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Improving User Experience for Device Consumption in Kubernetes

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Improving User Experience for Device Consumption in Kubernetes

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Kubernetes' birthplace

Uniformity of type of resources in data centers

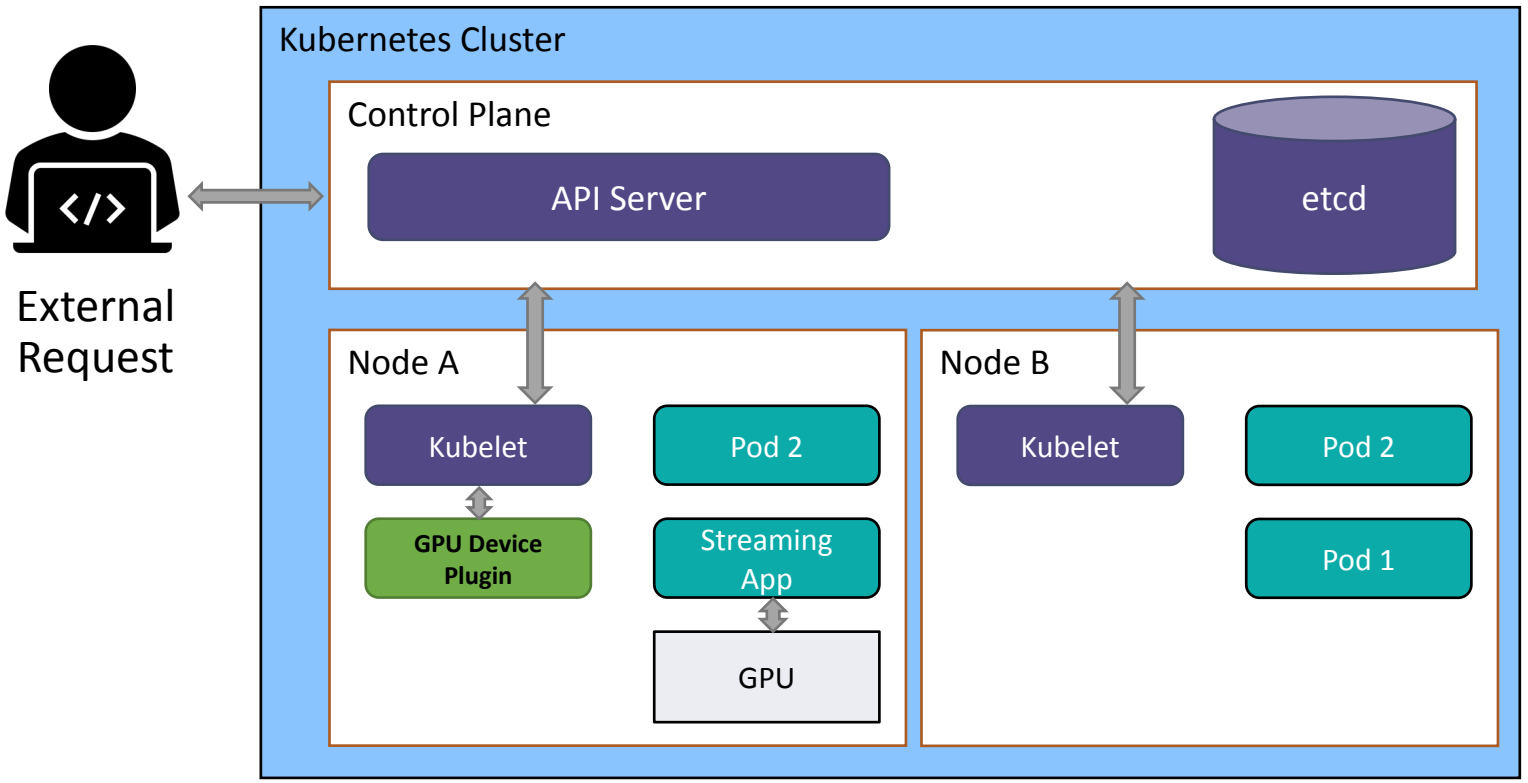
PodSpec: A Kubernetes Application UX


```
kind: Pod
metadata:
  name: streaming-app
spec:
  containers:
  - name: streaming-app
    image: streaming-app:1.0
    resources:
      requests:
        memory: 100Mi
        cpu: 10m
      limits:
        memory: 200Mi
        cpu: 50m
```

