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# BuildKit: A Modern Builder Toolkit on Top of containerd (BuildKit: 建立在containerd之上的现代构建工具包)

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# About us

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Software engineer
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Maintainer of BuildKit
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Software engineer
**NTT Corporation**

Maintainer of BuildKit,
containerd, Moby...

# What is BuildKit?

# How are container images built?

**Dockerfile**

**> docker build .**

Bundled into Docker daemon

# What’s the issue with old builder?

- Old design/codebase
- Tightly modeled after Dockerfile instructions
- Hard to add new (Dockerfile) features
- Suboptimal performance
- Leaks state to other Docker APIs
- Not usable for other projects

# BuildKit solves these problems

- Dozens on new features and bugfixes
- Much faster
- Language agnostic
- Componentized
- Toolkit for building opinionated builders

# Built on containerd

**containerd - An open and reliable container runtime**

- **Snapshotters**
- **Distribution**
- **Blobs storage**
- **GC**

# Embraces OCI standards

## OCI - Open Container Initiative

- Process execution with OCI Runtime specification
- Build results can be exported with OCI Image specification (including manifest lists)

# Part 2
# BuildKit Innovations

# Problems of legacy docker build



- The legacy `docker build` does not compute dependencies across Dockerfile instructions correctly

- Modifying line `N` always invalidates the cache for line `(N+1)`

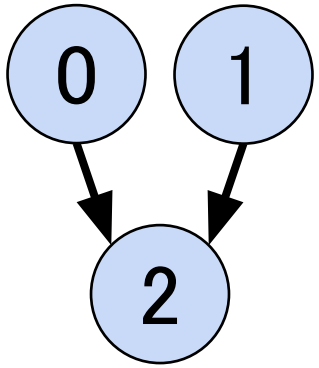
```
FROM    debian
EXPOSE 80
RUN     apt update && apt install -y HEAVY-PACKAGES
```

# Problems of legacy docker build

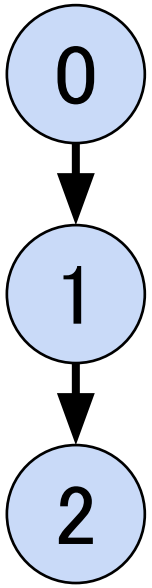


```
FROM    golang AS stage0
...
RUN     go build -o /foo ...

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

FROM    debian AS stage2
EXPOSE 80
RUN     apt ...
COPY --from=stage0 /foo /
COPY --from=stage1 /bar /
```

Expected schedule




Actual



# BuildKit LLB



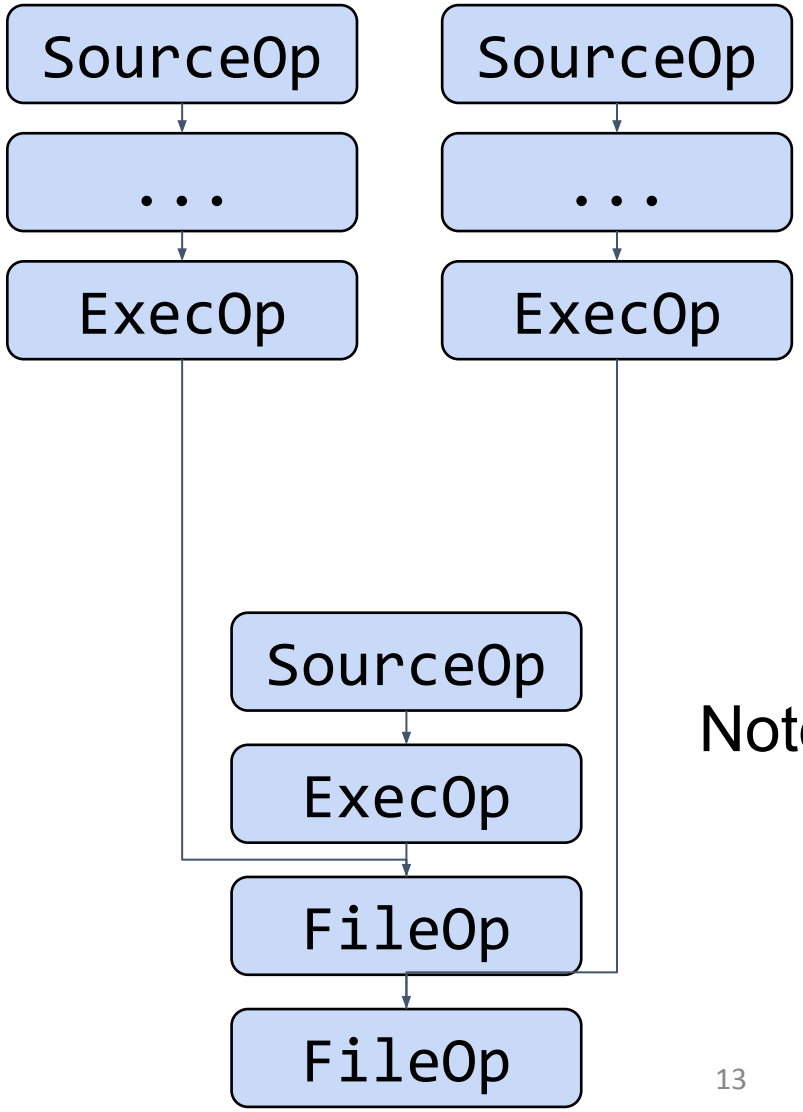
- LLB is to Dockerfile what LLVM IR is to C

