
KubeCon
CloudNativeCon
Europe 2023
TiKV

WG Batch: What's new and What's Next?

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What is the WG Batch

- Forum to discuss enhancements to better support batch workloads in core Kubernetes (eg. HPC, AI/ML, data analytics, CI).
- A goal is to reduce fragmentation in the Kubernetes batch ecosystem.
- Stakeholders:
  - SIG Scheduling
  - SIG Apps
  - SIG Node
  - SIG Autoscaling
- Other participants: ecosystem developers from Kubeflow, Armada, Yunikorn, among others.
- In scope:

Additions to the batch APIs (Job, CronJob)

Job queuing primitives

Primitives to maximize clusters utilization

Support for specialized hardware

Additions to the batch APIs

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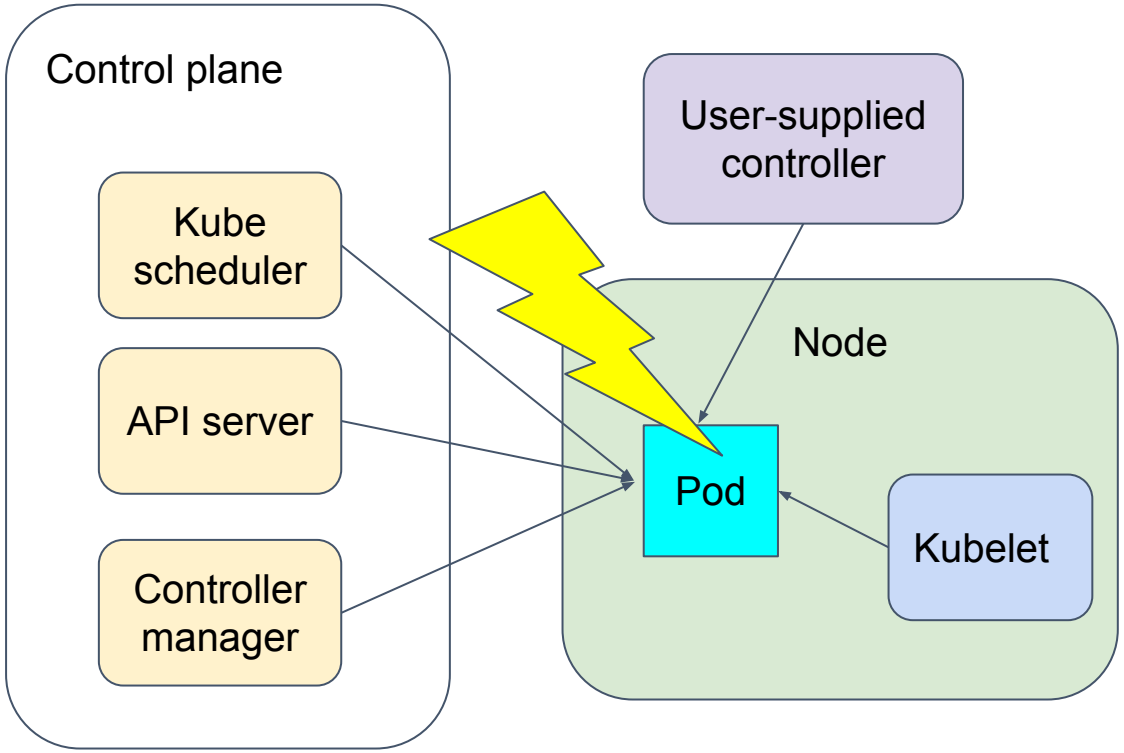
Job: More scalable than ever

- Job tracking with finalizers reached General Availability in Kubernetes 1.26 🎉
- Prior to this feature, the job controller lost progress of Jobs when Pods were deleted
  - 💥 Incompatible with Pod GC
- Pods get a finalizer `batch.kubernetes.io/job-tracking` before counting in the Job status.
- Indexed Jobs of up to 100k Pods can be processed in minutes 🚀

```yaml
apiVersion: batch/v1
kind: Job
metadata:
  name: sample-job
spec:
  parallelism: 10
  completions: 100
  completionMode: Indexed
  template:
    spec:
      containers:
      - name: job
        image: foo
status:
  active: 10
  completedIndexes: 0-9
  ready: 2
  succeeded: 10
  startTime: "2023-04-11T19:08:27Z"
```

Blogpost: [Job Tracking, to Support Massively Parallel Batch Workloads, Is Generally Available]

Job: Pod Failure Policies



Pod disruption scenarios

```yaml
backoffLimit: 6
podFailurePolicy:
  rules:
  - action: FailJob
    onPodConditions:
    - type: ConfigIssue
  - action: Ignore
    onPodConditions:
    - type: DisruptionTarget
  - action: FailJob
    onExitCodes:
      operator: In
      values: [1,2,126,127,128,139]
  - action: Ignore
    onExitCodes:
      operator: In
      values: [130,137,138,147]
```

- **New** in 1.27: kubelet guarantees all Pods reach a terminal phase

[Enabling HPC and ML Workloads with the Latest Kubernetes Job Features]

Job: Mutable completions

- `completions` is now mutable for Indexed Jobs
- Requirement: `parallelism` and `completions` need to match
- Use case: elastic jobs, such as Pytorch

```yaml
apiVersion: batch/v1
kind: Job
metadata:
  name: elastic-job
spec:
  parallelism: 100
  completions: 100
  completionMode: Indexed
  template:
    spec:
      containers:
      - name: job
        image: foo
```

```yaml
apiVersion: batch/v1
kind: Job
metadata:
  name: elastic-job
spec:
  parallelism: 90
  completions: 90
  completionMode: Indexed
  template:
    spec:
      containers:
      - name: job
        image: foo
```

Job: What's next

- 🚧 Subproject (in SIG Apps): JobSet
  - Use case: jobs that have Pods with different roles, such as driver-workers.
  - Each role is implemented as an Indexed Job.
  - Automates pod-to-pod communication and auth keys.
  - Corollary: #116993 creating environment variables from a file
- 💡 KEP3850: backoffLimit per Index
  - Use case: Parallel applications where each worker process and independent piece of data.
  - Corollary: #109131 retry specific indexes
- 💡 KEP3939: Count terminating Pods as active.
  - Use case: Tightly coupled applications that don't support more than one worker per Index.

Job: What's next

- 💡Open discussions:
  - #113221 Mutable scheduling directives when suspended
  - #111948 Deadline for Pending Pods
  - #115716 DaemonJob: Run at least once per Node
  - #115066 Stateful Indexed Job: Automate creation of PVCs for each index.

Job queueing and cluster utilization

Additions to the batch APIs (Job, CronJob)

Job queuing primitives

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Support for specialized hardware

Kueue: cloud-native job queueing

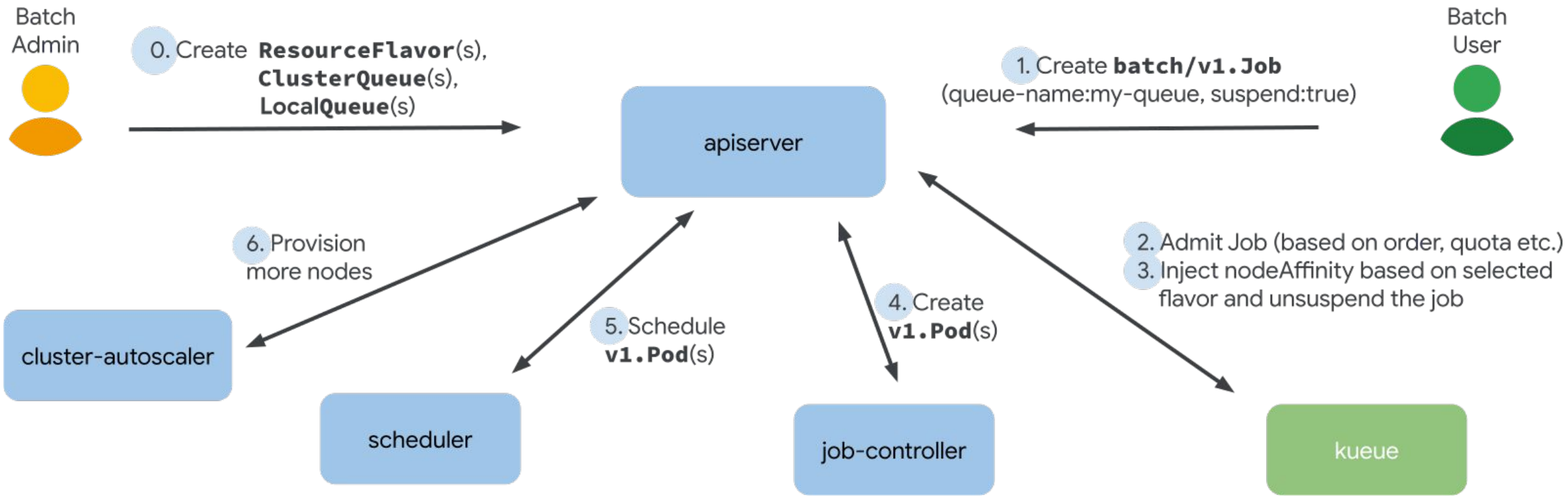
A Kubernetes-native job queueing system, offering:

- Resource quota management, with borrowing and preemption semantics.
- Resource fungibility in heterogeneous clusters.
- Support for k8s batch/v1.Job and kubeflow's MPIJob.
- Extension points and libraries for supporting custom job CRDs.
- More Job integrations coming soon

Latest version: v0.3 🎉

Kueue: overview

Design principle: compatibility and separation of concerns with standard k8s components: kube-scheduler, kube-controller-manager, cluster-autoscaler.



