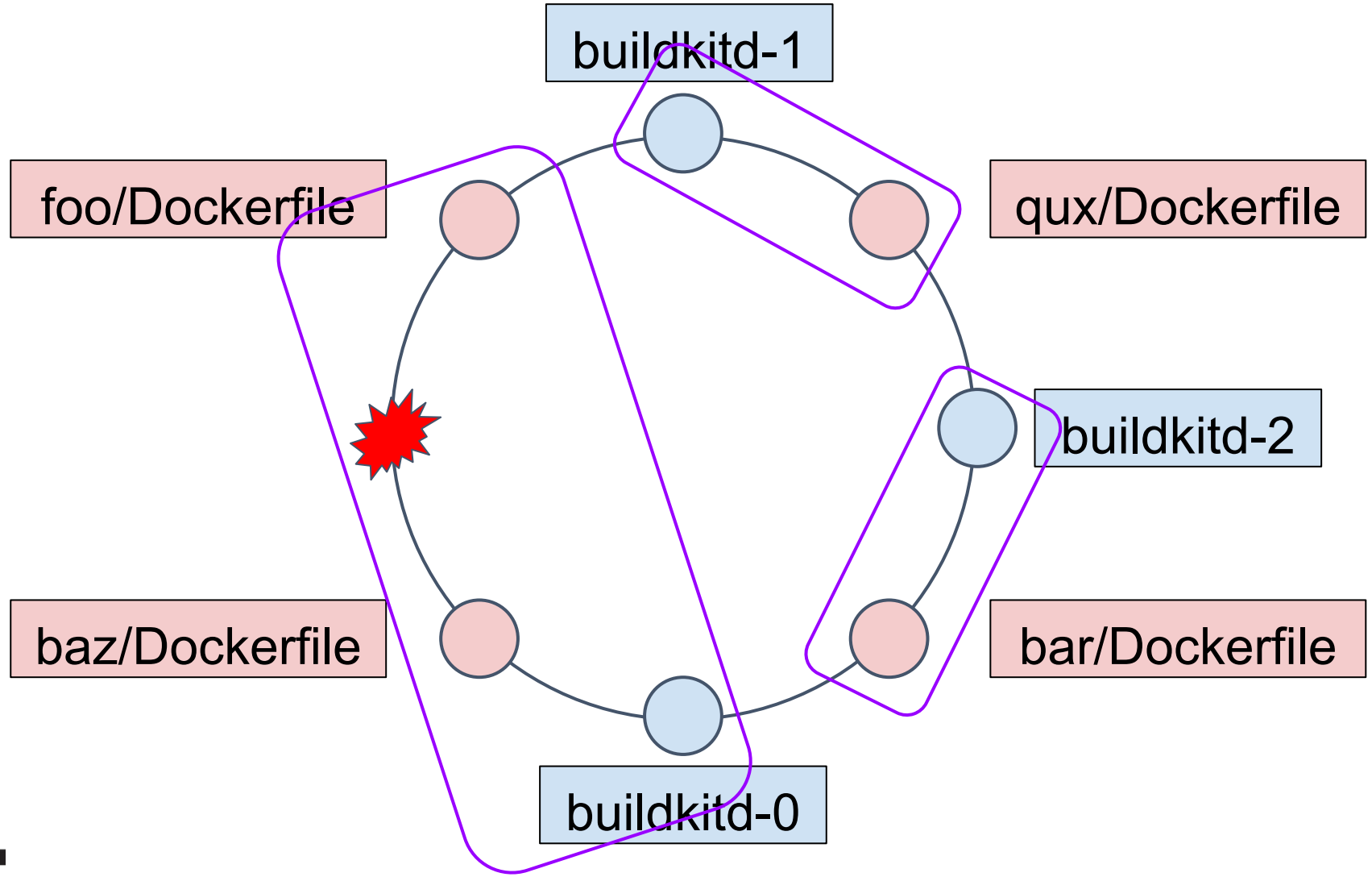
# Consistent hashing





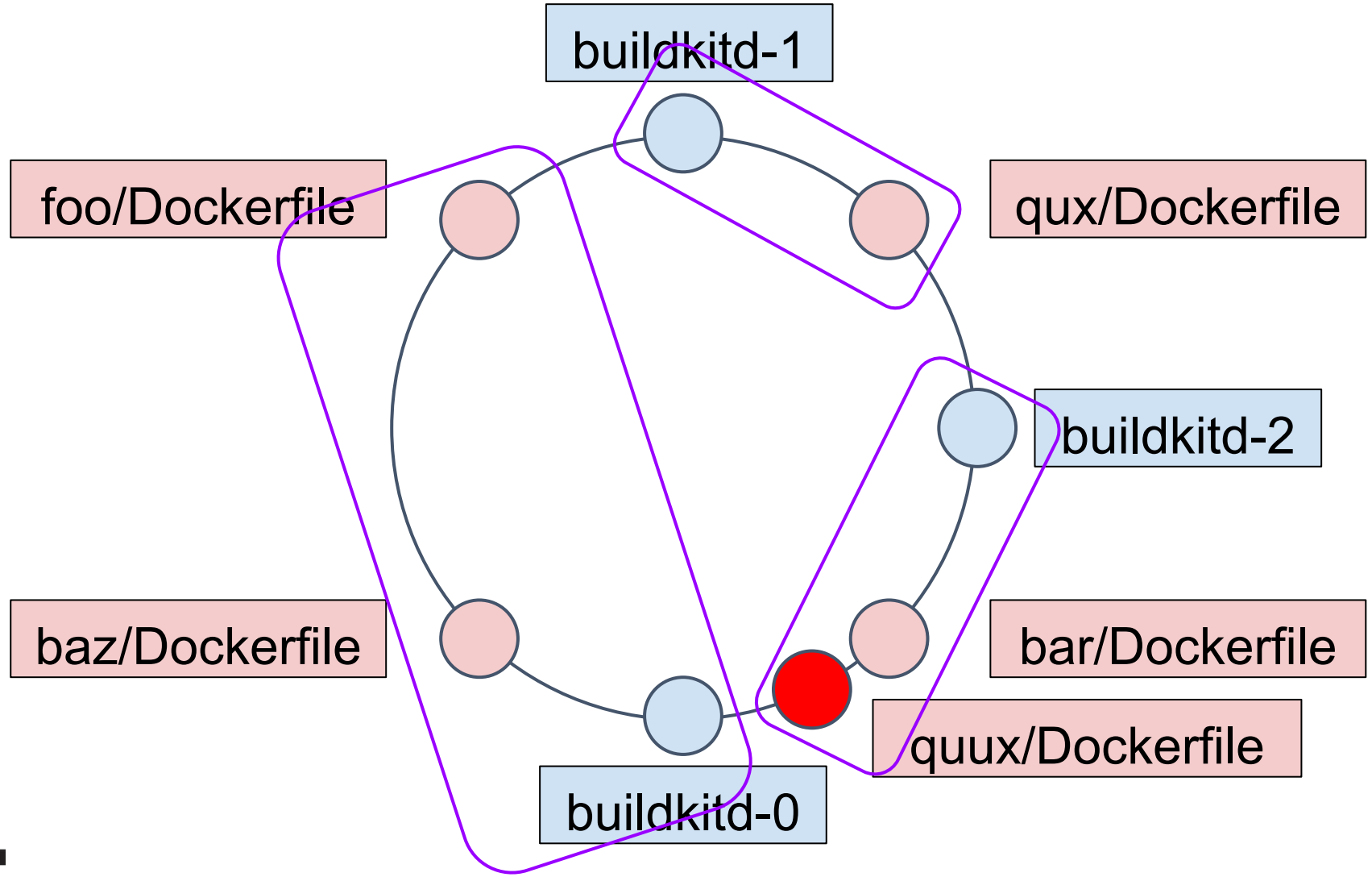
# Consistent hashing





# Consistent hashing





# Consistent hashing



- Caveats:
  - High I/O overhead on specific set of nodes
  - Some nodes might not be used at all

