PID 1, SIG Handling, Hooks & Probes: Managing Container Lifecycle Correctly

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About Me

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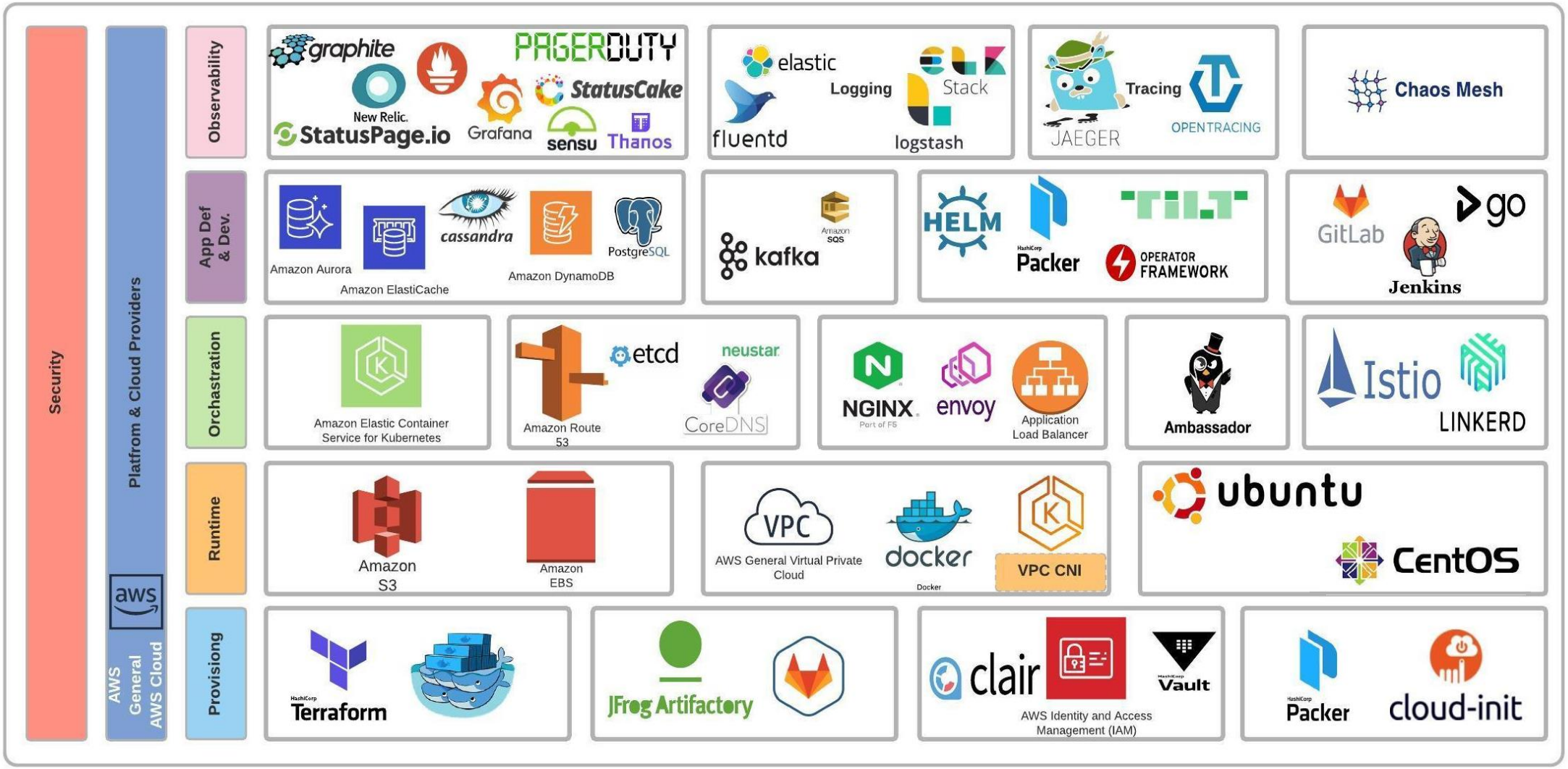
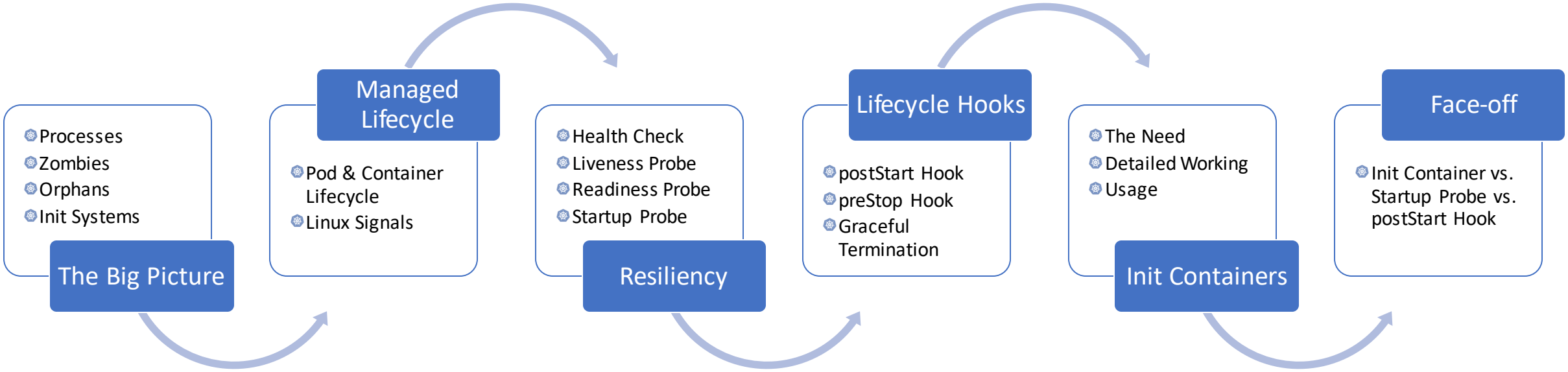
About OLX Group