Kueue: What's next

- ✨ Roadmap for v0.4
  - Improvements to WaitForPodsReady
  - Improvements to Preemption
  - [Nice-to-have] Support for Ray and kubeflow
- 💡 Open k8s discussions:
  - KEP3838 Mutable scheduling directives for gated Pods
  - #107294 A suspend/queueuing subresource

Batch+HPC Day:
Building a Batch System for the Cloud with Kueue

Support for specialized hardware

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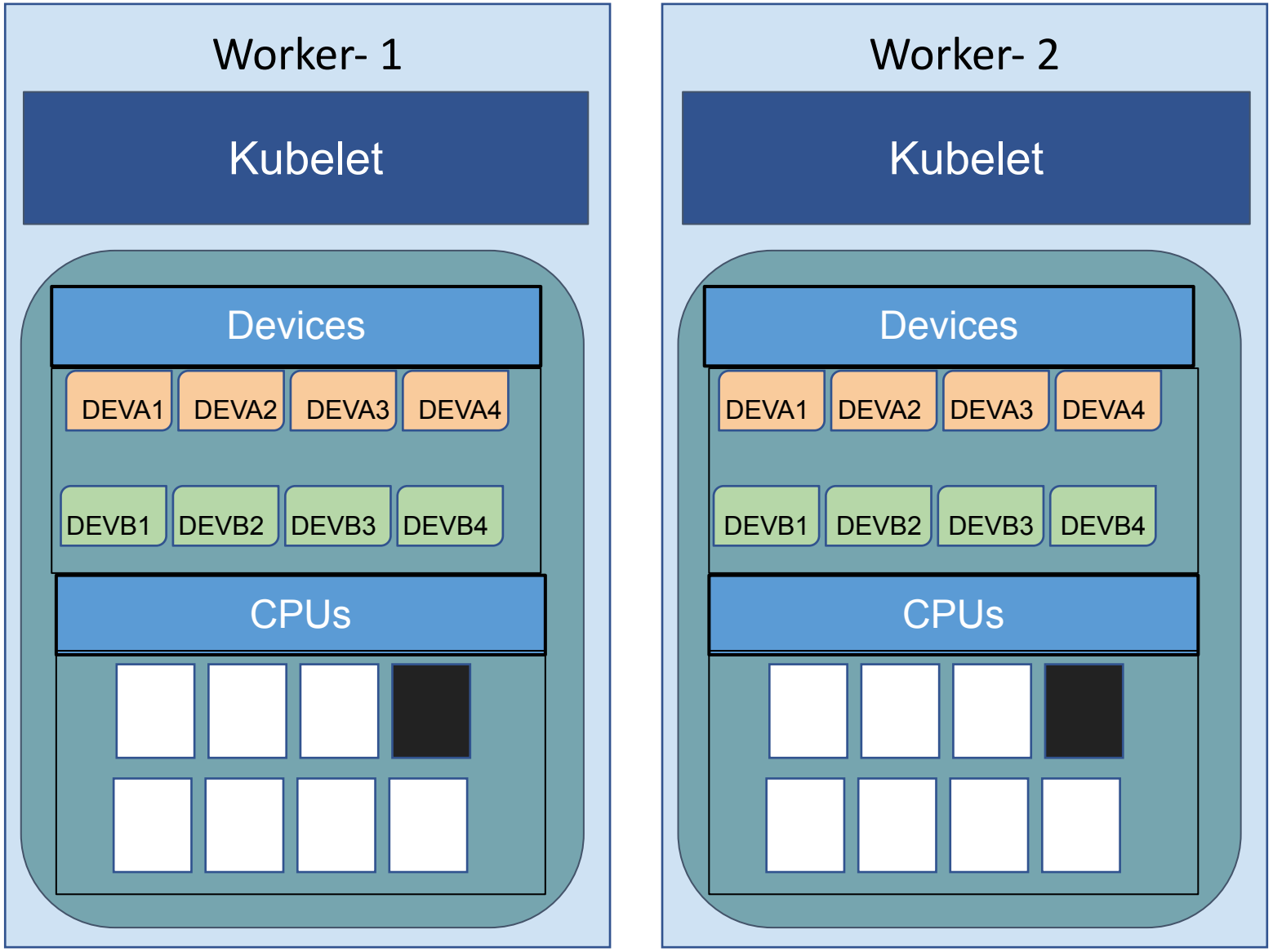
Topology-aware Scheduling - Problem statement

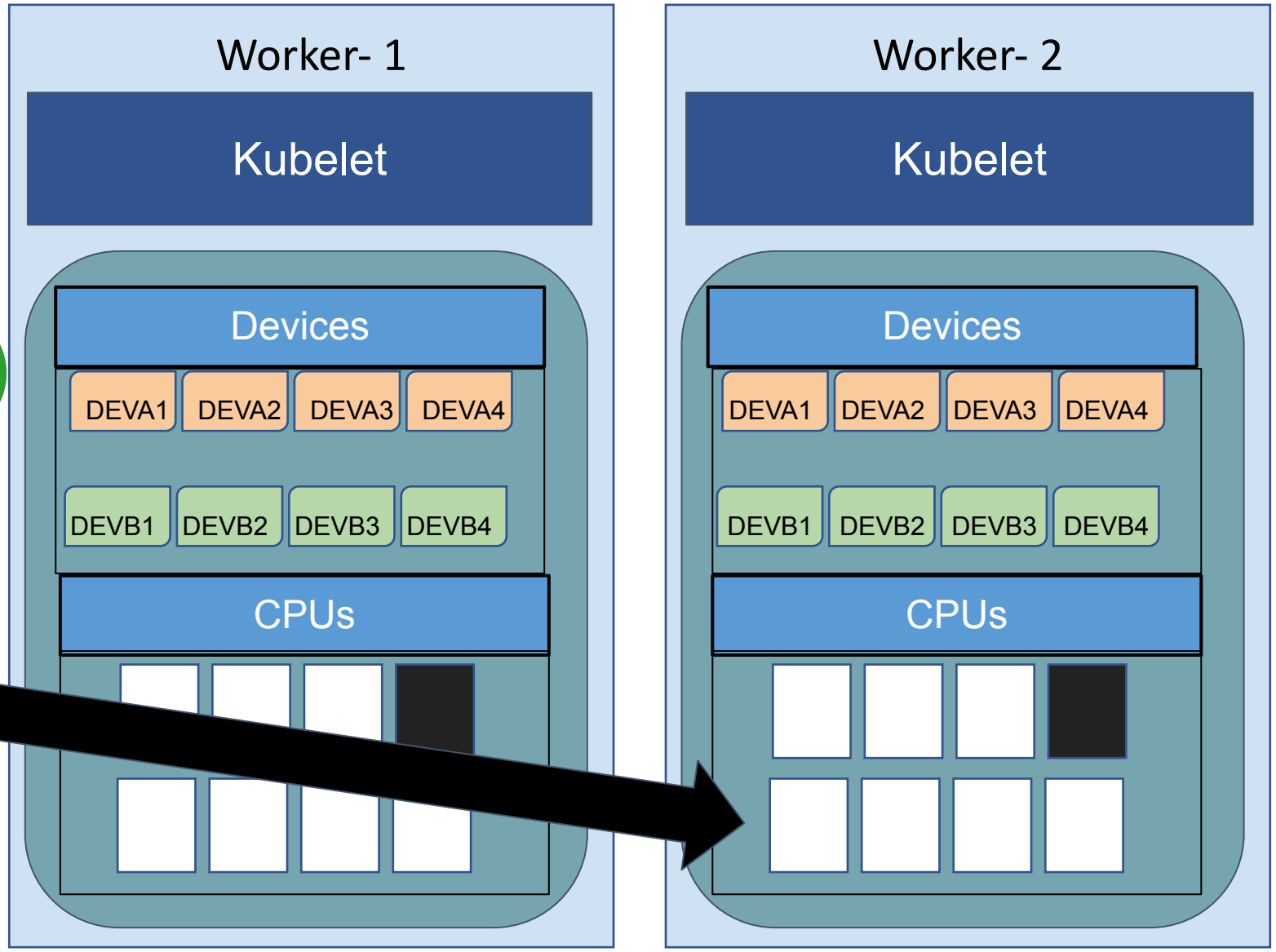

```
apiVersion: v1
kind: Pod
Spec:
  containers:
  - name: app
    Resources:
      Requests:
        cpu: 1
        memory: 2Gi
        example.com/deviceA: 1
        example.com/deviceB: 1
      Limits:
        cpu: 1
        memory: 2Gi
        example.com/deviceA: 1
        example.com/deviceB: 1
```



