Resize Your Pods In-Place with Deterministic eBPF Triggers

BUILDING FOR THE ROAD AHEAD

DETROIT 2022

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Agenda

- Cloud-Native Development Environments
  - They should be Cost Effective
- In-Place Pod Resize – the Need and Design
- In-Place Resize with eBPF
- Live Demo
- Takeaways

Use Case

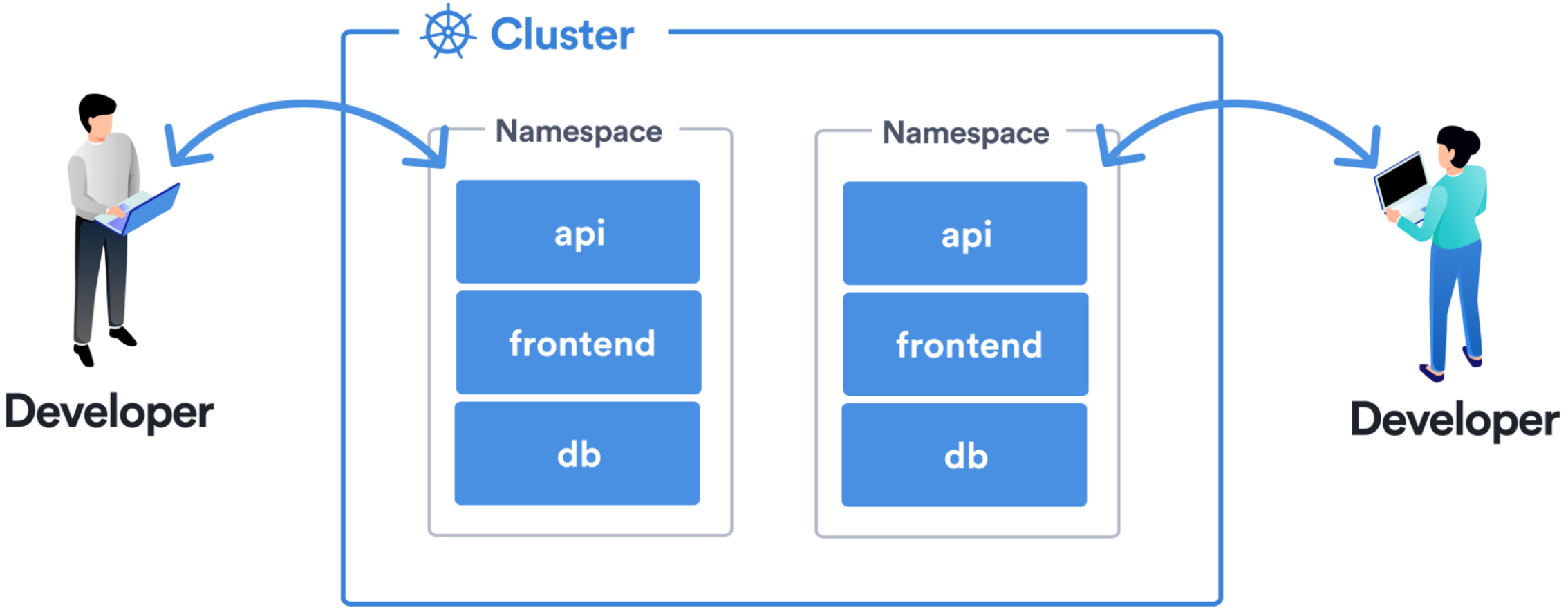
Cloud-Native Development Environments

The End of Local Development

- Bye bye monoliths 👋
- Mimicking production became increasingly tough:
  - Lack of CPU/Memory
  - Deployment of dependencies
  - Local configurations

- Environments disparity:
  - More integration issues
  - Less productivity
  - Less developer happiness