- Accurate dependency expression with graph structure
  - Efficient caching
  - Concurrent execution

- Encoded in protobuf; typically compiled from Dockerfile
  - Other “frontends” are also available: Buildpacks, Mockerfile, Gockerfile, Docker Assemble

# BuildKit LLB

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

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

FROM    debian AS stage2
EXPOSE 80
RUN     apt ...
COPY --from=stage0 /foo /
COPY --from=stage1 /bar /
```




Note: No “ExposeOp”

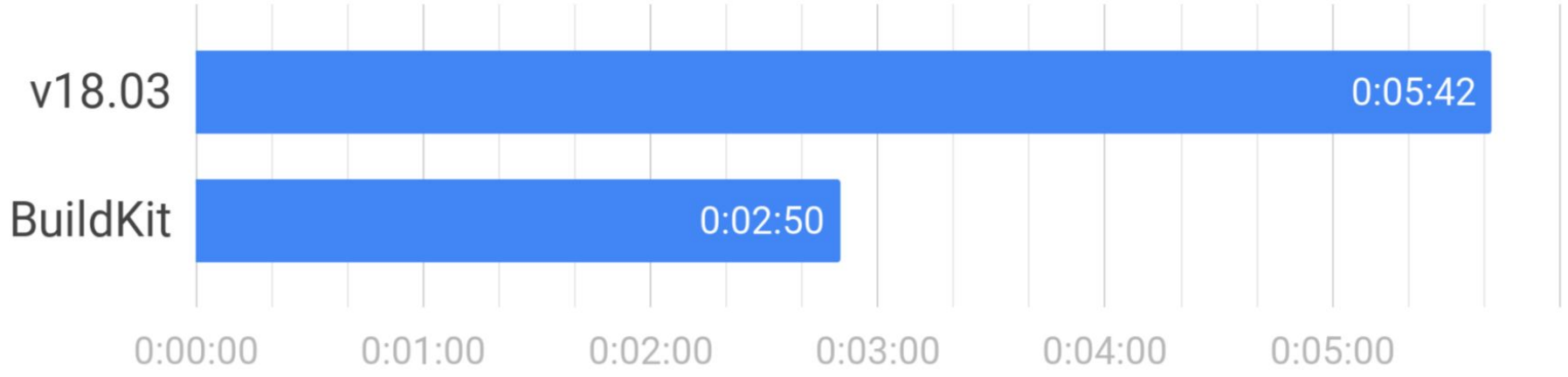
https://t.co/aUKqQCVmXa

## 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*

# Extensible syntax



- “LLB frontend” container can be specified in the first line of Dockerfile (`# syntax = ...`)

- You can also create your own LLB frontend container i.e. you can define your own syntax