Topology-aware Scheduling - Problem statement

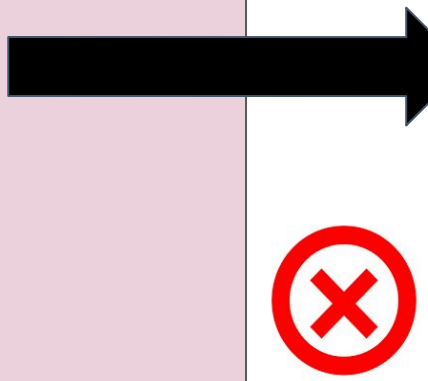

```
apiVersion: v1
kind: Pod
Spec:
  containers:
  - name: app
    Resources:
      Requests:
        cpu: 1
        memory: 2Gi
        example.com/deviceA: 1
        example.com/deviceB: 1
      Limits:
        cpu: 1
        memory: 2Gi
        example.com/devic
        example.com/deviceB: 1
```

Pod Running!

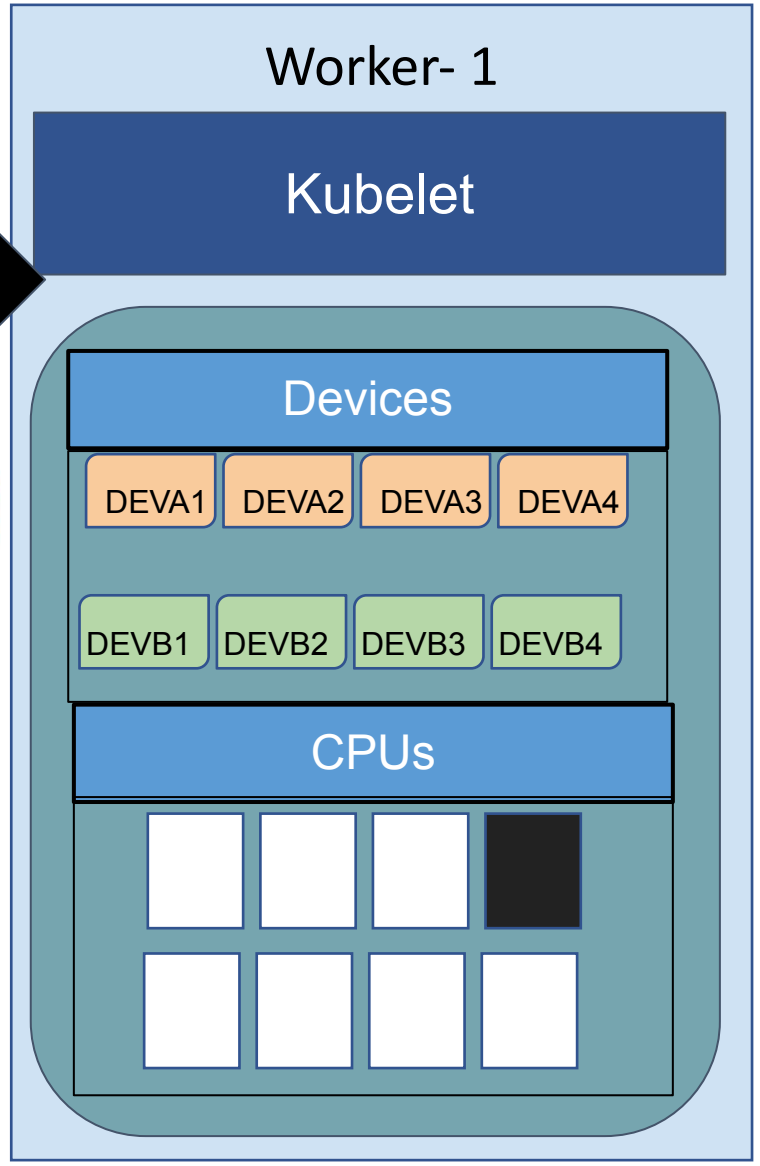


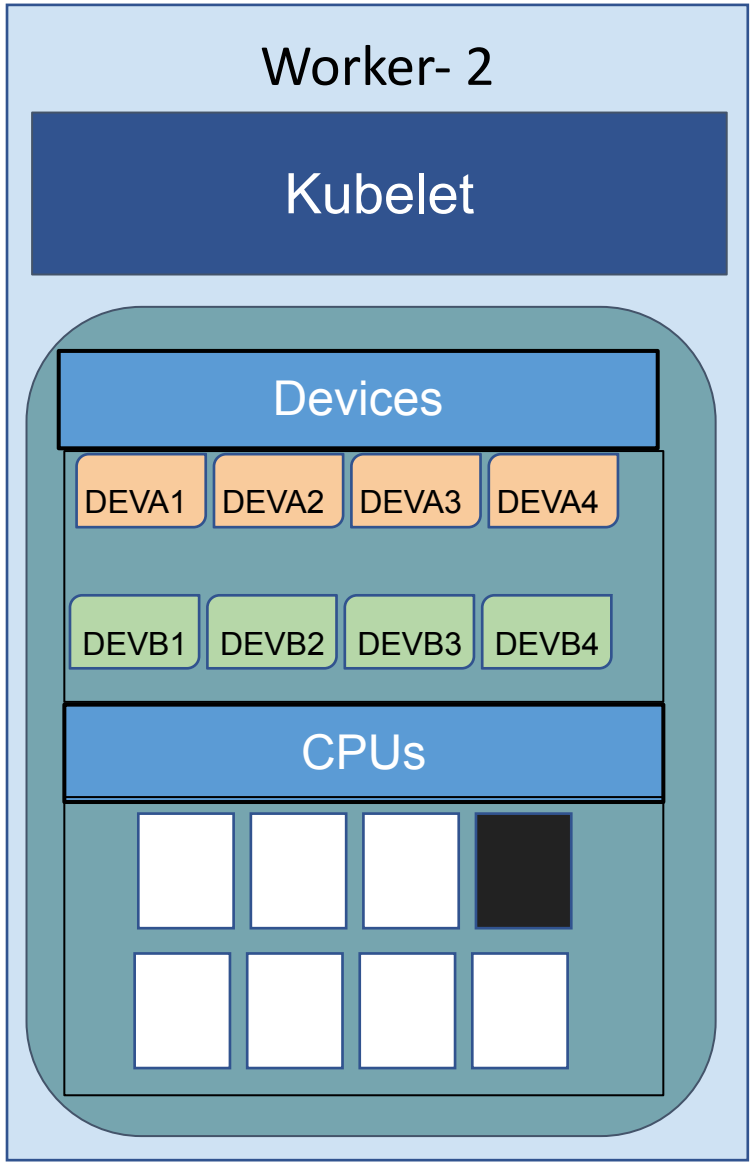
Topology-aware Scheduling - Problem statement


```
apiVersion: v1
kind: Pod
Spec:
  containers:
  - name: app
    Resources:
      Requests:
        cpu: 1
        memory: 2Gi
        example.com/deviceA: 1
        example.com/deviceB: 1
      Limits:
        cpu: 1
        memory: 2Gi
        example.com/deviceA: 1
        example.com/deviceB: 1
```