The Dawn of Cloud-Native Development



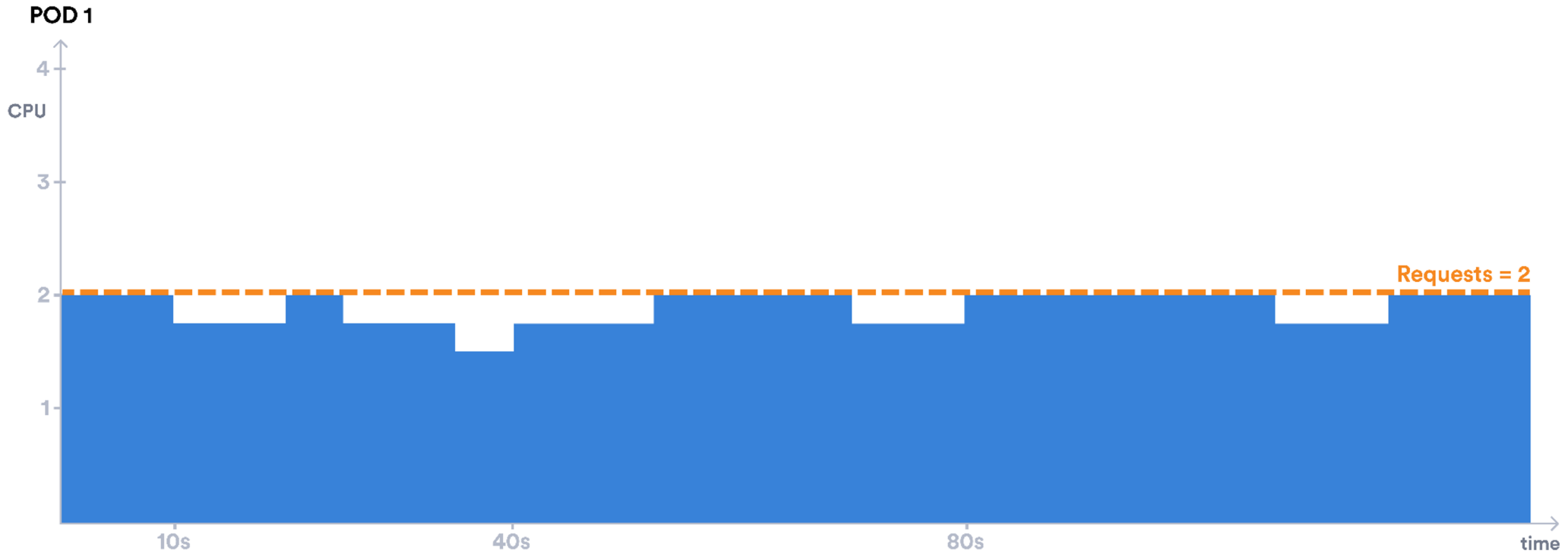
The Problem

Cost Reduction for Cloud-Native Development Environments

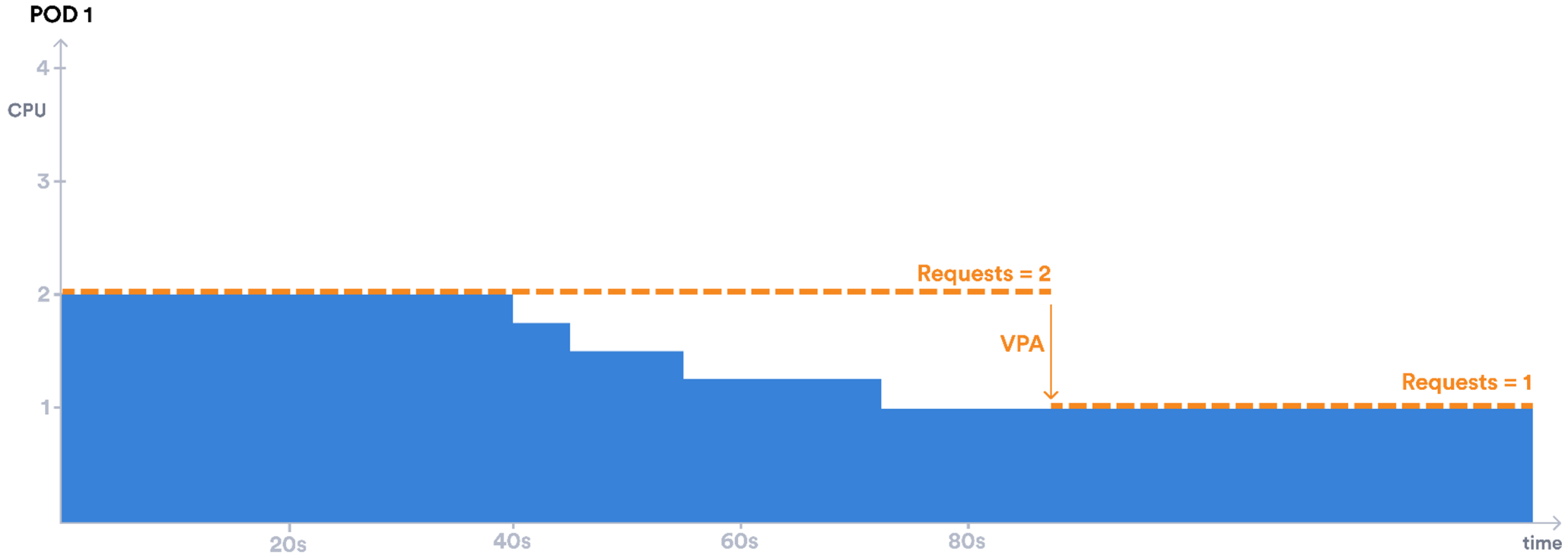
Cost Reduction

- Cloud-Native environments have an impact in your cloud bill 
- Kubernetes is great for resource allocation
  - CPU/Memory shared by several containers
  - Available capacity for spikes using “resource limits”
  - Cluster auto-scales up & down as needed
- But is Kubernetes that good for Development Environments?