- Global product and tech group (20+ brands)
- Online buying, selling, and exchange of products and services
- Serving approx. 350 million people per month
- Operating in about 45 countries across 5 continents
- More than 10 million online listings every single month
- Billions of Edge Hits per day
- Hundreds of Thousands of Cache reads per second
- Hundreds of Microservices

Infrastructure Landscape



Agenda


The Big Picture
Processes
Zombies
Orphans
Init Systems
Managed Lifecycle
Pod & Container Lifecycle
Linux Signals
Resiliency
Health Check
Liveness Probe
Readiness Probe
Startup Probe
Lifecycle Hooks
postStart Hook
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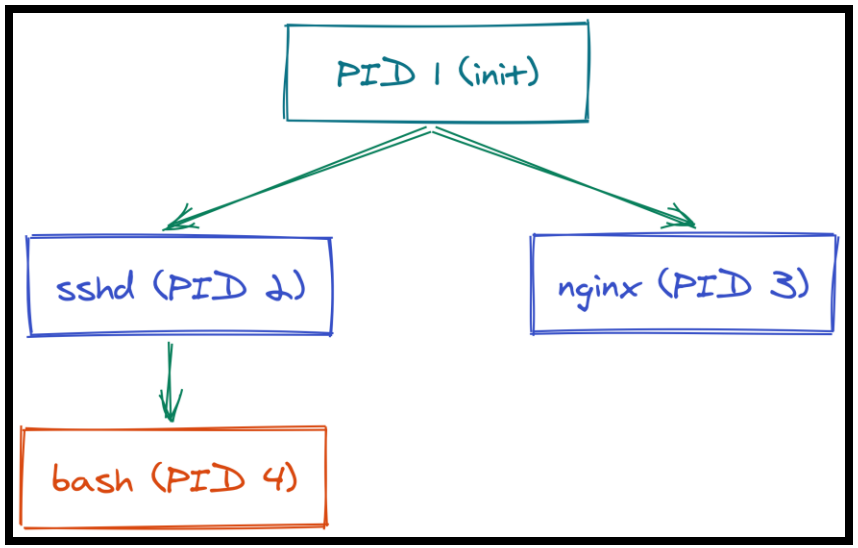
Graceful Termination
Init Containers
The Need
Detailed Working
Usage
Face-off
Init Container vs. Startup Probe vs. postStart Hook