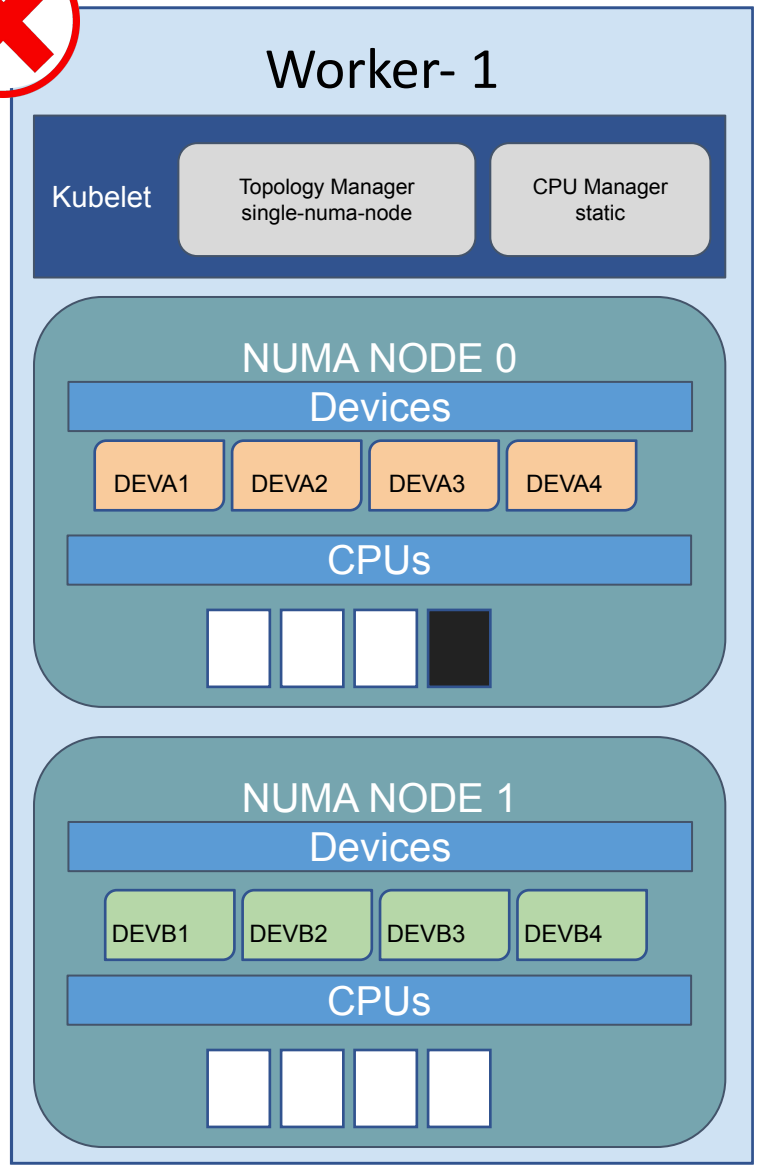
Pod Rejected!





Topology-aware Scheduling - Zooming in


```
apiVersion: v1
kind: Pod
Spec:
  containers:
  - name: app
    Resources:
      Requests:
        cpu: 1
        memory: 2Gi
        example.com/deviceA: 1
        example.com/deviceB: 1
      Limits:
        cpu: 1
        memory: 2Gi
        example.com/deviceA: 1
        example.com/deviceB: 1
```



Topology-aware Scheduling - Phase 1

An out-of-tree solution.

Development started in 2020 (alongside Kubernetes v1.22)

1. Topology-aware Scheduler Plugin:

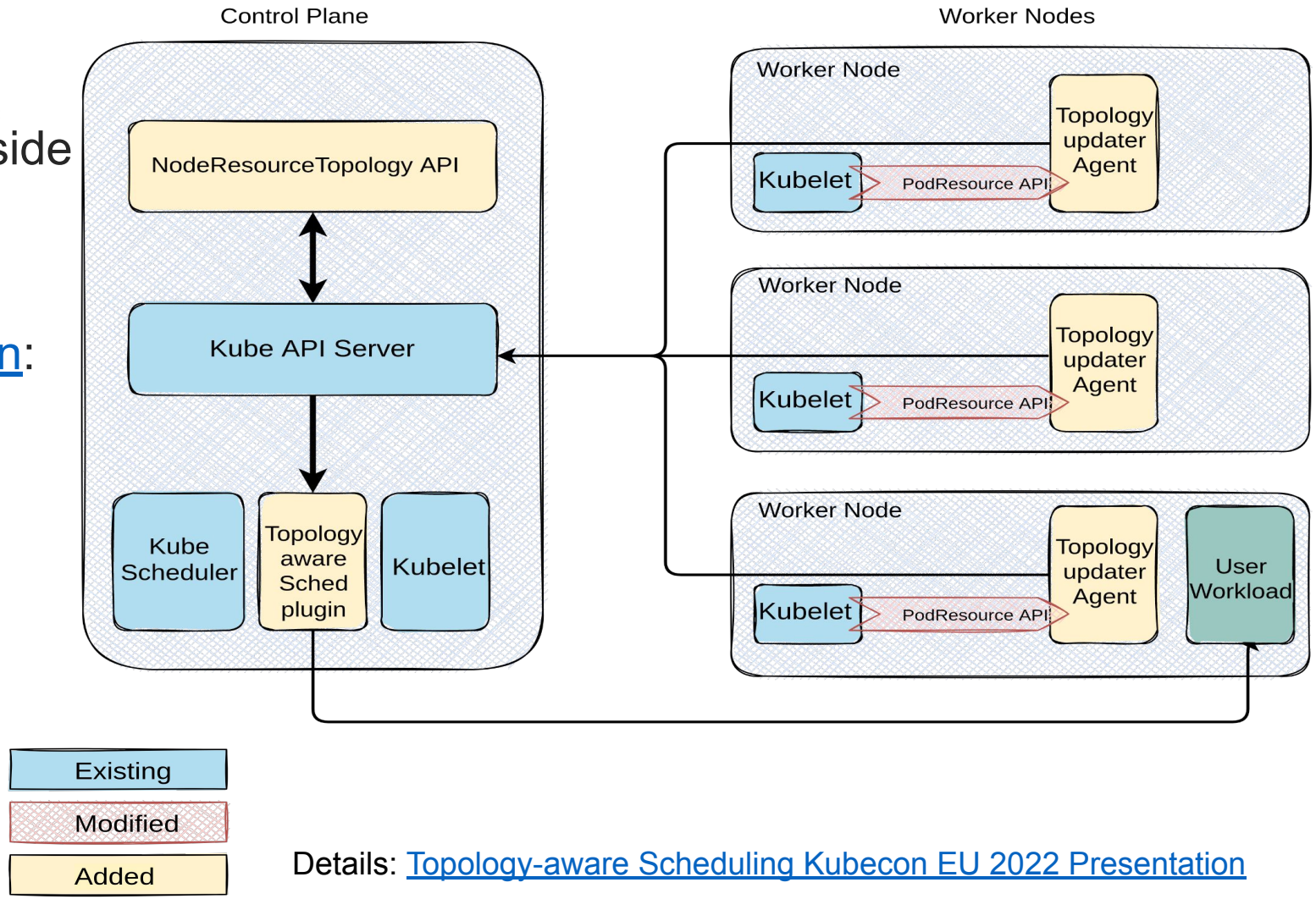
   (filter + scoring)

2. NodeResourceTopology API

3. Topology Updater Agent

   a. Node Feature Discovery

   b. Resource Topology Exporter



Details: Topology-aware Scheduling Kubecon EU 2022 Presentation

Topology-aware Scheduling Phase 2

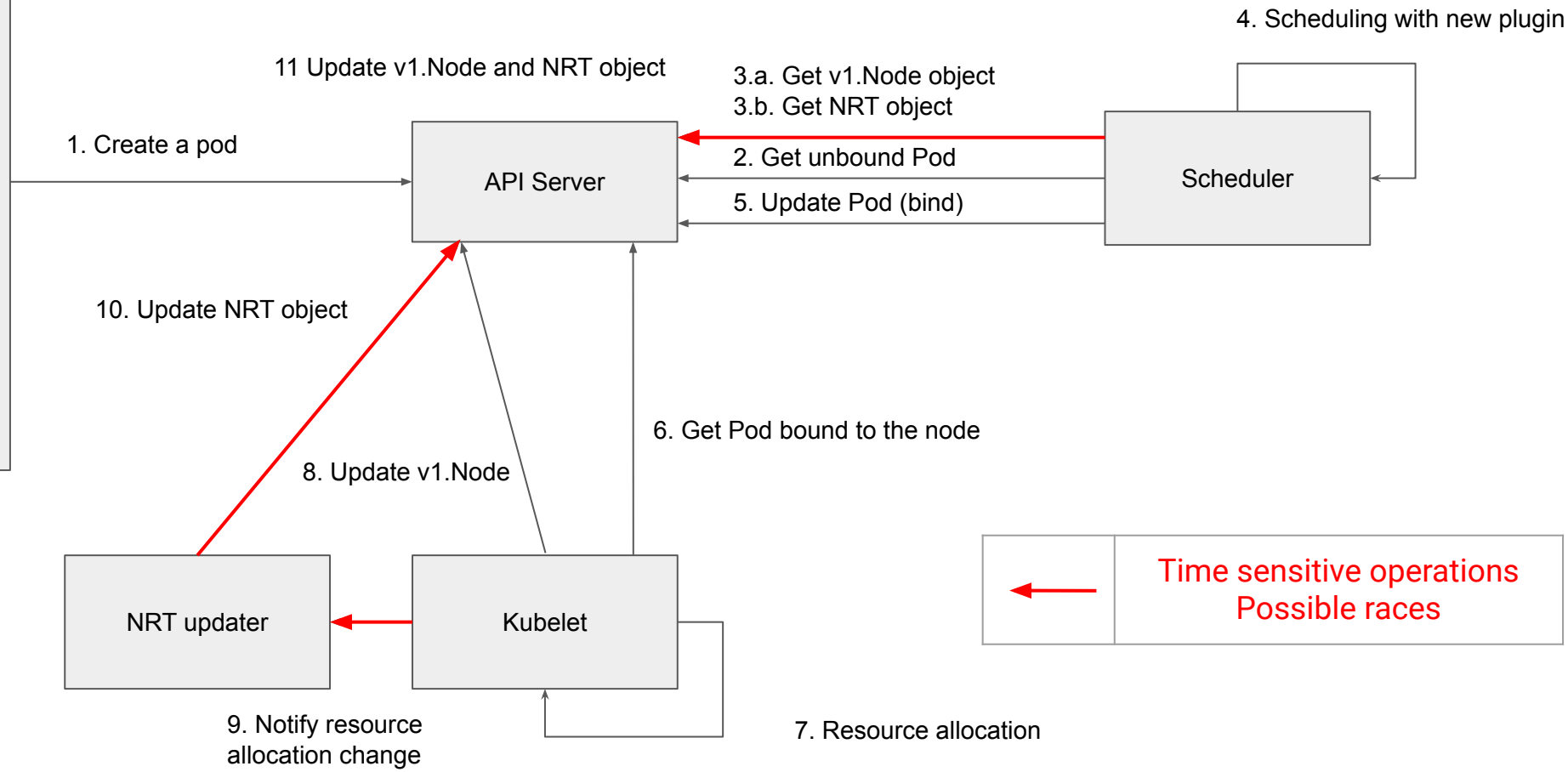
Improvements were made across the stack for stabilization of the solution