- Kubernetes allows you to *declare* what resources must be available for a Pod to be scheduled
- Pod will only be scheduled on Node with adequate resources
- The kubelet reserves the *request*ed amount of resource for Container
- The kubelet enforces resource *limit*
- Kubernetes resource types: CPU, memory (RAM), and hugepages

Servers started to vary, some having more specialized hardware

Kubernetes Device Plugin Interface

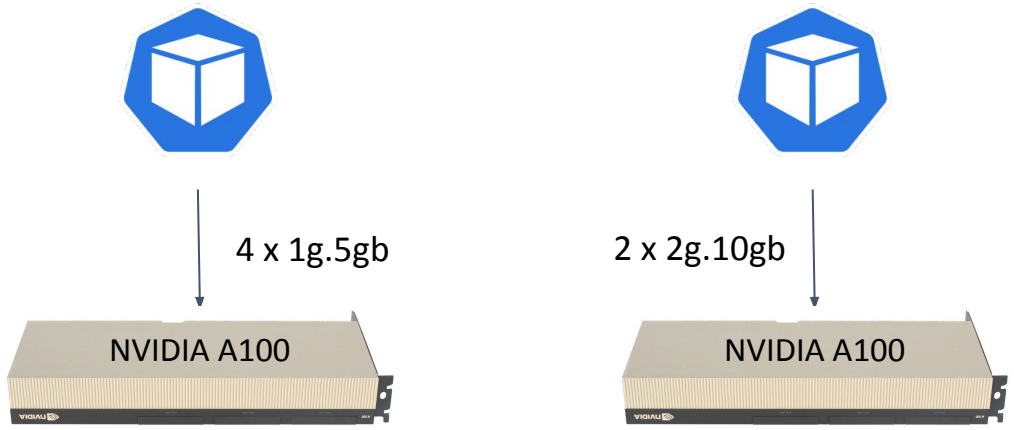



```
kind: Pod
metadata:
  name: streaming-app
spec:
  containers:
  - name: streaming-app
    image: streaming-app:1.0
    resources:
      requests:
        memory: 100Mi
        cpu: 10m
        vendor.com/gpu: 1
      limits:
        memory: 200Mi
        cpu: 50m
        vendor.com/gpu: 1
```

Device Plugins
Is it enough for modern world?

Devices UX: Device “size”?

- Many modern accelerators have internal resources
- Example of NVIDIA MIG:
  - GPU RAM
  - GPU compute units

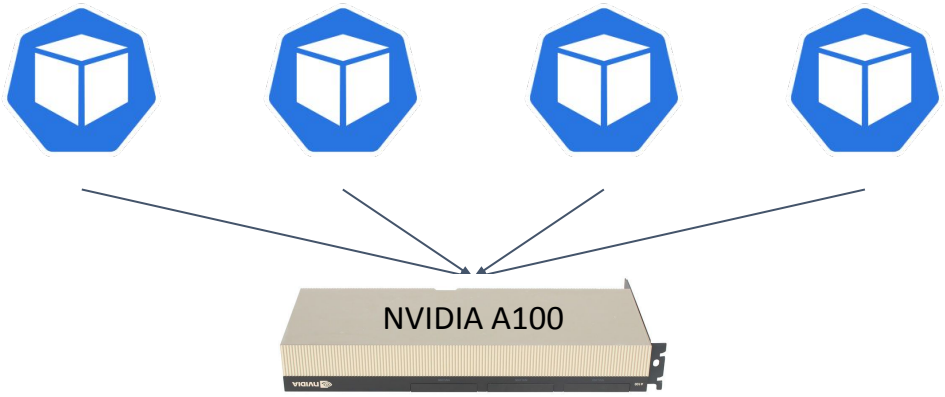



```
nodeSelector:
  csp.com/gpu-partition-size: 1g.5gb
...
containers:
...
- name: container-1
  image: registry.user.io/app:1.0
  resources:
    limits:
      nvidia.com/gpu: 1
```

Reference: Improving GPU Utilization using Kubernetes - Maulin Patel, Google

Devices UX: Shared device?