The Big Picture

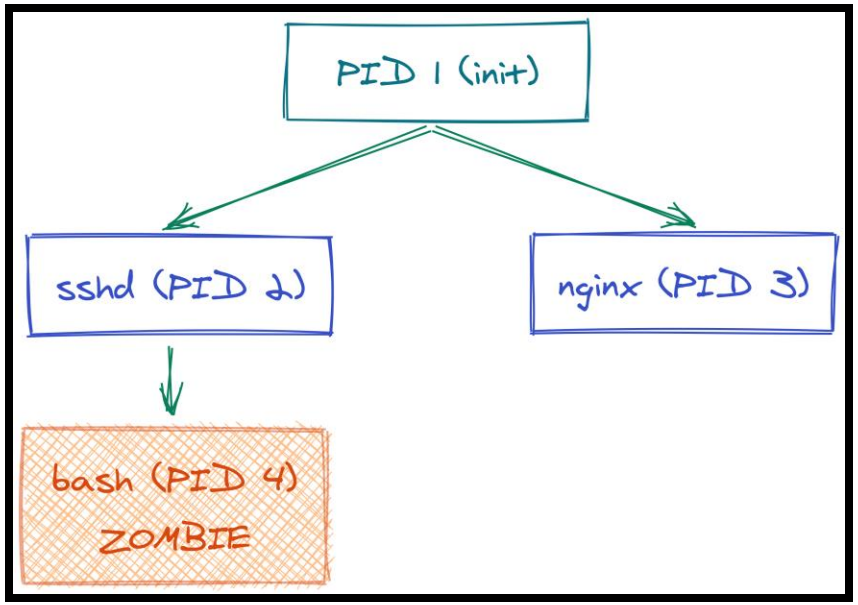
Processes, Zombies, Orphans, and Init Systems

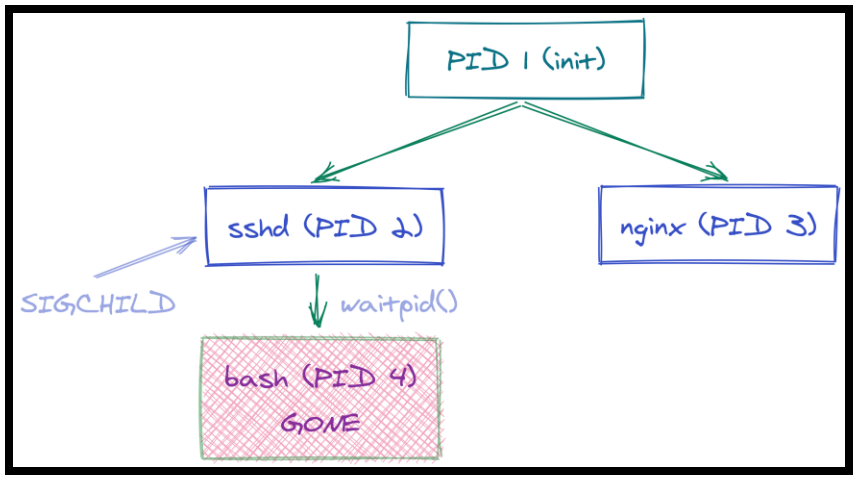
Unix Processes



- Instance of a running application
- Ordered in form of a tree
- Each process can spawn several child processes
- Each process has a parent, except for the top-most process ***(init / PID 1)***
- PID 1 is started by the kernel
- PID 1 acts as a parent process and starts the rest of the system and processes

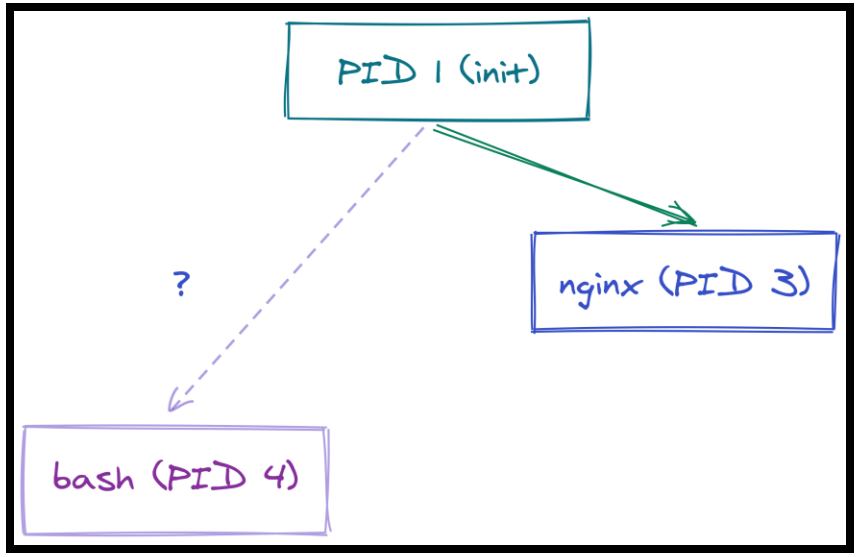
Zombies





- ***Defunct / Zombie*** processes?
- ***waitpid()*** system call
- ***Reaping?***
- ***SIGCHILD*** signal
- *ZOMBIES ARE THE PROCESSES THAT HAVE TERMINATED BUT HAVE NOT YET BEEN WAITED FOR BY THEIR PARENT PROCESSES*

Orphans



- What if the parent process terminates somehow?
- What happens to its children? ***Orphaned?***
- Time for PID 1 to take over? Adoption?
- Who does the reaping now? PID 1?