```
# syntax = docker/dockerfile:1.1-experimental
FROM ...
RUN  ...
```

# RUN --mount=type=cache



- Allows preserving caches of compilers and package managers

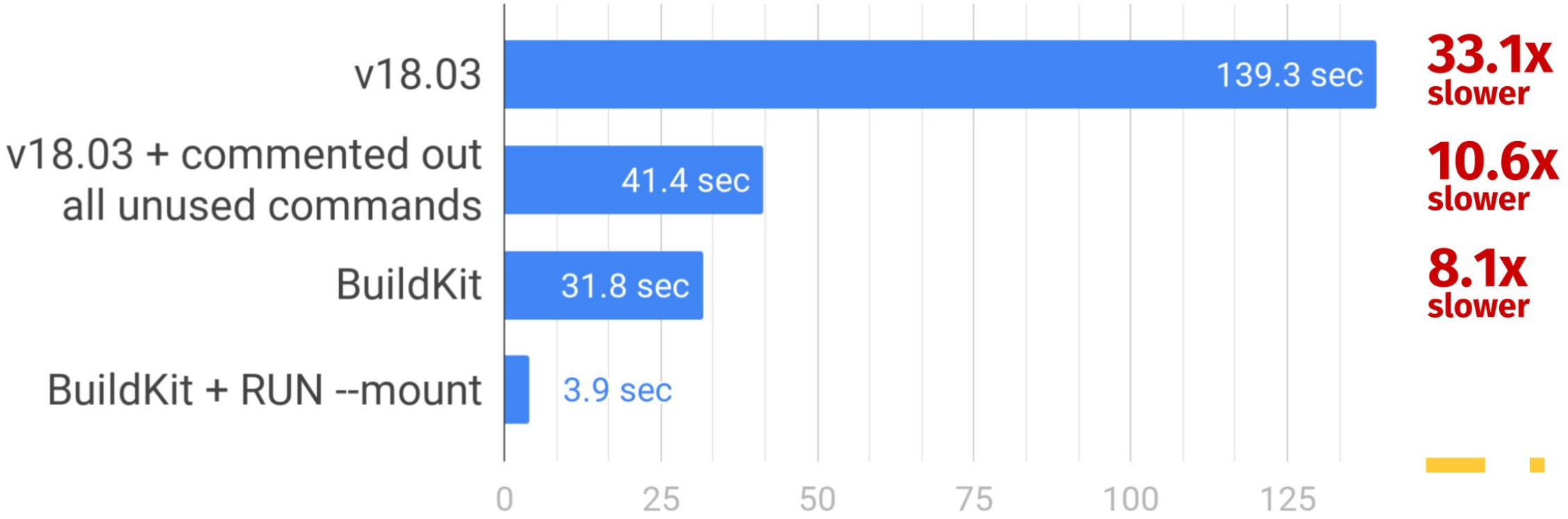
```
# syntax = docker/dockerfile:1.1-experimental
...
RUN --mount=type=cache,target=/root/.cache go build
...
```

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*

dockercon SF 18

# 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)
```

# Part 3
# Using BuildKit

# Many ways to use BuildKit

- **Docker, docker buildx**
- **img**
- **Tekton**
- **Rio**

With or without daemon, in container, in **k8s**,

with **containerd** daemon, without root privileges, etc.

# Docker

- Integrated into “docker build” v18.09+
- Opt-in:

```
export DOCKER_BUILDKIT=1
```

# Docker

3. root@dev3: /mnt/nfs/docker (ssh)

```
# docker build .
```

# Docker Buildx

- Next generation Build command from Docker
- Familiar Docker UI + full BuildKit
- Manages instances of Builders and Build nodes
- With container driver, works with any version of Docker engine

# Buildx: Full BuildKit

- **Remote caching (eg. for CI)**
- **Multi-platform images support**
  - `--platform=linux/amd64,linux/arm64`
  - QEMU, distributed among nodes, or cross-compilation in multi-stage Dockerfile