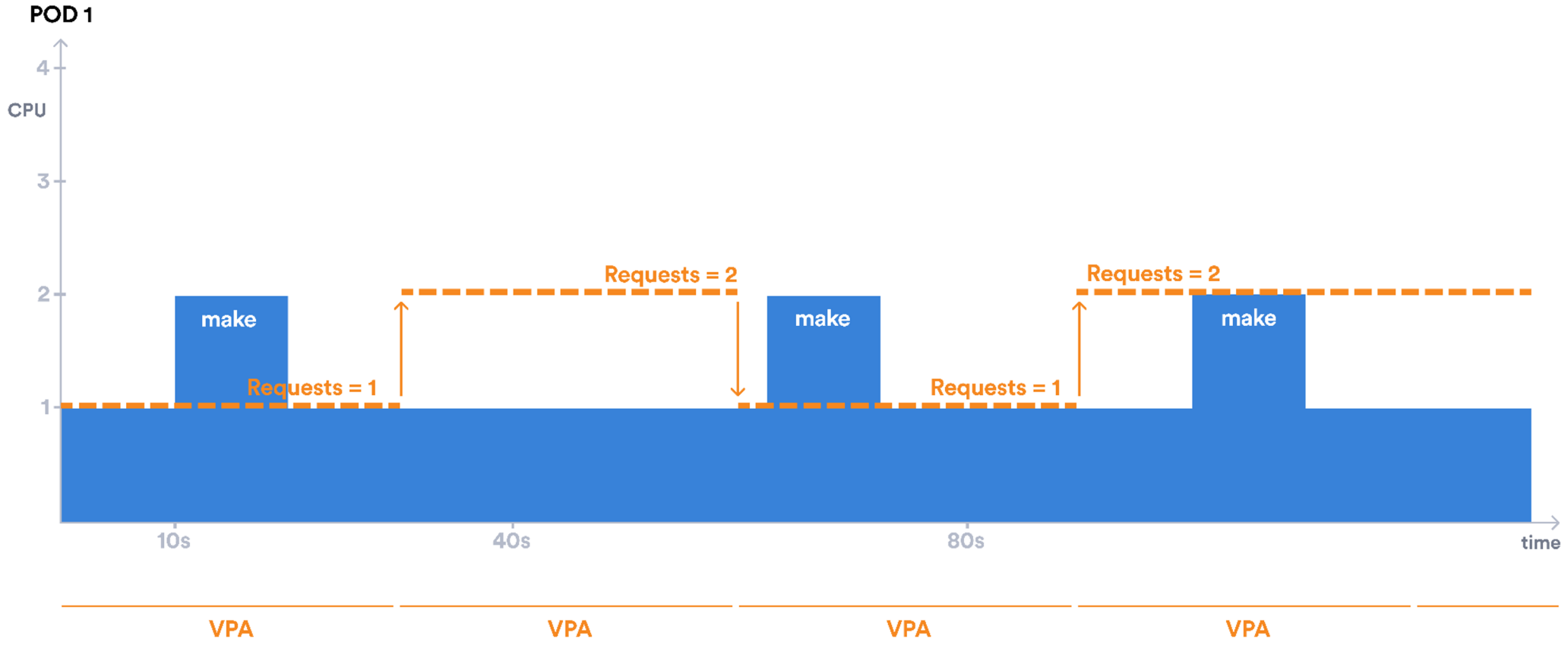
Predictable CPU Usage in Production



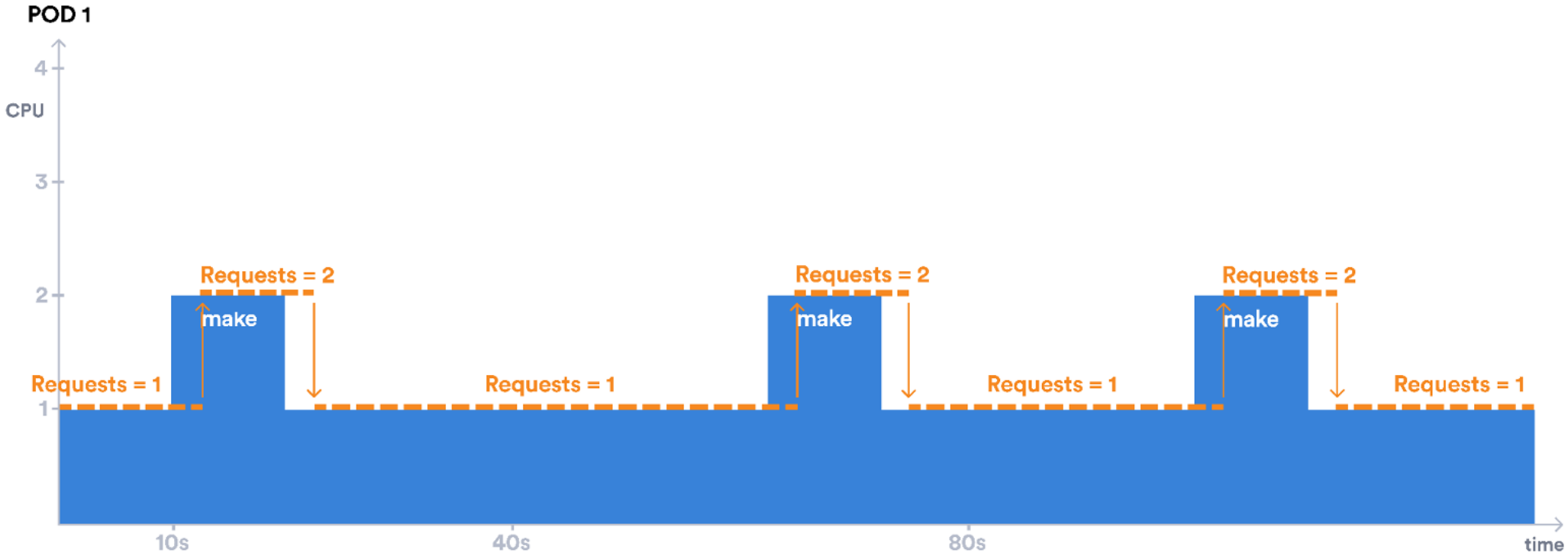
Booting Spikes + VPA + In-Place Pod Resize



“make” Spikes + VPA + In-Place Pod Resize