Are Zombies Harmful?

- Entry in the process table?
- Kernel resources?
- Creation of new processes?
- Resource starvation?

Zombies and Containers

- Generally, one main application process runs per container
- Does this main process act like an init process?
- What about reaping?
- Zombies all around?
- What about Docker containers managed by some third-party?
- Need for a proper init system?
- How about using bash?

Init System To The Rescue

- Upstart? Systemd? The heavyweight systems…
- Tini or dumb-init?

Tini Init System

- https://github.com/krallin/tini
- Simple and lightweight
- Appropriate for containers
- Reaps zombies
- Performs signal forwarding
- Adding or removing Tini doesn't have any negative impact

Setting Up Tini


```
FROM debian:stretch
RUN apt-get update && apt-get -y install procps python3
COPY defunct.py /app/
# CMD ["python3", "/app/defunct.py"]

# Add Tini
ENV TINI_VERSION v0.19.0
ADD https://github.com/krallin/tini/releases/download/${TINI_VERSION}/tini /tini
RUN chmod +x /tini
ENTRYPOINT ["/tini", "--"]

# Run your program under Tini
CMD ["python3", "/app/defunct.py"]
```

```
#!/usr/bin/env python3
import os
import subprocess

child_pid = os.fork()
if child_pid == 0:  # child process
    pid2 = os.fork()
    if pid2 != 0:
        print("The zombie pid will be: {}".format(pid2))
else:  # parent
    print("Parent PID: {}".format(os.getpid()))
    os.waitpid(child_pid, 0)
    subprocess.check_call(('ps', 'xawuf'))
```