# Buildx: Multi-platform images

- **Webassembly: wasi/wasm**

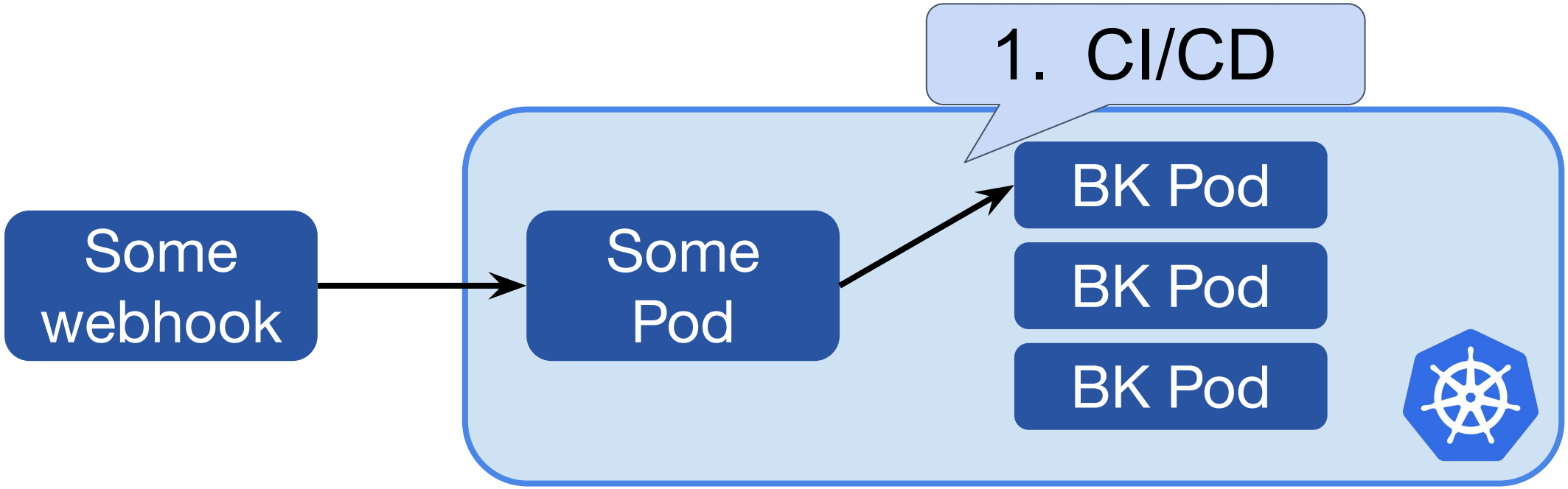
  https://github.com/tonistiigi/wasm-cli-plugin