Optimal “make” Spikes Behavior



Cost Savings

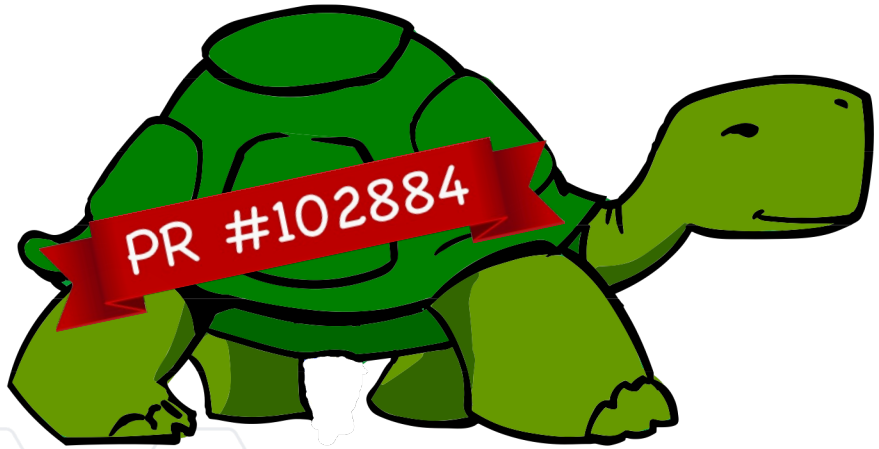
- Standard Kubernetes requests/limits:
  - 8 pods per node
- Ad-Hoc solution based on real cpu/memory load:
  - 80 pods per node