- Accelerators are not 100% utilized all the time
- Time-sharing between workloads is often needed



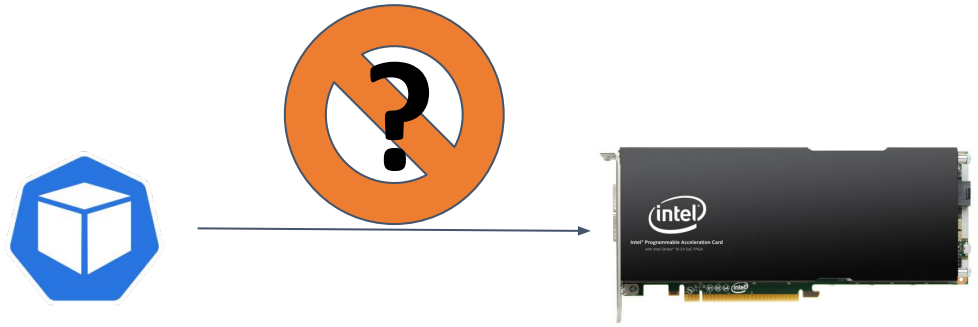

```
nodeSelector:
  csp.com/gpu-sharing-strategy: time-sharing
  csp.com/max-time-shared-clients-per-gpu: 10
...
containers:
...
- name: container-1
  image: registry.user.io/app:1.0
  resources:
    limits:
      nvidia.com/gpu: 1
```

Reference: Improving GPU Utilization using Kubernetes - Maulin Patel, Google

Devices UX: Optional accelerator?

- Some workloads can benefit from optional accelerator devices
  - e.g. crypto for service mesh components
- Can fallback to CPU-only

- Not possible to express in current device model




```
containers:
...
- name: container-1
  image: registry.user.io/app:1.0
  resources:
    requests:
      vendor.com/accelerator: 0
    limits:
      vendor.com/accelerator: 1
```

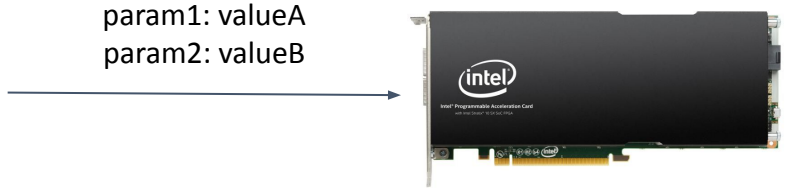
Devices UX: Device parameters?


```
resources:
  limits:
    fpga.intel.com/d5005-compress: 1
```

```
apiVersion: fpga.intel.com/v2
kind: FpgaRegion
metadata:
  name: d5005
spec:
  interfaceId: bfac4d851ee856
```

```
apiVersion: fpga.intel.com/v2
kind: AcceleratorFunction
metadata:
  name: d5005-compress
spec:
  afuId: d8424dc4a4a3c413f89e433683f9040b
  interfaceId: bfac4d851ee856
  mode: region
```