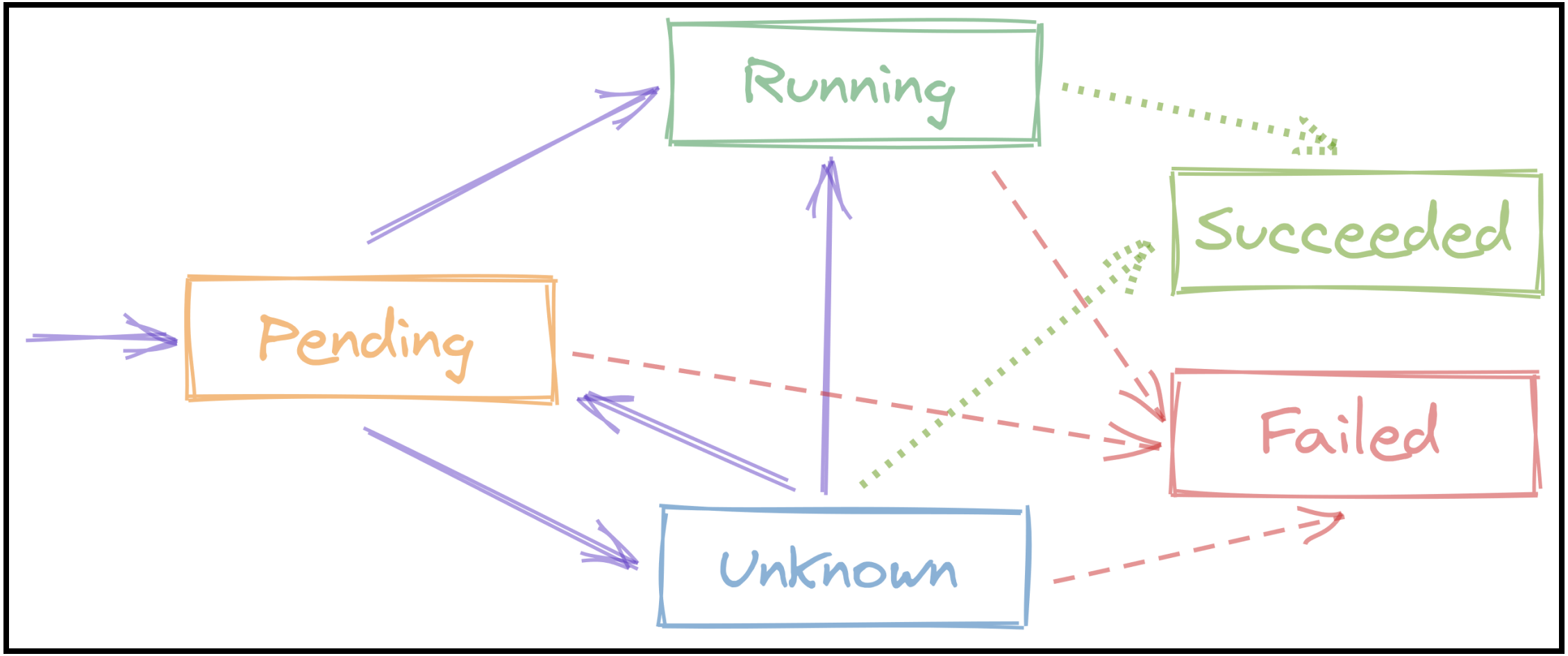
More Details

- Tini needs to run as PID 1 in order to reap zombies
- Can act as a process sub-reaper if not started as PID 1
  - Passing `-s` argument to Tini (tini –s -- …)
- Exits with child's exit code; remapping possible

Managed Lifecycle

Pod & Container Lifecycle, and Linux Signals

Pod Lifecycle Phases



Container Lifecycle States

Terminating Gracefully

- Very important
- Need for cleanups?
- Forced termination? Downtime?
- ***SIGTERM?*** A gentle poke…
- ***SIGKILL?*** The hard kill…

Termination Lifecycle

Set the grace period | Enter TERMINATING state | Stop getting traffic

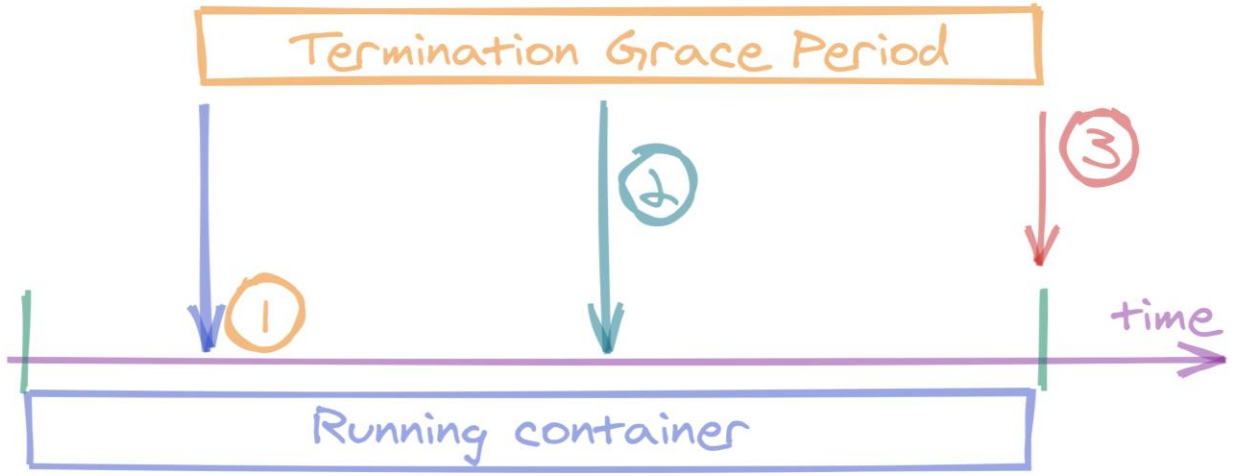
Execute preStop hook, if present | grace of extra 2 seconds possible

Send SIGTERM to PID 1 of each container

Grace period ends | Issue SIGKILL

API server deletes the Pod's API Object

Termination Lifecycle



1. preStop hook executed | Shutdown process begins
2. SIGTERM issued
3. SIGKILL issued | Forcibly shutdown

Resiliency

Health Check,
Liveness Probe,
Readiness Probe,
and Startup Probe

Health Probe Pattern

- About how an application can communicate its health state to Kubernetes
- Kubernetes should know the state of the Pod so that it can decide whether to send requests to the Pod or not
- Containers must provide APIs for different kinds of health checks

Self-Healing Containers

- Kubelet brings up the containers and keep them running until the Pod dies
- Kubelet restarts a container in case if it crashes; done via the Process Health Checks (generic)
- How can a container's main process crash?

Problems

- What if an application stops working without its main process crashing? Deadlock, Infinite Loop, Memory Leak, Thrashing, and numerous other reasons could be there
- Can applications handle these situations well using some complex logic?
- Should other services be able to access or send requests to a crashed application?
- How to tackle such problems?