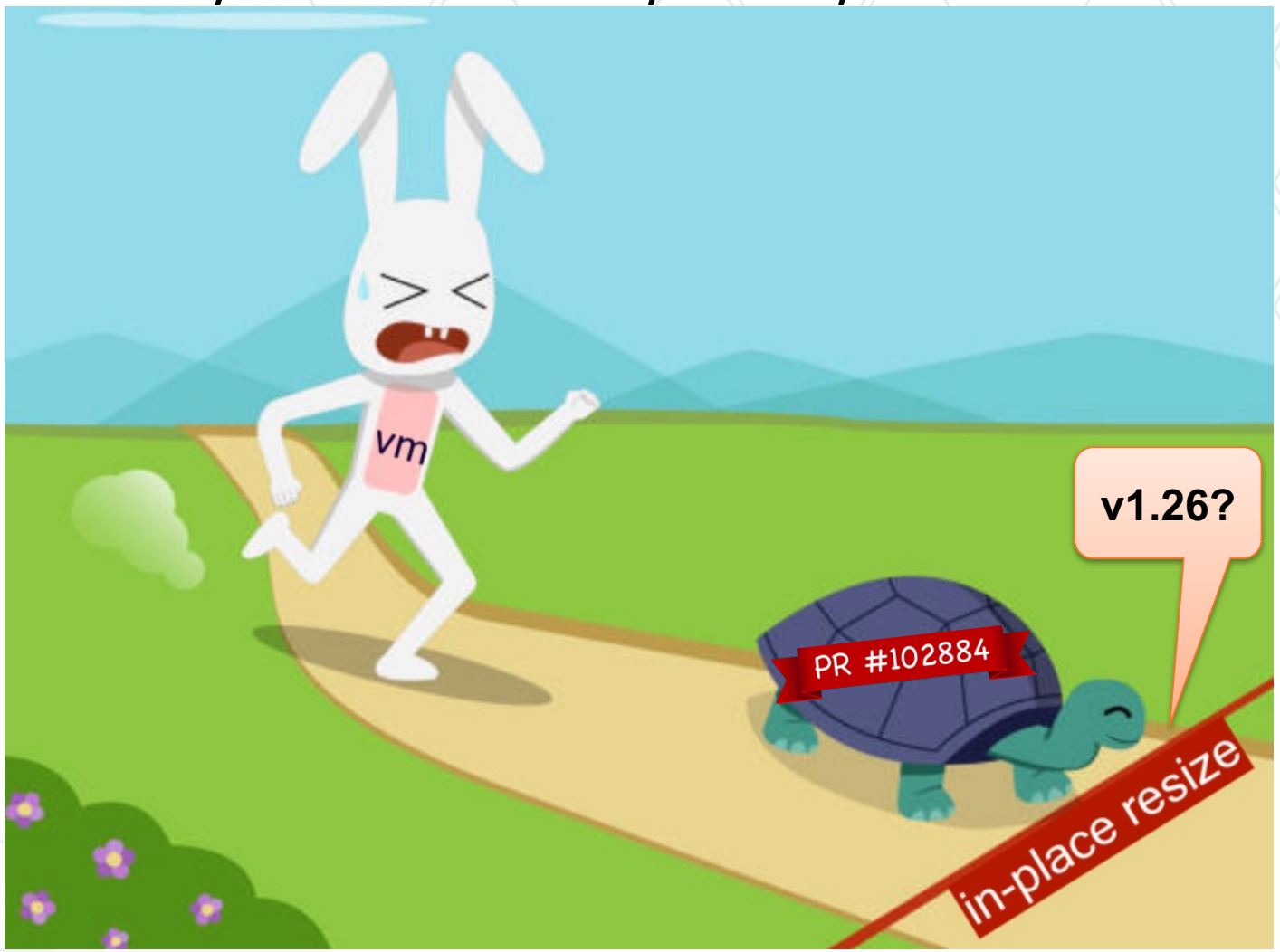
Is there a better way?