param1: valueA
param2: valueB

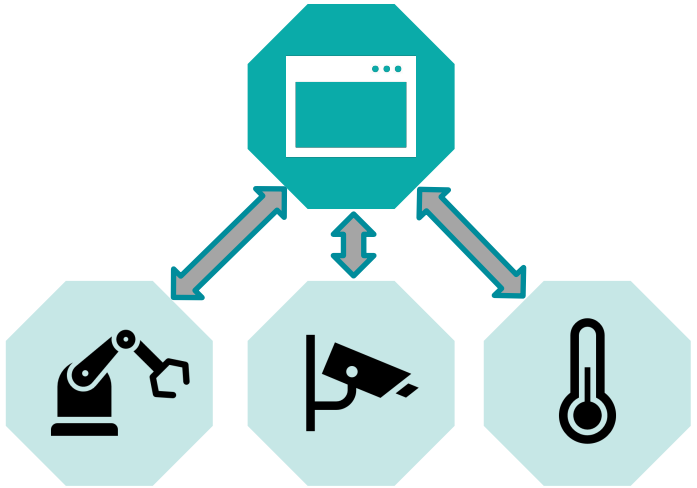



```
containers:
...
- name: container-1
  resources:
    limits:
      fpga.intel.com/region-bfac4d851ee856: 1
  env:
    - name: fpga_afuId
      value: d8424dc4a4a3c413f89e433683f9040b
```


Apps started leveraging resources external to the servers

Expanding K8s Device UX beyond Static Hardware

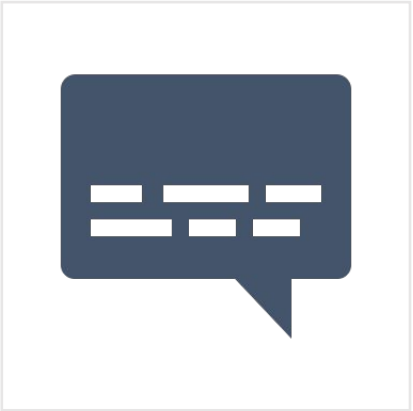

```
kind: Pod
metadata:
  name: factory-app
spec:
  containers:
  - name: factory-app
    image: factory-app:1.0
    resources:
      requests:
        memory: 100Mi
        cpu: 10m
        vendor.com/thermometer: 1
        vendor.com/ip-camera: 2
        vendor.com/robot: 1
```



How to expand Kubernetes functionality

Operator

CustomResourceDefinition (CRD) + Controller



Kubernetes core

Kubernetes Enhancement Proposal (KEP) + implementation

Akri: A Kubernetes Resource Interface

- Discovers devices. Handles dynamic appearance and disappearance of IoT devices
- Creates a device plugin for each discovered device, representing them as a native Kubernetes resources
- Kubernetes Operator
- Open-source CNCF Sandbox Project

Using other devices with Akri

1. Declare what to add as an extended Kubernetes resource

```
kind: Configuration
metadata:
  name: ip-camera
spec:
  discoveryHandler:
    name: onvif
     discoveryDetails:
       ipAddresses:
          action: Exclude
          items:
          - 10.0.0.1
          - 10.0.0.2
        macAddresses:
          action: Exclude
          items: []
        scopes:
          action: Include
          items:
          - onvif://..GreatONVIFCamera
          - onvif://..AwesomeONVIFCamera
```