- See `examples/kube-consistent-hashing` in the `moby/buildkit` repo

# Remote cache vs Consistent hashing?

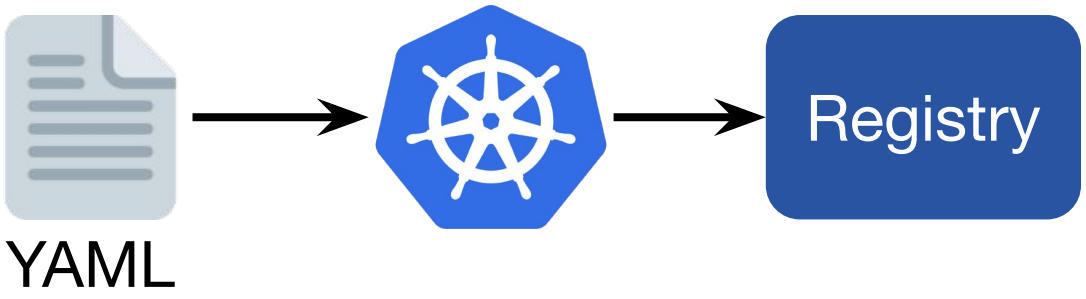


- If your cache registry is fast enough for your Dockerfiles, remote cache w/  load-balancing might be better