In-Place Pod Resize

In-Place Pod Resize

KEP: https://github.com/kubernetes/enhancements/issues/1287





In-Place Pod Resize – What Changed?

- PodSpec.Containers[i].Resources becomes mutable for cpu & memory to allow expressing desired resources
- PodStatus.Resize – new field that shows status of requested pod resize
  - Proposed: API has validated requested resize and updated object store (etcd)
  - InProgress: Resize request has been accepted by kubelet, and is being actuated
  - Deferred: Requested resize is possible, but not right now, kubelet will retry
  - InFeasible: Requested resize is never possible, no retries

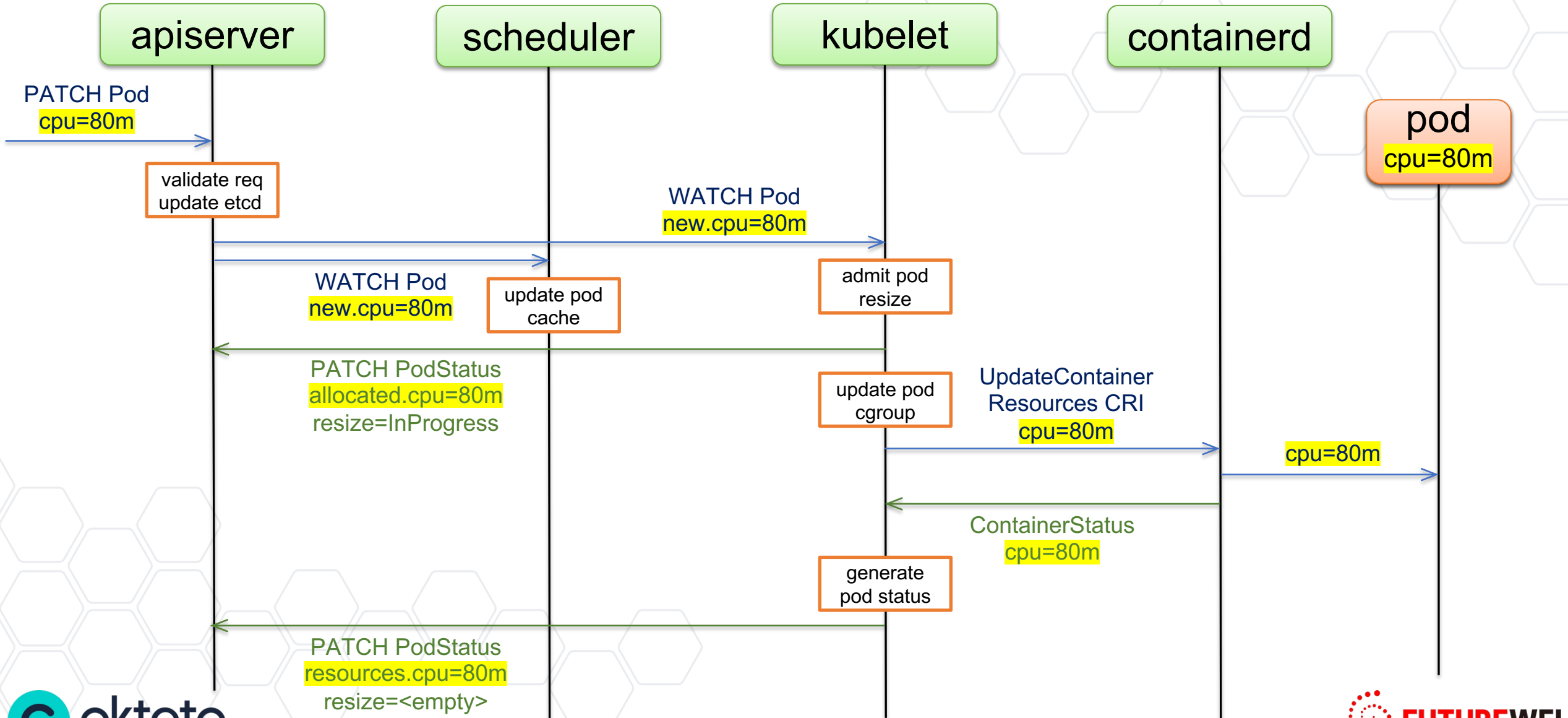
- PodStatus.ContainerStatuses[i].ResourcesAllocated – new field that shows requests allocated by kubelet for the pod
- PodStatus.ContainerStatuses[i].Resources – new field that shows actual resources configured for the pod

- PodSpec.Containers[i].ResizePolicy – new field that controls how to resize
  - RestartNotRequired: Resize container without restarting if possible (default)
  - RestartRequired: Restart the container when resizing it

In-Place Pod Resize – What Does It Involve?