2. Akri finds it and advertises it to kubelet

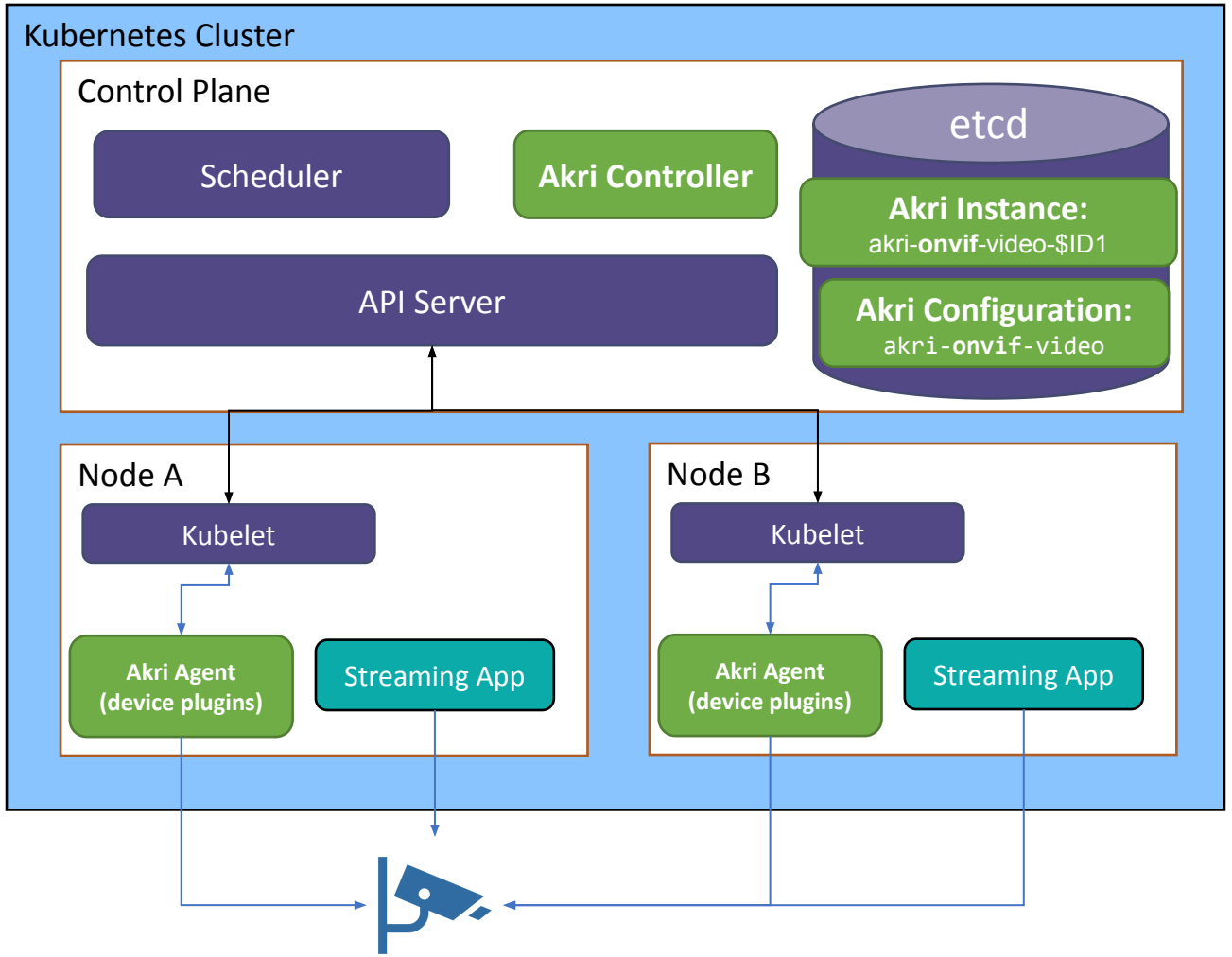
3. Request it in your Pod spec just like any other resource

```
kind: Pod
metadata:
  name: streaming-app
spec:
  containers:
  - name: streaming-app
    image: streaming-app:1.0
    resources:
      requests:
        akri.sh/akri-onvif-video-$ID1: 1
```

Akri Operator Components


```
kind: Configuration
metadata:
  name: akri-onvif-video
spec:
  discovery-handler:
    name: onvif
  brokerSpec:
    spec:
     containers:
     - name: streaming-app
       image: streaming-app:1.0
```

```
kind: Pod
metadata:
  name: streaming-app
spec:
  containers:
  - name: streaming-app
    image: streaming-app:1.0
    resources:
      requests:
        akri.sh/akri-onvif-video-$ID1: 1
```