- If you don’t like transferring cache, consistent hashing might be better

# Part 2.4
# CRD

# YAMLIFY ALL THE THINGS



# CRD



Container Builder Interface (CBI)



- The first common build CRD
- Supports Docker, BuildKit, Buildah, kaniko, img, Google Cloud Container Builder, Azure Container Registry Build, and OpenShift S2I
- Complex design with a bunch of microservices
- Now being deprecated

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# CRD



Container Builder Interface (CBI)

- Simpler than CBI and easily extensible
- The build component (not entire Knative) might be going to be deprecated in favor of Tekton


- Spun out from Knative
- Much more simple and extensible

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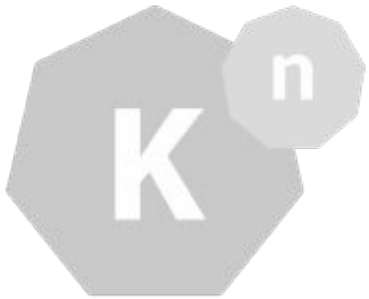
# CRD



Container Builder Interface (CBI)




- Simpler than CBI and easily extensible
- The build component (not entire Knative) might be going to be deprecated in favor of Tekton


- Spun out from Knative
- Much more simple and extensible

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# Tekton



```
apiVersion: tekton.dev/v1alpha1
kind: TaskRun
metadata:
  name: foobar
spec:
  taskRef:
    name: buildkit
...
```

The interface is same as other image builders (Buildah, Kaniko, and Makisu)

# Tekton



```
inputs:
  resources:
  - name: source
    resourceSpec:
      type: git
      params:
      - name: url
        value: git@github.com:foo/bar.git
```

SSH credential is loaded from the `Secret` associated with the `ServiceAccount`

# Tekton



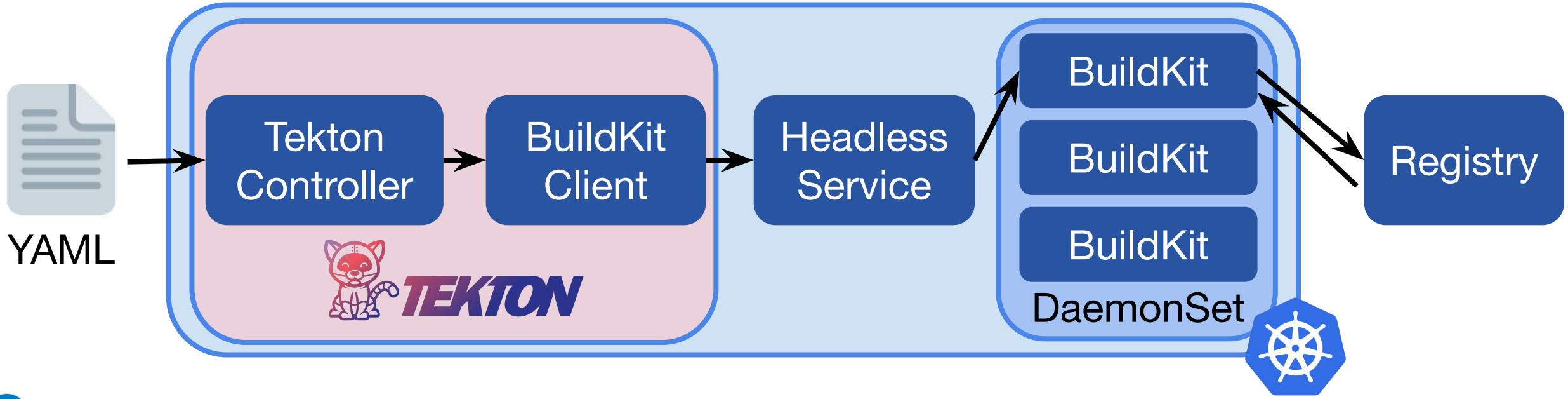
```
outputs:
  resources:
  - name: image
    resourceSpec:
      type: image
      params:
      - name: url
        value: registry.example.com/foo/bar
```

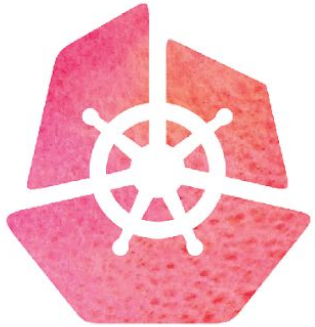
Registry credential is loaded from the `Secret` associated with the `ServiceAccount`

# Wrap-up



- BuildKit is fast and secure
- Several deployment plans, w/ and w/o daemon
- Example:





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Join us: https://github.com/moby/buildkit