Updates were made to the three main components:

1. **Topology-aware Scheduler Plugin**
2. **NodeResourceTopology API**
3. Topology Updater Agent: **Node Feature Discovery**

Time sensitive operations

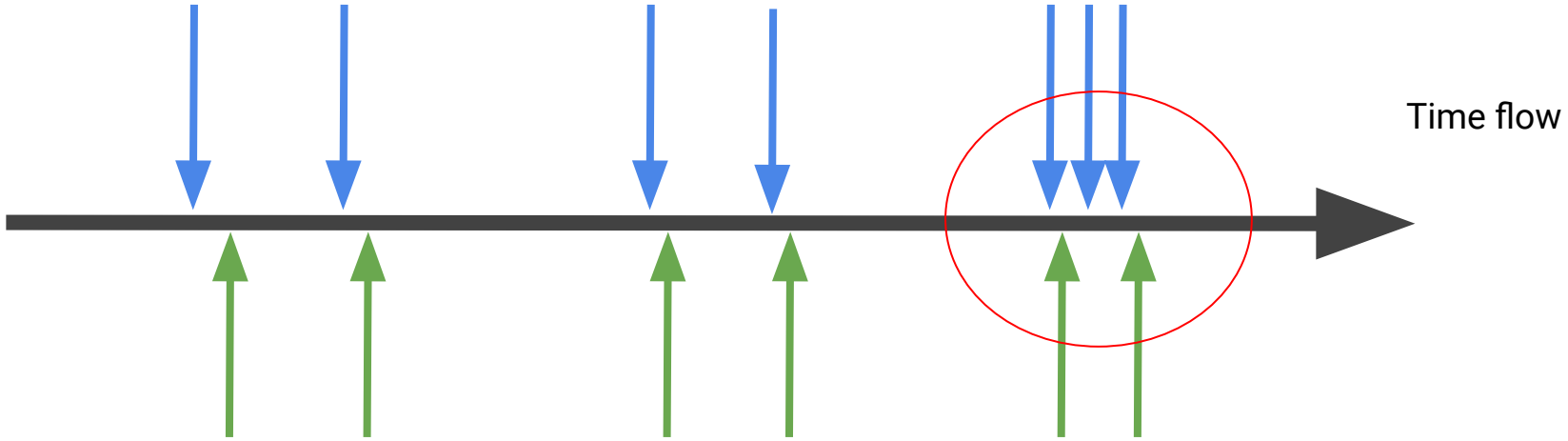
```
apiVersion: v1
kind: Pod
Spec:
  containers:
  - name: dpdk-app1
    Resources:
      Requests:
        cpu: 4
        memory: 2Gi
        hugepages-1Gi : “2Gi”
        intel.com/vf: “1”
      Limits:
        ...
```



NRT = Node Resource Topology

Race between scheduler and updater

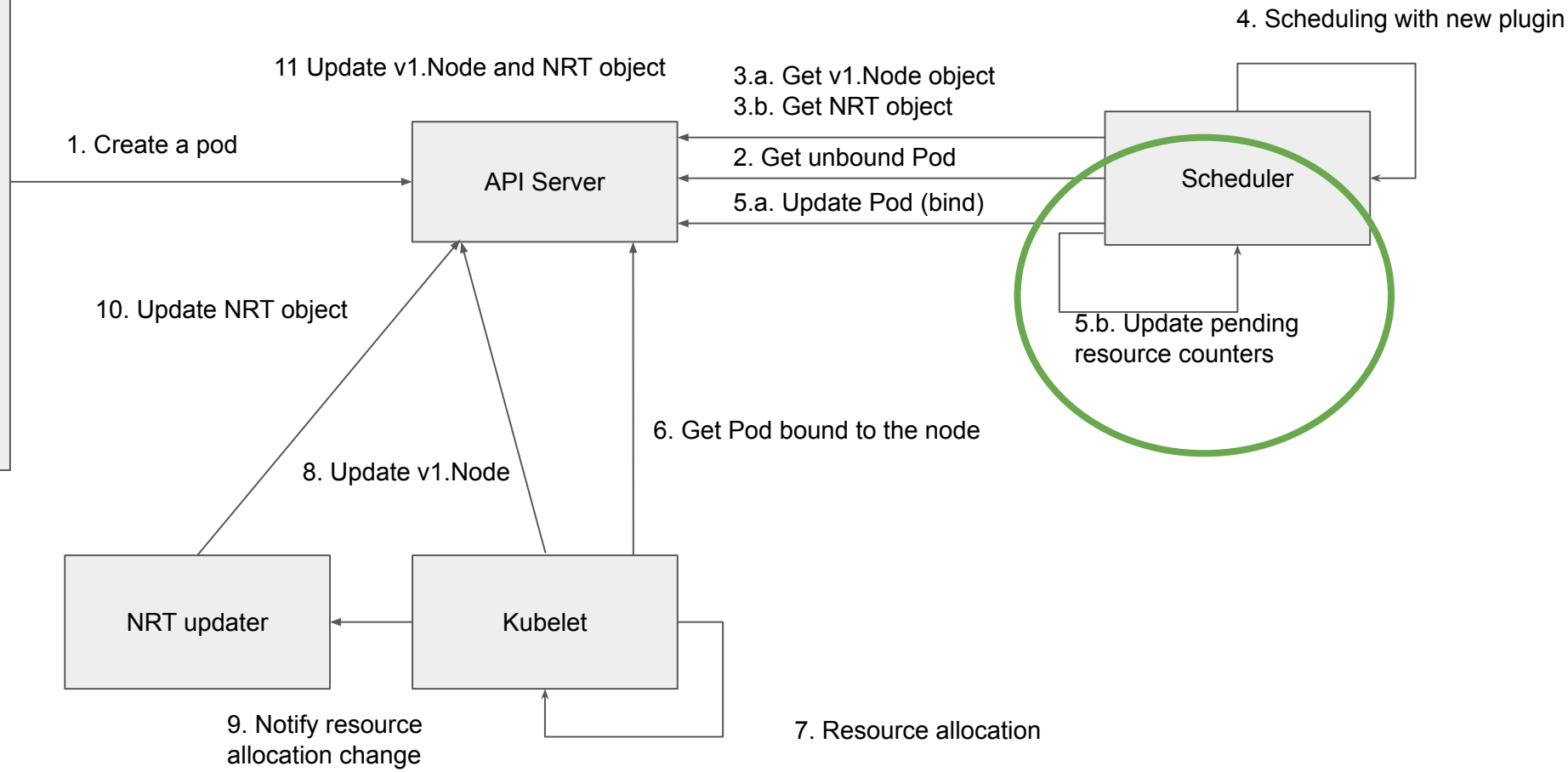
Pod to be scheduled - each arrow is a new pod



Node Resource Topology (NRT) objects updates, as seen by the scheduler - each arrow is update

Scheduler plugin: Local cache with reserve plugin

```
apiVersion: v1
kind: Pod
Spec:
  containers:
  - name: dpdk-app1
    Resources:
      Requests:
        cpu: 4
        memory: 2Gi
        hugepages-1Gi : “2Gi”
        intel.com/vf: “1”
      Limits:
        ...
```