- API Server
  - Validates desired resize request
  - Updates object store
- Kubelet
  - Admits desired resize request
  - Enacts pod cgroup resize
  - Invokes CRI for container resize
  - Updates resize status
- Scheduler
  - Supports resize by using max (Desired, Actual) during resize
- Runtime
  - Enacts desired container resources configuration

In-Place Pod Resize - Design



In-Place Pod Resize – Container Resize Order

- If net increase, pod cgroup is resized-up before resizing container(s)
- If net decrease, pod cgroup is resized-down after resizing container(s)
- Container resizes are ordered such that decreases are invoked before increases
- Scenario:
  - 2Gi memory available for pods
  - A single pod with two containers: c1 (1Gi) + c2 (1Gi)
  - Resize: c1(1Gi -> 1.5Gi), c2(1Gi -> 0.5Gi)
  - Resizing order [c1, c2] will fail – exceeds available memory

In-Place Resize – Expectations From Runtime

- Support UpdateContainerResources CRI API
  - Invoked to update container CPU and/or memory resources
- Synchronous and Transactional resource update handling
  - Return Success or Error
  - Do NOT queue a task for deferred/async processing
- Add support for newly added Resources field in ContainerStatus CRI API
  - Runtime response updates the newly added Resources field in PodStatus
- Add / Verify support for cgroup v2

In-Place Pod Resize – Innovating with eBPF

- Remote development environment example: K8s repo in a pod
  - Edit code and build K8s in a pod

```
1   apiVersion: v1
2   kind: Pod
3   metadata:
4     name: kube-build-pod
5   spec:
6     containers:
7     - name: kube-build-ctr
8       image: skiibum/kube-build-arm64:v1.25
9       imagePullPolicy: IfNotPresent
10      command: ["tail", "-f", "/dev/null"]
11      resources:
12        limits:
13          cpu: "5"
14          memory: "50Mi"
15        requests:
16          cpu: "4"
17          memory: "50Mi"
```

In-Place Pod Resize – Innovating with eBPF

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```
# podsnoop.py: Prototype eBPF program that snoops on pod exec activity
#              requires linux-headers, bpfcc-tools, kubectl
#              To run: sudo python3 podsnoop.py
import os
from bcc import BPF

POD_SNOOP_eBPF_CODE = r"""TRACEPOINT_PROBE(syscalls, sys_enter_execve) {
    char task_cmd[32];
    bpf_get_current_comm(&task_cmd, sizeof(task_cmd));
    bpf_trace_printk("Launching program: %s\n", task_cmd);
    return 0;
}"""
bpf = BPF(text = POD_SNOOP_eBPF_CODE)

while True:
    try:
        (task, pid, cpu, flags, ts, msg) = bpf.trace_fields()
        if str.__contains__(msg.decode("utf-8"), "make"):
            pod_name = os.popen("nsenter -t %s -u hostname 2>/dev/null" % pid).read().strip()
            if pod_name == "kube-build-pod":
                patch_str = '{"spec":{"containers":[{
                                "name":"kube-build-ctr",
                               "resources":{"requests":{"memory":"5Gi"},"limits":{"memory":"5Gi"}}}]}}'
                patch_cmd = "kubectl patch pod %s --patch '%s' > /dev/null" % (pod_name, patch_str)
                os.system(patch_cmd)
    except ValueError:
        continue
```

trace exec syscall

resize pod if “make” program launched