Akri Instance CRD: Handling resource sharing

- Akri Instance regulates device usage across nodes
- Akri Agents update the instance when they discover the device (`nodes`)
- Akri Agents check and reserve the device availability (`deviceUsage`) before allowing a Pod requesting the device to be run.

```
kind: Instance
metadata:
  name: akri-onvif-video-ID1
  namespace: default
  ownerReferences:
  - apiVersion: akri.sh/v0
    kind: Configuration
    name: akri-onvif-video
spec:
  brokerProperties:
    ONVIF_DEVICE_IP_ADDRESS: 10.0.0.4
    ONVIF_DEVICE_MAC_ADDRESS: 48:0f:cf:7e:1a:5e
    ONVIF_DEVICE_SERVICE_URL: http://10.0.0.4:1000/onvif/device_service
  configurationName: akri-onvif
  deviceUsage:
    akri-onvif-video-ID1-0: node-a
    akri-onvif-video-ID1-1: node-b
    akri-onvif-video-ID1-2: ""
  nodes:
  - node-a
  - node-b
  shared: true
```

Improving Akri UX be better?

Dream UX

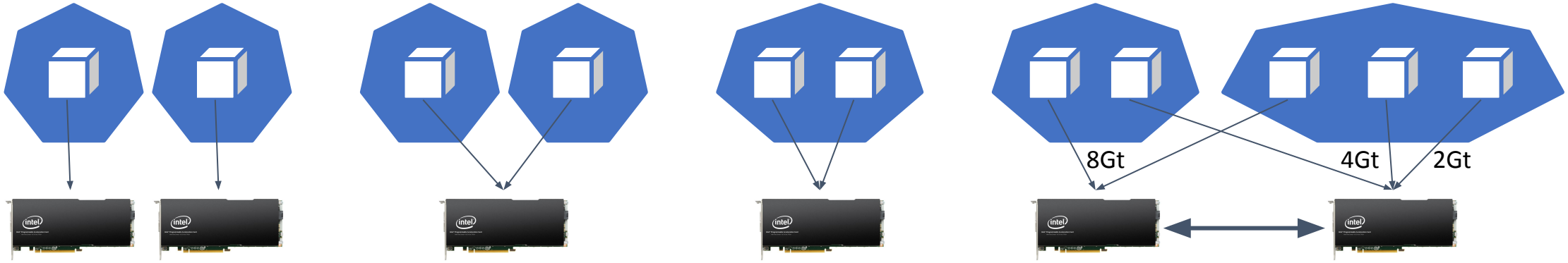
```
kind: Pod
metadata:
  name: streaming-app
spec:
  containers:
  - name: streaming-app
    image: streaming-app:1.0
    resources:
      requests:
        memory: 100Mi
        cpu: 10m
        akri.sh/usb-thermometer: 1
        akri.sh/ip-camera: 2
        akri.sh/opcua-robot:
                fast: 1
                precise: 1
```

Today

```
kind: Pod
metadata:
  name: streaming-app
spec:
  containers:
  - name: streaming-app
    image: streaming-app:1.0
    resources:
      requests:
        memory: 100Mi
        cpu: 10m
        akri.sh/usb-thermometer-$ID1: 1
        akri.sh/ip-camera-$ID1: 1
        akri.sh/ip-camera-$ID2: 1
        akri.sh/opcua-fast-robot-$ID1: 1
        akri.sh/opcua-precise-robot-$ID1: 1
```

Devices UX
What do we want?

Devices usage scenarios



- Concept
  - Separation of “Claim” with parameters and the use of “Allocated Instance”

- Example Usages
  - 2 Pods, 2 Devices
  - 2 Pods sharing same Device
  - 2 Containers within Pod to share Device
  - Multiple Containers in multiple Pods to share dynamically partitioned interconnected Devices (e.g. different device RAM slots)

Container Orchestrated Devices WG

- Idea and early discussions
  - early in 2019 - NVIDIA and Intel
- Informal group forming – KubeCon NA’19
  - NVIDIA, Intel, IBM, RedHat
- Formal COD WG era under CNCF TAG-Runtime - summer 2020
  - NVIDIA: Renaud Gaubert, Evan Lezar, Kevin Klues, Zvonko Kaiser
  - Intel: Alexander Kanevskiy, Ed Bartosh, Krisztian Litkey, Patrick Ohly
  - RedHat: Mrunal Patel, Urvashi Mohnani
  - IBM: Mike Brown