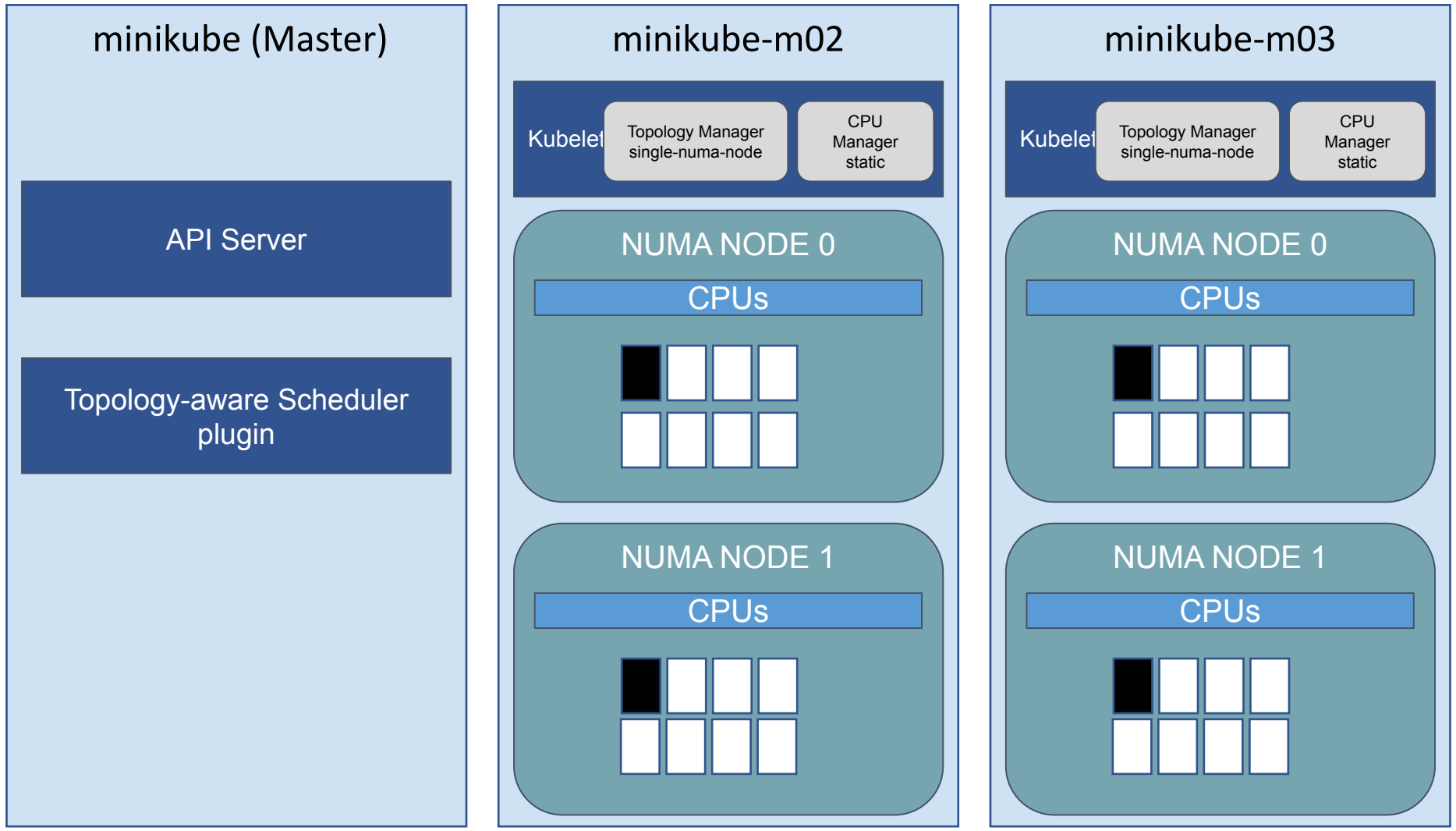


NRT = Node Resource Topology

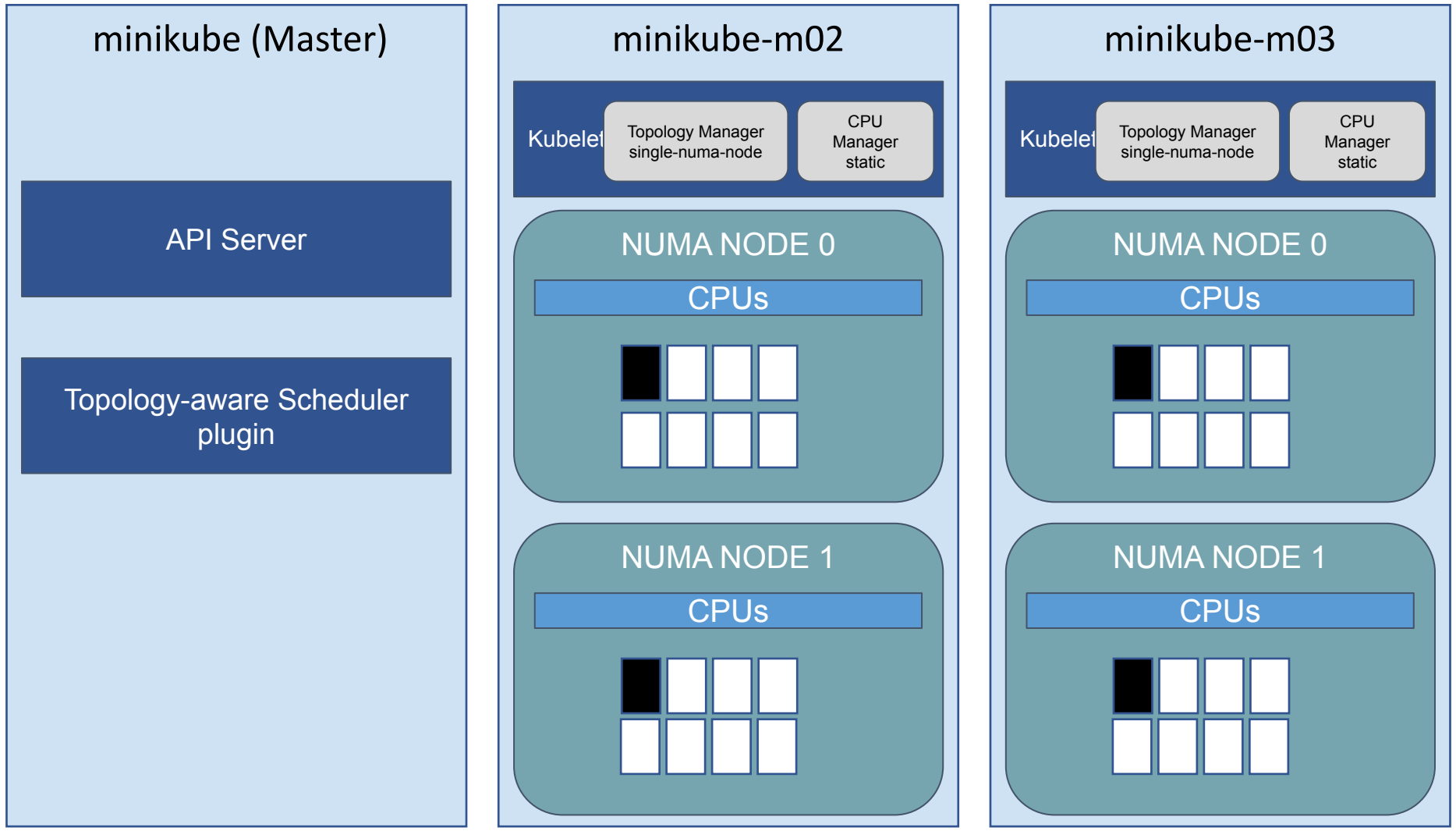
Solution: Local cache with reserve plugin

1. Keep a cache of resources **allocated but not yet reported in NRT objects by the updater** (unreported resources). Cache is updated after a pod is scheduled.
2. Account the unreported resources **against ALL the NUMA zones** on the given node as the scheduler cannot foresee the NUMA node from which resources are allocated.
3. **Invalidate the cache** on each NRT object changes (e.g. updates)