Probes

- A diagnostic performed by the Kubelet on a container
- Provides resiliency
- Helps in better load balancing and request routing
- Ensures timely response to each request

Technicalities of Probes

- Periodically performed by the Kubelet
- Possible via calling Handlers implemented by the container
- **Type of Handlers / Probing Mechanisms:**
  - **Exec:** Executes a command in a container
  - **TCP Socket:** Performs a TCP check against the specified port of the Pod
  - **HTTP GET:** Makes an HTTP GET request on container's IP address, a specified port and path; success is considered for 2xx or 3xx HTTP response codes
- **Resultant states:**
  - Success
  - Failure
  - Unknown

Container Probes

- Liveness Probe
- Readiness Probe
- Startup Probe

Liveness Probe

- Tells whether a container is alive or dead
- In case of failure, the Kubelet kills the container
- Whether the container will restart or not depends on the `***restartPolicy***` of the container (which can be ***Always***, ***OnFailer***, or ***Never***)
- **TIPS:**
  - Always define a liveness probe for pods running in production
  - Have the application expose a health-check API endpoint (like */health*)
  - The health-check API endpoint should not require authentication, else the probe will always fail
  - Keep it light on the computational resources (probe's CPU time is part of the container's CPU time quota)

Readiness Probe

- A container may need to perform some warm-up procedure
- Signals whether a container is ready to accept requests / connections
- Until all the containers of a Pod are ready, the Pod isn't treated to be ready
- Unlike the Liveness Probe, on failure, a container isn't killed
- **Note:** After receiving a **SIGTERM** signal, even though if the readiness check passes, Kubernetes tries to prevent the container from receiving new requests

Code Walkthrough


```yaml
spec:
  containers:
  - name: hello-python
    image: python-checks:latest
    imagePullPolicy: Never
    livenessProbe:
      httpGet:
        path: /health/live
        port: 5000
      initialDelaySeconds: 2
      failureThreshold: 2
      periodSeconds: 2
    readinessProbe:
      httpGet:
        path: /health/ready
        port: 5000
      initialDelaySeconds: 2
      failureThreshold: 2
      periodSeconds: 2
```

```python
@app.route("/health/ready")
def readiness():
    global POD_READY
    if POD_READY == 0:
        return jsonify({'message': 'The Pod is ready.'}), 200
    else:
        return jsonify({'message': 'The Pod is not ready.'}), 502

@app.route("/health/stop/ready")
def stopReady():
    global POD_READY
    POD_READY = 1
    return jsonify({'message': 'The POD_READY status has been set to false.'}), 200

@app.route("/health/start/ready")
def startReady():
    global POD_READY
    POD_READY = 0
    return jsonify({'message': 'The POD_READY status has been set to true.'}), 200
```

Startup Probe

- Indicates whether the application within the container has started
- All other probes are disabled until Startup Probe succeeds
- Useful for slow-starting containers
- The Startup Probe is meant to be executed only at the startup, unlike others
- A decent `***failureThreshold***` should be provided

Lifecycle Hooks

postStart Hook,
preStop Hook, and
Graceful Termination

Need for Lifecycle Hooks

- Using only process signals for managing container / application lifecycle is somewhat limited
- Helps maintain the container / application lifecycle in a better manner

postStart Hook

- Executed just after a container is created, asynchronously with the main container process
- Warm-up logic can be implemented
- Can be used to delay the startup state of the container while giving time to the main container process to initialize
- Precondition checks can be done – any failure would result in the main process getting killed
- Can be used to signal to an external listener about the application getting started