- **Initial RISC-V support: linux/riscv64**

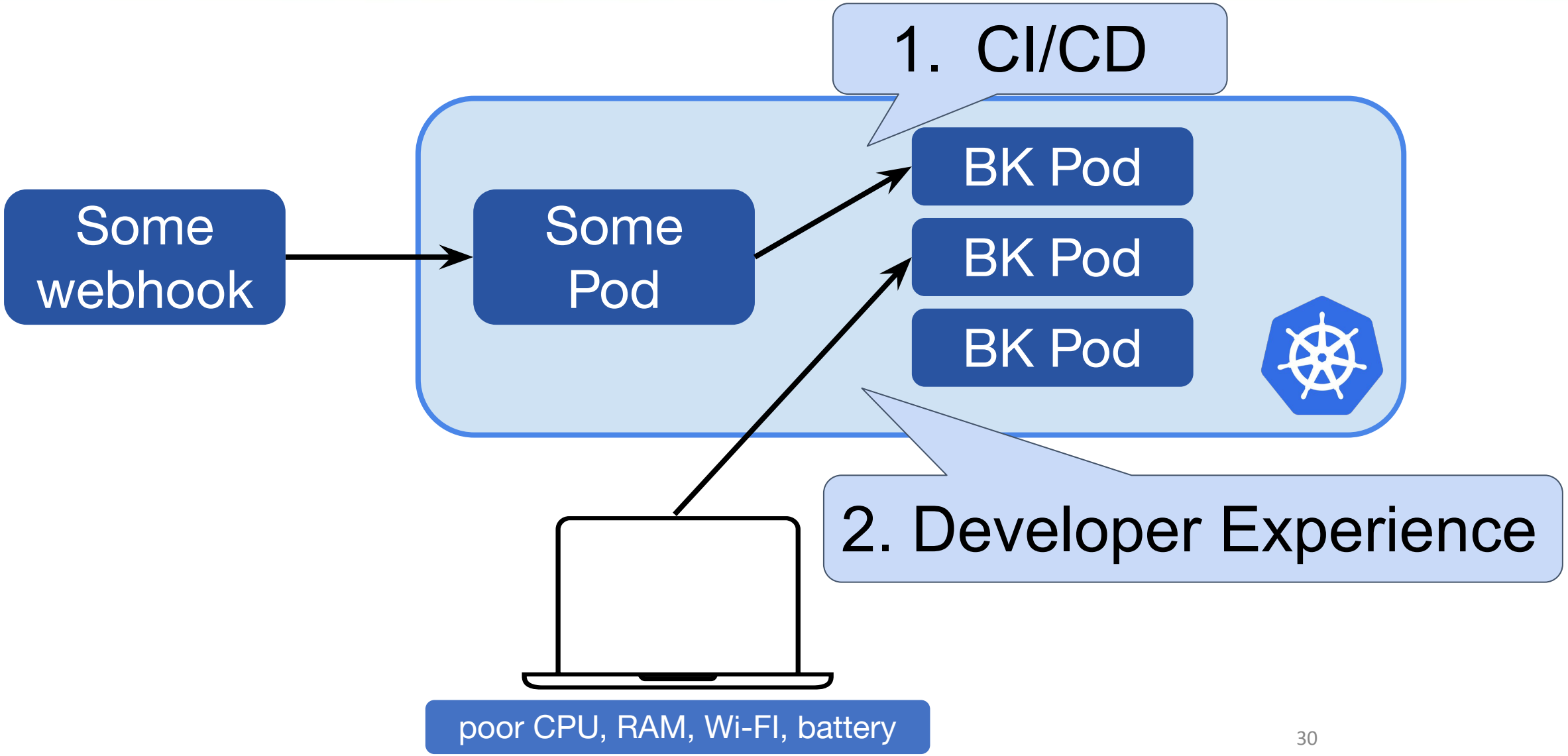
  https://tinyurl.com/docker-riscv

# Part 4
# Deploying BuildKit on Kubernetes

# Why build images on Kube?



# Why build images on Kube?



# Legacy docker build on Kubernetes

- 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

# Rootless mode

- BuildKit can be executed as a non-root user so as to protect the host from potential BuildKit vulns

- No extra `securityContext` configuration needed (but seccomp and AppArmor need to be disabled)

# Rootless BuildKit vs Kaniko

- Kaniko runs as the root user 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

# Deployment strategy

Deployment?

DaemonSet?