Demo: System setup



Demo: Burst of pods being scheduled

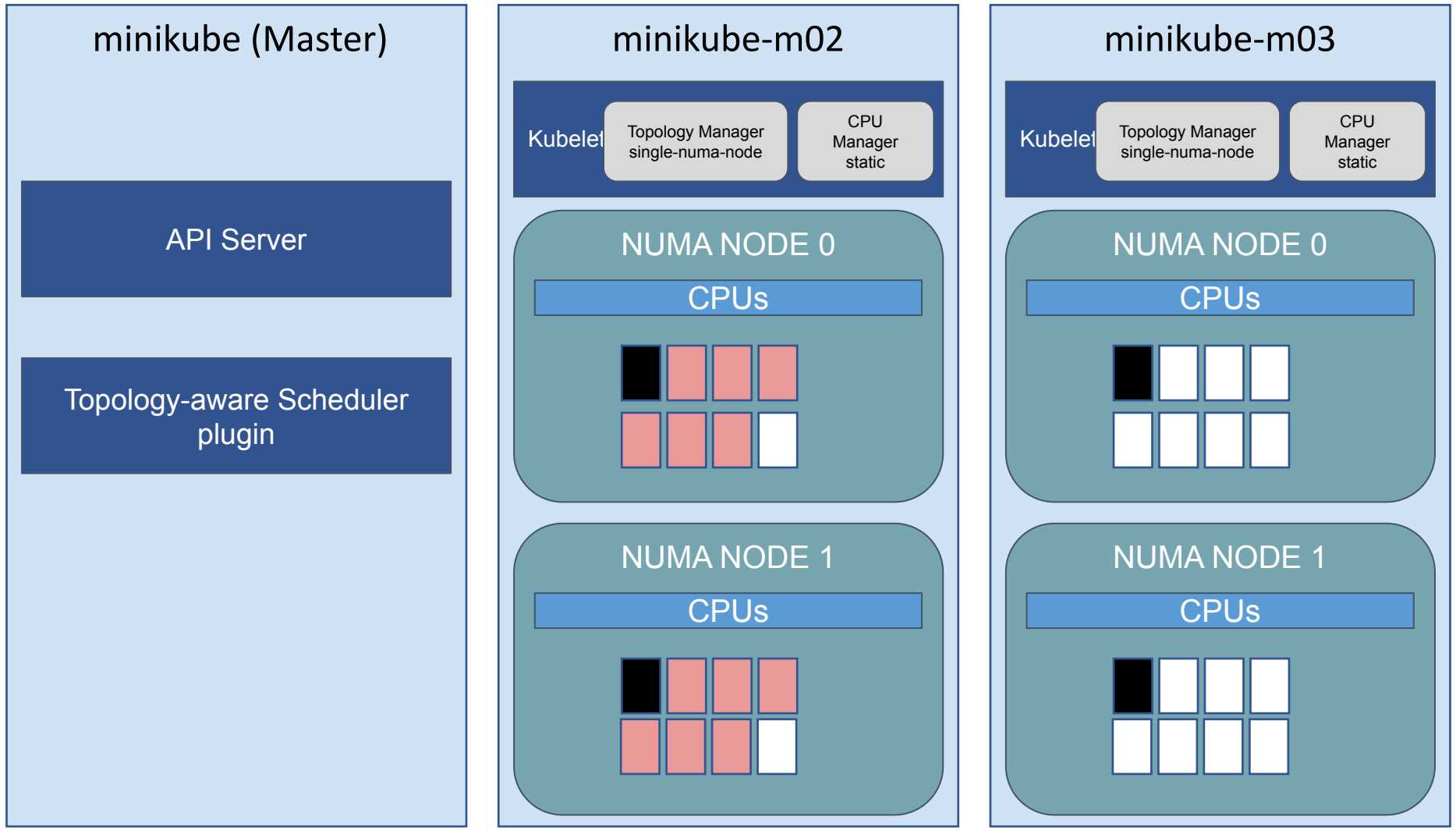



```
kind: Pod
metadata:
  name: testpod1
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt1
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

```
kind: Pod
metadata:
  name: testpod2
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt2
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

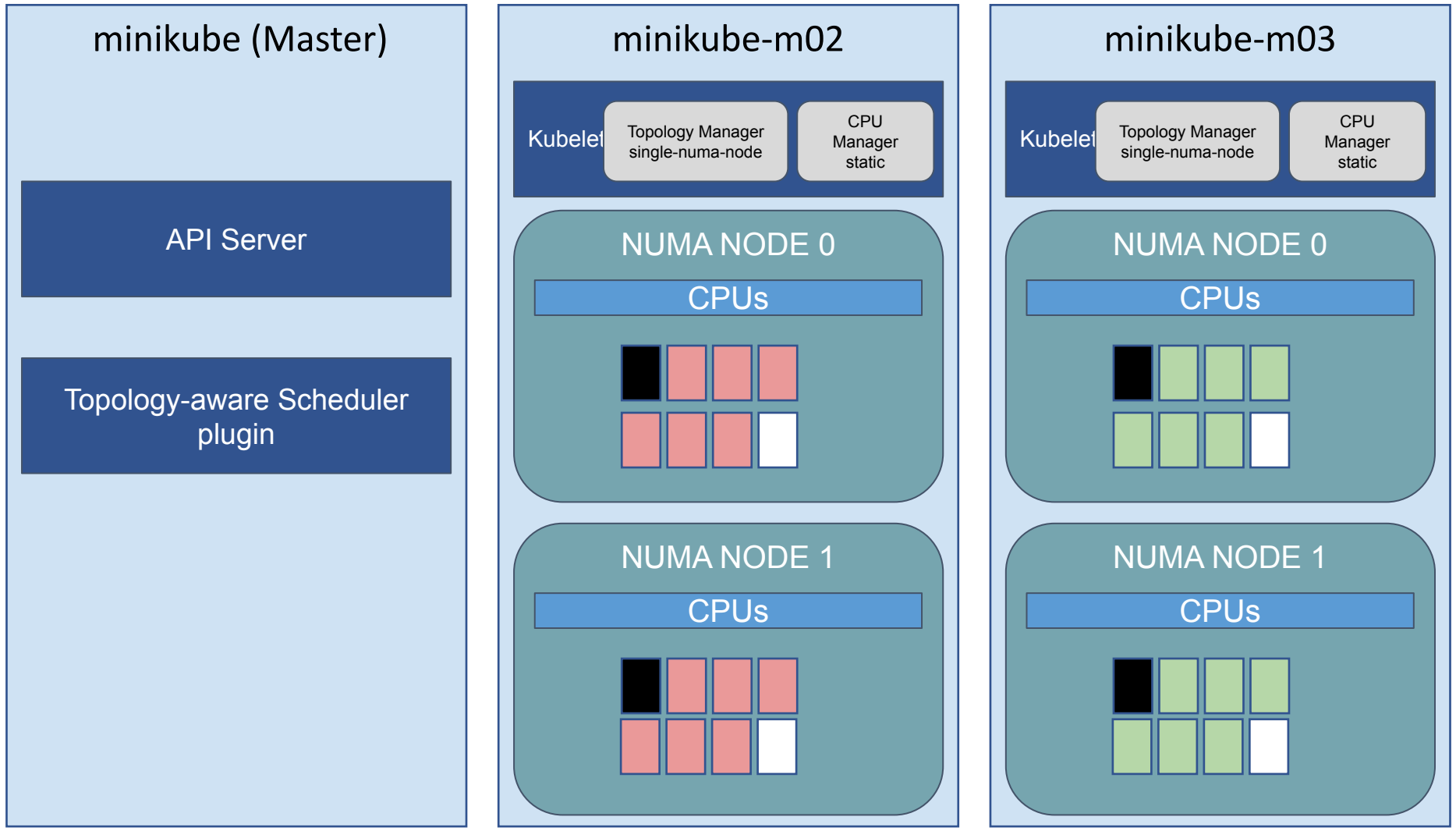
```
kind: Pod
metadata:
  name: testpod3
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt3
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

Demo: testPod1 scheduled




```
kind: Pod
metadata:
  name: testpod1
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt1
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