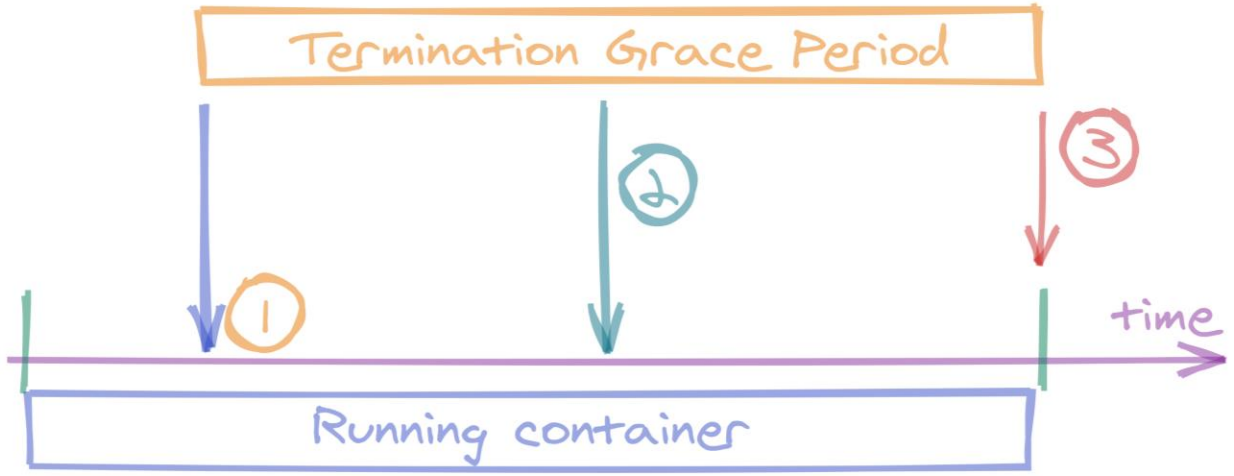
postStart Hook Behaviour

- No guarantees of running
- postStart action is a blocking call
- Container status remains `***Waiting***` until the postStart handler completes, which in turn keeps the Pod status in the `***Pending***`status
- postStart hook runs in parallel with the main container process – ***it may happen that the hook gets executed before the container has started***
- No retries happens

preStop Hook

- Call sent to the container before it is terminated
- Initiates graceful termination
- Use when reacting to **SIGTERM** signal is not possible from within the application
- Useful when using third-party managed container images

Revisiting Termination



1. preStop hook executed | Shutdown process begins
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Code Walkthrough


```yaml
spec:
  containers:
  - name: lifecycle
    image: nginx
    lifecycle:
      postStart:
        exec:
          command:
            - /bin/sh
            - -c
            - echo '<h1>postStart Hook</h1>' >> /usr/share/nginx/html/index.html && sleep 20
      preStop:
        exec:
          command:
            - /bin/sh
            - -c
            - |
              echo '<h1>preStop Hook</h1>' >> /usr/share/nginx/html/index.html && sleep 20
              nginx -s quit
              while killall -0 nginx; do sleep 1; done
```

The Specialized Init Containers

Need, Working, and Usage

Init Containers

- Run before the application containers
- Contains the utilities or setup which is not present in the application's image
- A Pod can have one or more init containers
- Must run to successful completion
- Don't support lifecycle hooks or probes

Init Containers Continued

- If an init container fails during execution and the Pod's `***restartPolicy***` is not set to `***Never***`, the Kubelet would repeatedly restart the init container until it succeeds
- If the Pod's `***restartPolicy***` is set to `***Never***` and an init container fails during execution, the Pod is treated as failed
- Use separate image(s)
- If multiple init containers are defined, they run sequentially in the specified order; one must successfully complete before the next one starts executing
- Can share the same volume with the application containers
- Altering an init container leads to restarting of the Pod