```
apiVersion: v1
kind: Pod
metadata:
  name: kube-build-pod
spec:
  containers:
  - name: kube-build-ctr
    image: skiibum/kube-build-arm64:v1.25
    imagePullPolicy: IfNotPresent
    command: ["tail", "-f", "/dev/null"]
    resources:
      limits:
        cpu: "5"
        memory: "50Mi"
      requests:
        cpu: "4"
        memory: "50Mi"
```

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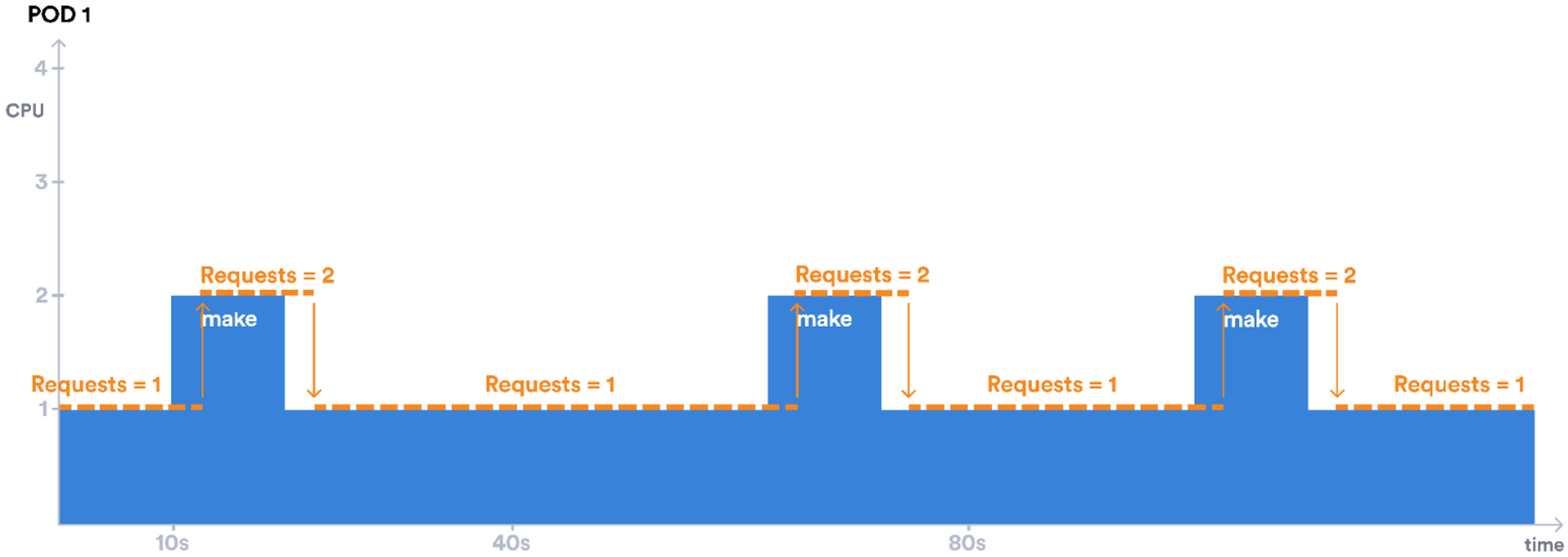
In-Place Pod Resize + eBPF + BPF maps

- eBPF program + BPF map
  - BPF_MAP_TYPE_HASH
  - Key: Container's Cgroup ID
  - Value: Commands to trace
    - E.g: "make"
- Pod Watcher
  - Read 'ebpf-resize' annotation
    - It specifies [container, [command, desired resources]]
  - Create BPF map entries [cgroup_id, [command]] based on annotation
- Initiate resize based on BPF trace
- Deployed as Daemonset
- https://github.com/vinaykul/ebpf-playground/tree/main/ebpf-pod-resize
- https://github.com/vinaykul/ebpf-playground/tree/main/ebpf-pod-resize-libbpf-rs-CO-RE

```
1   apiVersion: v1
2   kind: Pod
3   metadata:
4     name: kube-build-pod
5     annotations:
6       "ebpf-resize": '{
7               "cname": "kube-build-ctr",
8               "commands": ["make"],
9               "resize": "{\"requests\":{\"memory\":\"5Gi\"},\"limits\":{\"memory\":\"5Gi\"}}"
10      }'
11  spec:
12    containers:
13    - name: kube-build-ctr
14      image: skiibum/kube-build-arm64:v1.25
```

In-Place Pod Resize + eBPF – Live Demo

“make” Spikes + In-Place Pod Resize + eBPF



Key Takeaways

- Cloud-Native development environments
  - Ephemeral, Replicable, and Production-like
  - Cost-effective
- Add runtime support for container resource resize
  - Users don’t worry whether their runtime supports in-place resize
- Say “InPlacePodVerticalScaling=true”
  - Help us get to a rock-solid GA
  - Contributions are most welcome!
- Give eBPF a whirl!!

Almost Lunch Time…

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