Container Orchestrated Devices WG

- CDI: Container Device Interface for runtimes
  - https://github.com/container-orchestrated-devices/container-device-interface
    - CRI-O 1.23.2+
    - containerd 1.7 (unreleased)
- Dynamic Resource Allocation - KEP-3063

Dynamic Resource Allocation

DRA Design Decisions

- Some aspects inspired by Container Storage Interface (CSI) volumes:
  - ResourceClaim object represents requirements.
  - Can be specified via template inside PodSpec.
  - Pods specify claims, containers reference them.
  - Allocation can be immediate or wait for usage by a Pod.

- Differences:
  - ResourceClaim status represents the full state (allocated, reserved, …).
  - Parameters are separate objects and opaque to Kubernetes, with validation through CRD.
  - Communication between scheduler and resource driver through apiserver.

DRA for Users: Inline Claim


```yaml
apiVersion: v1
kind: ResourceClass
metadata:
  name: example
driverName:
  test-driver.cdi.k8s.io
```

```yaml
apiVersion: v1
kind: ConfigMap
metadata:
  name: inline-claim-parameters
  namespace: default
data:
  a: b
```

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: test-inline-claim
spec:
  containers:
  - name: with-resource
    image: registry.k8s.io/e2e-test-images/dra-test:1.0
    resources:
      claims:
      - my-resource
  - name: without-resource
    image: registry.k8s.io/e2e-test-images/dra-test:1.0
  resourceClaims:
  - name: my-resource
    claim:
      template:
        metadata:
          labels:
            app: inline-resource
        spec:
          resourceClassName: example
          parameters:
            kind: ConfigMap
            name: inline-claim-parameters
```

DRA for Users: Separate Claim


```yaml
apiVersion: v1
kind: ResourceClaim
metadata:
  name: external-claim
spec:
  resourceClassName: example
  parameters:
    kind: ConfigMap
    name: external-claim-parameters
```

```yaml
apiVersion: v1
kind: ResourceClass
metadata:
  name: example
driverName:
  test-driver.cdi.k8s.io
```

```yaml
apiVersion: v1
kind: ConfigMap
metadata:
  name: inline-claim-parameters
  namespace: default
data:
  a: b
```

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: test-external-claim
spec:
  containers:
  - name: with-resource
    image: registry.k8s.io/e2e-test-images/dra-test:1.0
    resources:
      claims:
      - my-resource
  - name: without-resource
    image: registry.k8s.io/e2e-test-images/dra-test:1.0
  resourceClaims:
  - name: my-resource
    claim:
      resourceClaimName: external-claim
```

DRA for Kubernetes

- KEP accepted for 1.25, updated for 1.26
- Code to be merged into 1.26, pending in PR #111023
- Modified components:
  - kube-apiserver: new types in core API group
  - kube-controller-manager:
    - create claims from inline templates
    - remove completed pods from claim status
  - kube-scheduler: filter nodes, communication with resource drivers
  - kubelet: prepare resources, inject into containers

DRA for Vendors

- Must implement controller and kubelet plugin.
- Controller must handle allocation and resource tracking:
  - could be done through CRDs (similar to how Akri does it)
- Document deployment and usage for customers.

- Generic helper code to be published in k8s.io/dynamic-resource-allocation Go module.
- Open source drivers:
  - Reference resource driver in k/k/test/e2e/dra/test-driver
  - NVIDIA: https://gitlab.com/nvidia/cloud-native/k8s-dra-driver

Contact

- Container Orchestrated Devices WG
  - Every second Tuesday
  - 7:00-8:00 PST
  - Kubernetes Slack: #sig-node
  - CNCF Slack: #tag-runtime
- docs.akri.sh
  - Every first Tuesday
  - 9:00-10:00 PST
  - Kubernetes Slack: #akri

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Q & A

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