Code Walkthrough

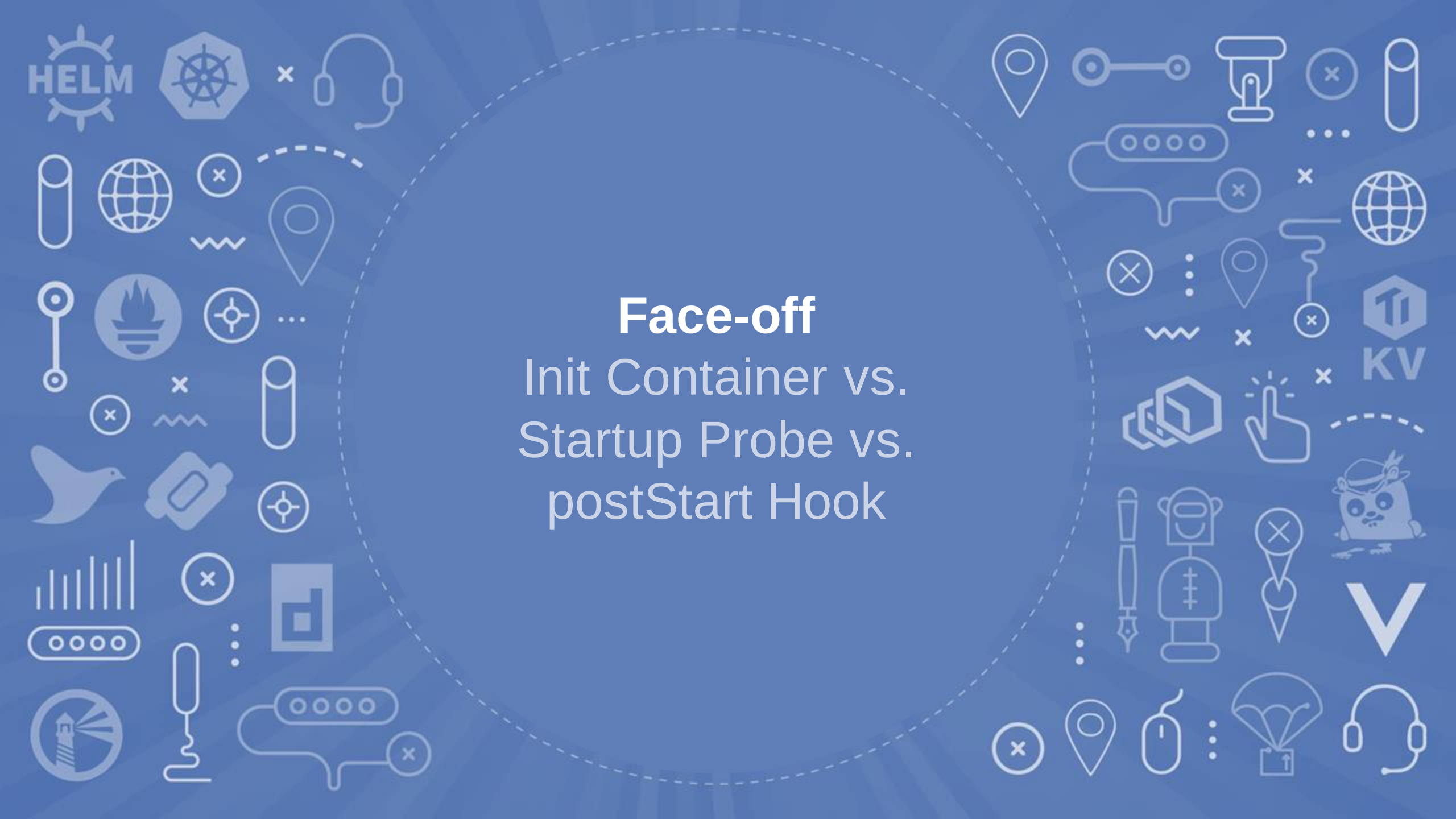

```
 5 spec:
 6   initContainers:
 7   - name: initializer
 8     image: busybox
 9     command:
10     - bin/sh
11     - -c
12     - echo '<h1>Hello World from Init Container</h1>' >> /initmessage/index.html
13     volumeMounts:
14     - mountPath: /initmessage
15       name: nginxinit
16   containers:
17   - name: helloworld
18     image: nginx
19     volumeMounts:
20     - mountPath: /usr/share/nginx/html
21       name: nginxinit
22   volumes:
23   - name: nginxinit
24     emptyDir: {}
```

Usage of Init Containers

- Delaying the application container startup
- Perform precondition checks
- Run utilities or code that is not part of the application container or is not secure to be run through the application container
- Seed data in the database before the application starts
- Wait for some service to become available before the application starts
- Configure things at the runtime
- Perform database schema preparation
- Perform database migrations
- Create user accounts
- And much more…

Scheduling and Resources

- Init containers and application containers co-exist inside a Pod
- Pod's effective request/limit for a resource depends on what is specified for the init containers as well as the application containers
- **Pod's effective request/limit for a resource is the higher of:**
  - The sum of request/limit for a resource of all the application containers
  - The effective request/limit for a resource of the init containers – ***it is the highest of any particular resource request/limit defined on all the init containers***



Face-off

Init Container vs. Startup Probe vs. postStart Hook

Face-off

Parameters	postStart Hook	Init Container	Startup Probe

Face-off

Parameters	postStart Hook	Init Container	Startup Probe
Container	Same as application	Separate container	Same as application

Face-off

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Container	Same as application	Separate container	Same as application
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Container Image	Same as application	Separate image	Same as application

Face-off

Parameters	postStart Hook	Init Container	Startup Probe
Container	Same as application	Separate container	Same as application
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Container Image	Same as application	Separate image	Same as application
Run Guarantee	No	Must run successfully	Must run successfully

Face-off

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Count	Exactly one but supports multiple commands using Exec mechanism	Multiple	Exactly one but supports multiple commands using Exec mechanism

Time for Q/A

@Slack #2-kubecon-101


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