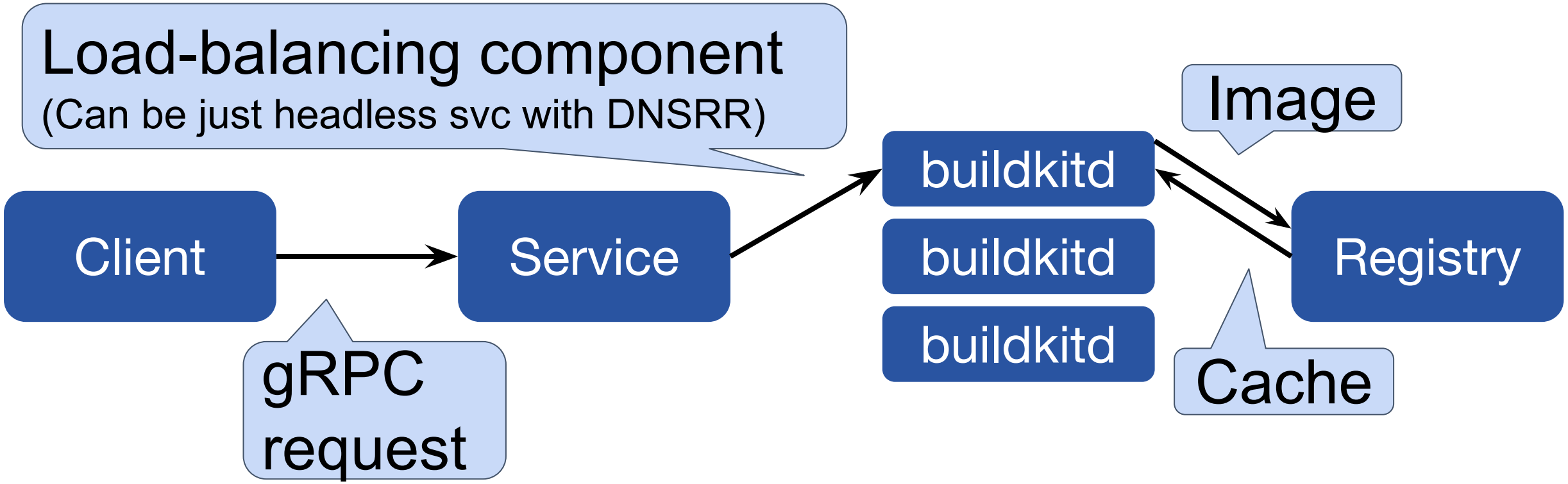
StatefulSet?

Job?

# Deployment strategy

- `Deployment`
  - Most typical deployment
- `DaemonSet`
  - Optimal load-balancing but non-optimal caching
- `StatefulSet`
  - Good for Consistent Hashing (discussed later)
- `Job` (client and ephemeral daemon in a single container)
  - No need to manage the life cycles of the daemons

# Caching


Load-balancing component
(Can be just headless svc with DNSRR)
Image
buildkitd
buildkitd
buildkitd
Client
Service
Registry
gRPC request
Cache

# Caching

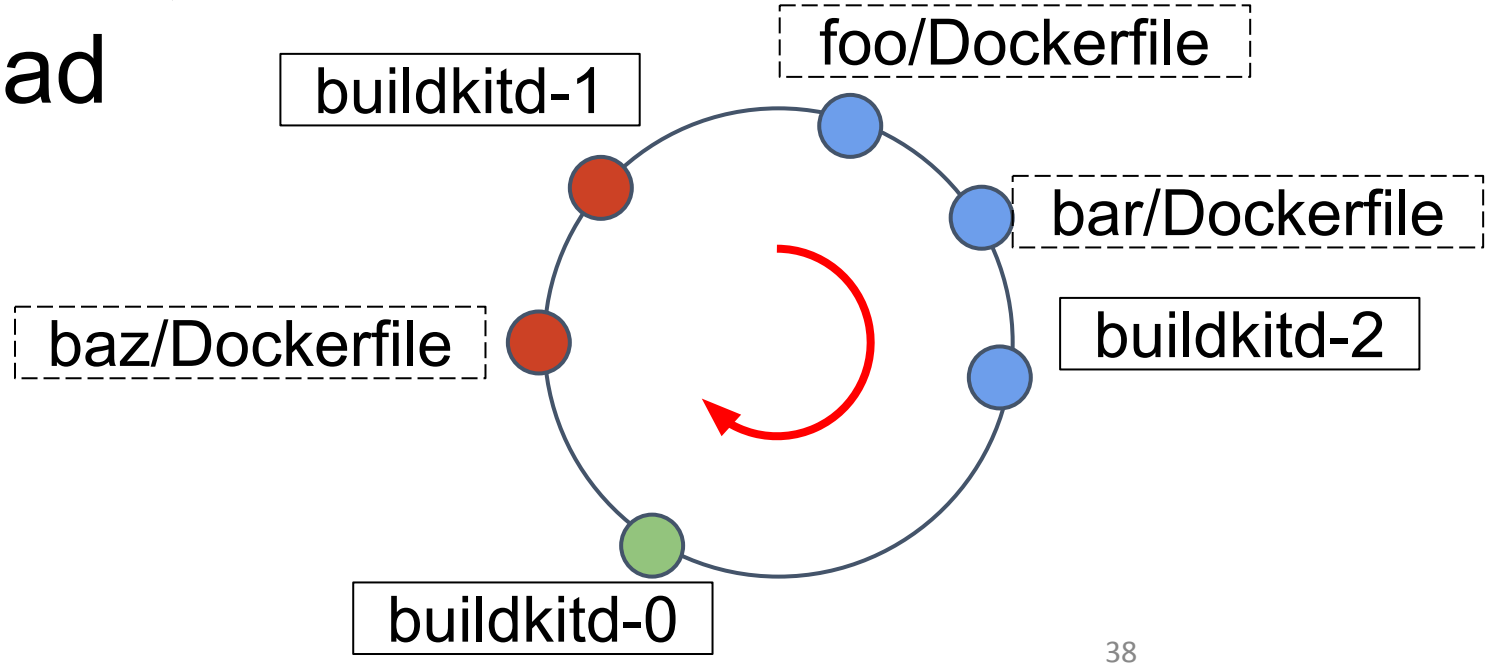
- Remote cache might be slow compared to the daemon-local cache