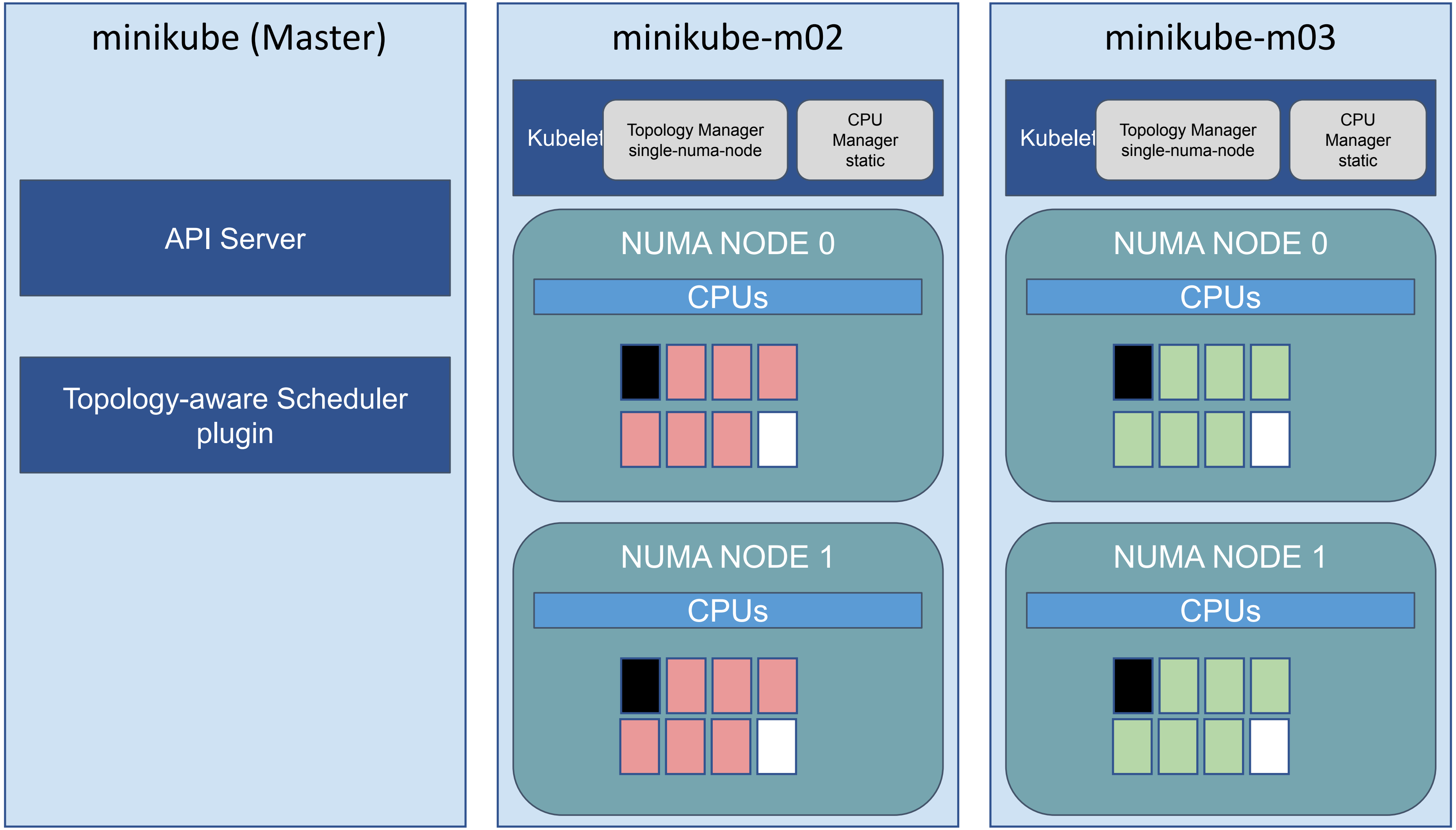
Demo: testPod2 scheduled




```
kind: Pod
metadata:
  name: testpod1
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt1
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

```
kind: Pod
metadata:
  name: testpod2
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt2
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

Demo: testPod3 pending



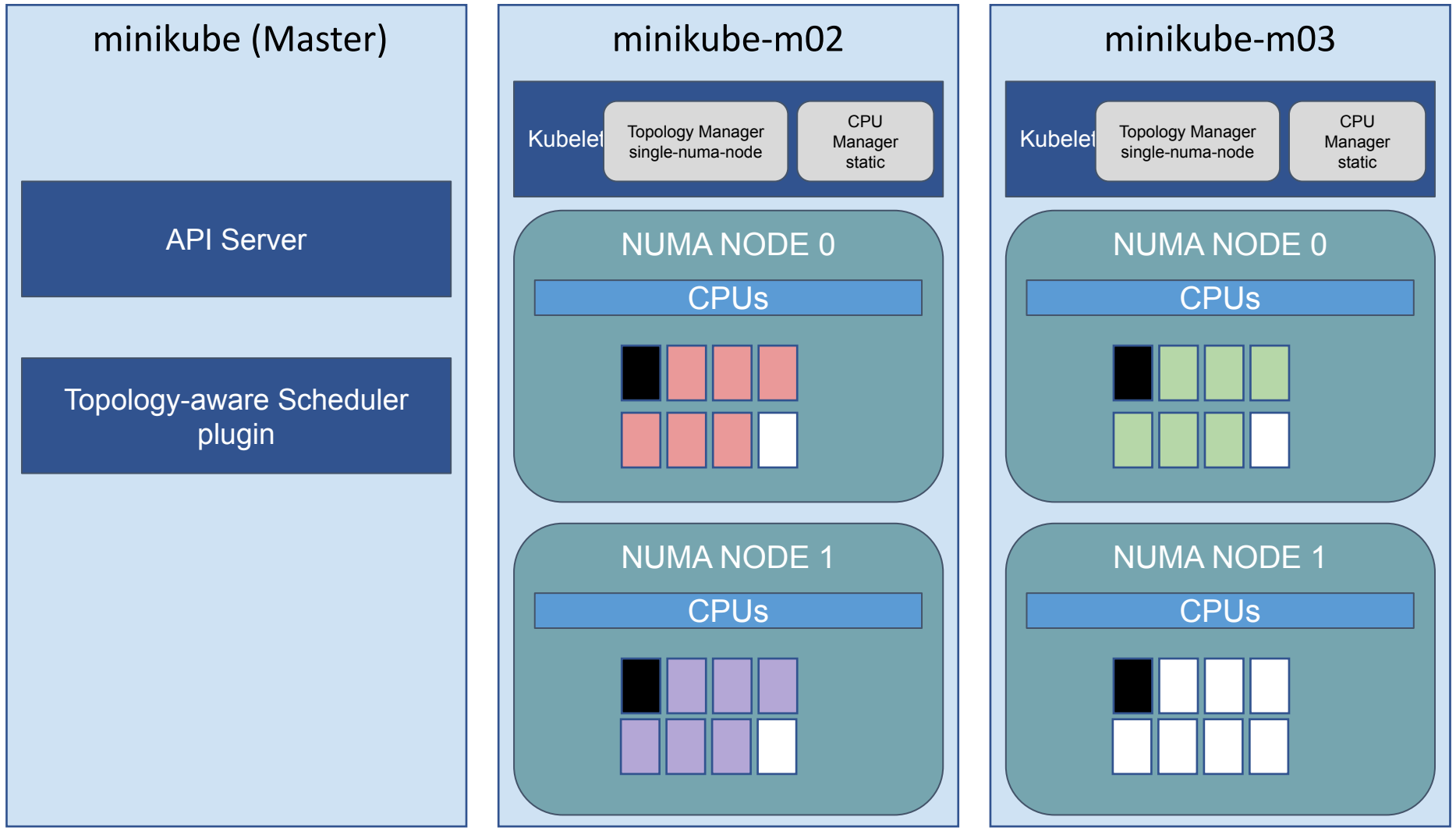

```
kind: Pod
metadata:
  name: testpod1
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt1
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

```
kind: Pod
metadata:
  name: testpod2
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt2
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

```
kind: Pod
metadata:
  name: testpod3
spec:
  schedulerName: […]ler
  containers:
  - name: te[…]
    resou[…]
        […]y: 128Mi
        […]: 6
      […]mits:
       memory: 128Mi
        cpu: 6
```

PENDING

Demo: After reconciliation




```
kind: Pod
metadata:
  name: testpod1
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt1
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

```
kind: Pod
metadata:
  name: testpod2
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt2
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

```
kind: Pod
metadata:
  name: testpod3
spec:
  schedulerName: my-scheduler
  containers:
  - name: testcnt3
    resources:
      requests:
        memory: 128Mi
        cpu: 6
      limits:
       memory: 128Mi
        cpu: 6
```

Demo

Recording: here

Scheduler Plugin: phase 2 developments

1. Local cache enablement with Reserve plugin (PR#315, PR#437, PR#439)
    a. Different caching strategies: overReserve and DiscardReservedNodes (PR#558)
2. NUMA aware scoring: LeastNUMANodes scoring strategy (KEP, PR)
3. noderesourcetopology: overhaul Topology Manager configuration management #488

NodeResourceTopology API: Phase 2

CRD based API definition used for enabling Topology-aware Scheduling and other use cases!

https://github.com/k8stopologyawareschedwg/noderesourcetopology-api

New v1alpha2 version of the API (PR #25) by incorporating feedback received on v1alpha1:

i. add top-level Attributes

ii. deprecate the TopologyPolicies field in the favour of attributes

Next Step: Gather more feedback and defer extensive cleanups and changes to v1beta1

Node Feature Discovery: Phase 2

NFD and RTE are topology updater agents and work is being done to have feature parity between these software components.

1. Catch up with RTE features (introduce exclude list: PR#949, reactive updates: PR#1031)
2. Enable reserve Plugin Support (PR#1049)
3. Consume NRT API v1alpha2 (update to v1alpha2: PR#1053, policy and scope as attributes: PR#1054)

Next Step: Continue enhancing NFD to make it the primary reference implementation as a topology updater agent.

Topology-aware Scheduling Future plans

1. Scalability Testing
2. Integration with DRA and VPA
3. (more long term) Support in core k8s - also shaped by DRA/VPA integration.

For TAS work: Special Shoutout! 🎉

- Francesco Romani
- Markus Lehtonen
- Piotr Prokop
- Talor Itzhak
- Wei Huang

WG Batch: Getting involved

- ➔ slack.k8s.io #wg-batch
- ➔ wg-batch@k8s.io
- ➔ issues.k8s.io?q=label:wg/batch
- ➔ Participate in WG Batch
  git.k8s.io/community/wg-batch
  - ◆ Meetings every other Thursday at 2PM UTC

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