- Example:
  - No cache: 2m50s
  - Remote cache: 36s
  - Daemon-local cache: 0.5s

# Caching

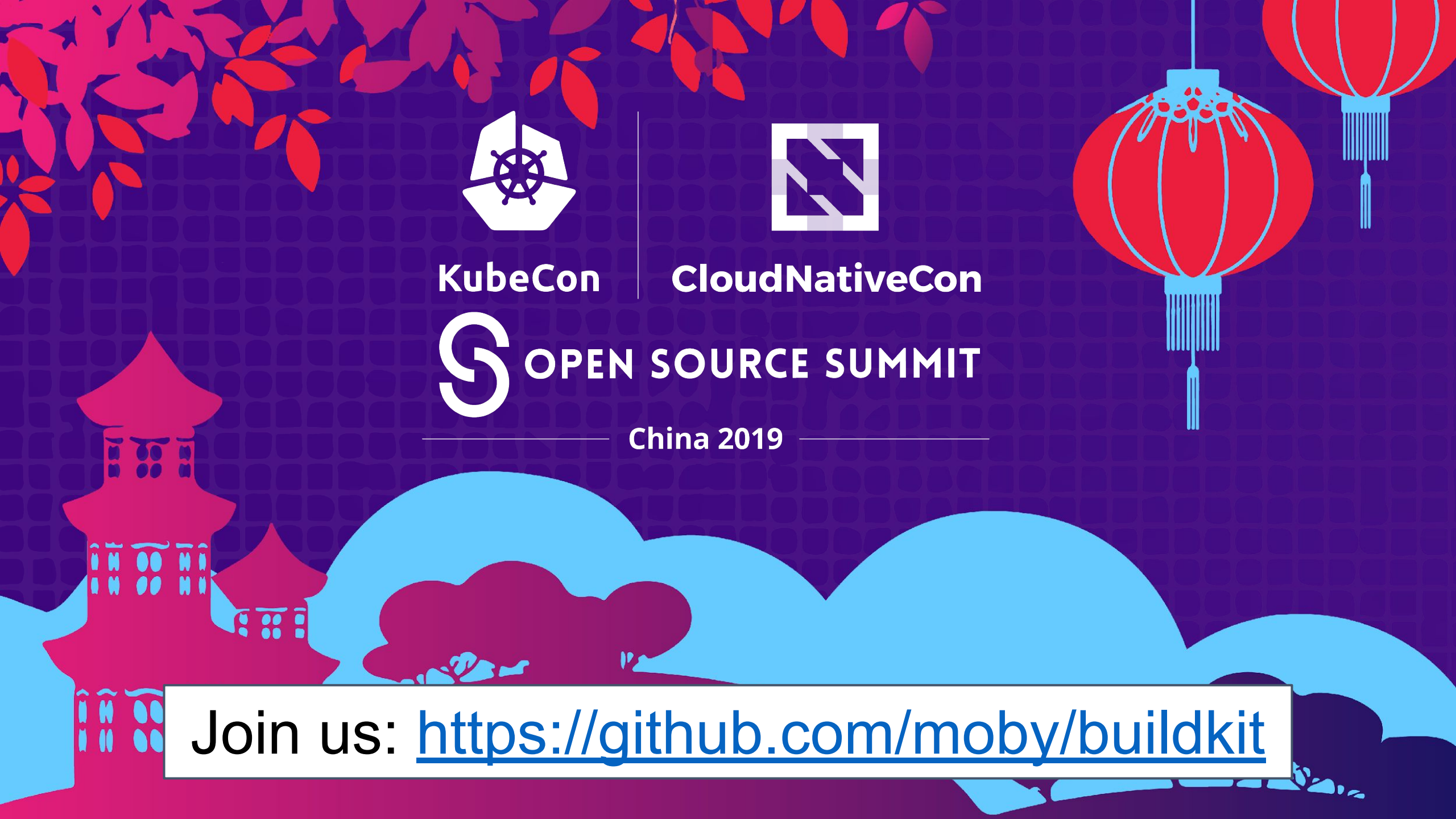
- Consistent hashing allows sticking a build request to a specific `Pod` in `StatefulSet`

- Always hits the cache, but non-optimal load balancing



# Recap

- BuildKit is a **modern** container Build toolkit
- **Significant advantages** over previous tools
- Usable with **Docker**, **K8s** and many other tools
- **Open** platform for collaboration around build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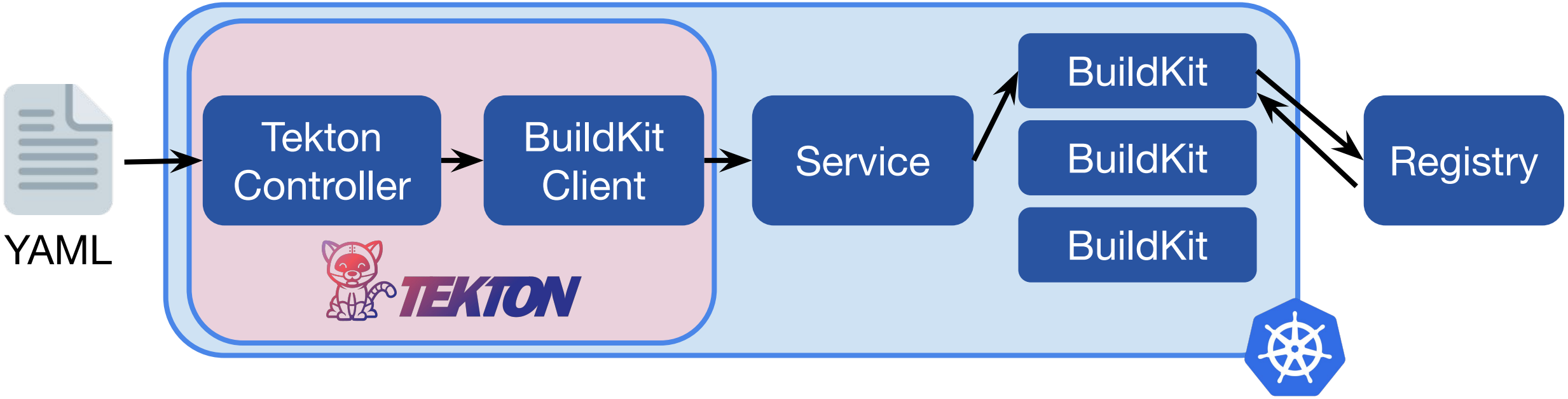
Join us: https://github.com/moby/buildkit

# Extra slides

# Tekton

- CRD for building images
- Successor of Knative Build



# Tekton

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

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

Credentials are loaded from the `Secret` associated with the `ServiceAccount`

# Tekton

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

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

# Rancher Rio

- k8s/k3s-based micro PaaS
- “`rio run https://github.com/…`” builds and deploy app in one-line
- Internally using BuildKit, but users don’t need to care about BuildKit