Device Assignment for VMs in Kubernetes

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$ whoami

- Golang, Python engineer
- working on oVirt and KubeVirt
  - node/host management level virtualization tech
    - device assignment w/ VFIO, (v)GPU, SR-IOV
    - NUMA, hugepages, CPU architectures
- https://mpolednik.github.io/

The Stack

- VM device assignment (VFIO)
- libvirt
- Docker
- Kubernetes
- KubeVirt

Devices & Virtualization

What even is a device?

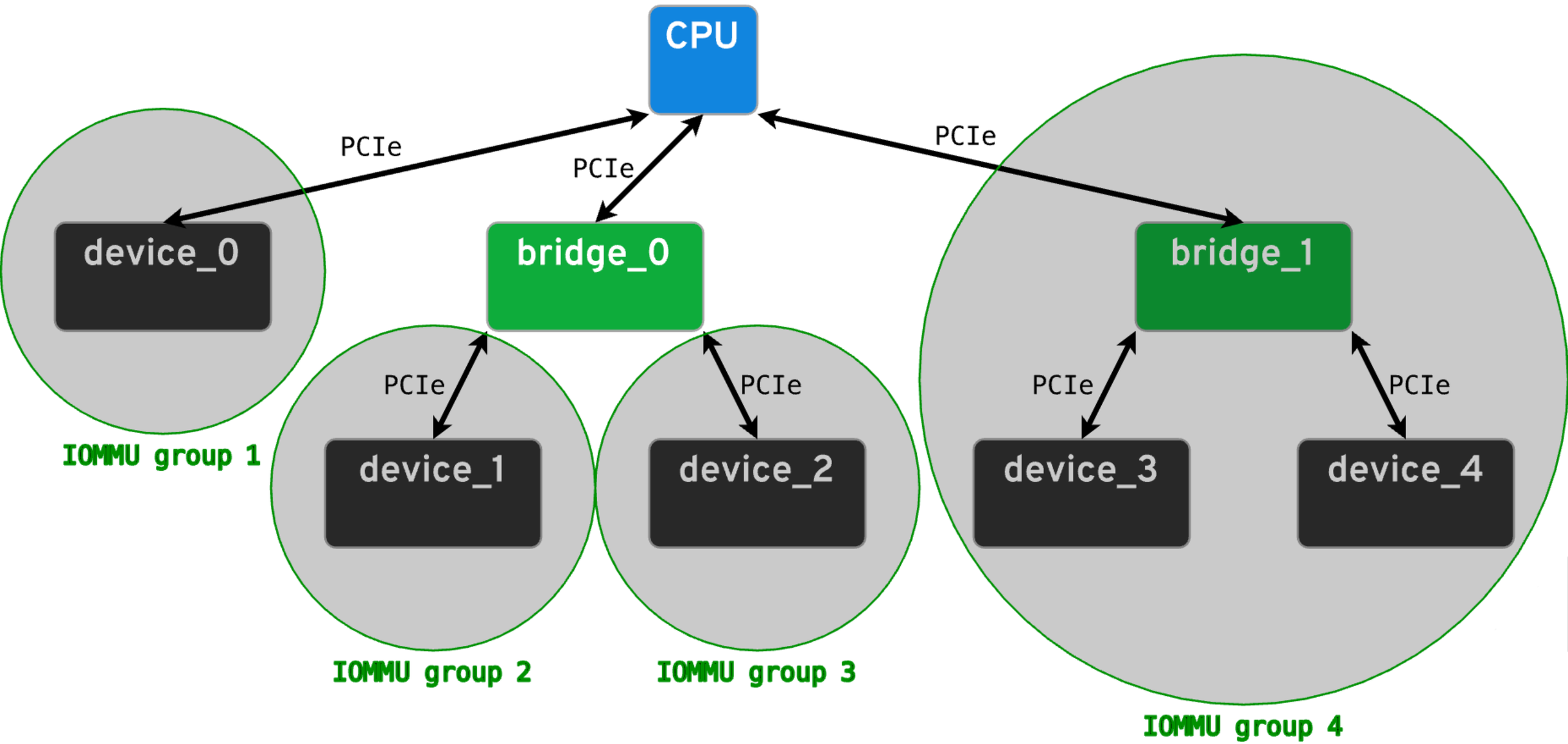
- many memory regions!
- /sys/bus/pci/${device_address}/...
- /dev/...

VFIO 101

- PCI driver
- devices bound to it can be used in VMs
- IOMMU groups based on DMA isolation
- explained in Slicing a (v)GPU talk at DevConf.cz
  - https://www.youtube.com/watch?v=G8b9jIFN-nk

IOMMU Groups

- group contains 1-N devices
- assignment granularity at group level
- e.g. GPU + HDMI sound card
- accessed at /dev/vfio/${N}


CPU
PCIe
PCIe
PCIe
device_0
bridge_0
bridge_1
PCIe
PCIe
PCIe
PCIe
device_1
device_2
device_3
device_4
IOMMU group 1
IOMMU group 2
IOMMU group 3
IOMMU group 4

libvirt

- daemon & library for single-node VM management
- abstracts QEMU cmdline interface by XML
- **refers to devices by their PCI address**

libvirt

```
...
<devices>
    ...
    <hostdev managed="no" mode="subsystem" type="pci">
        <source>
            <address bus="7" domain="0" function="0" slot="0" />
        </source>
    </hostdev>
    ...
</devices>
...
```

Devices in Containers

Overview

- no special driver needed
- device path exposed to container
    - --device, --volume (?), --privileged (?!)
    - DRI, toolkits, any required endpoints
- also sets up cgroups

Overview

- sufficient unless orchestration is needed
- ... in that case, building block for Kubernetes device assignment

Devices in Kubernetes

Kubernetes 101

- orchestrate containers (in declarative way)
- pod = several containers
- pod, container, node etc. are just resources
    - the talk will show resources in YAMLs

NVIDIA GPUs

- vendor-specific feature since 1.3
- `accelerators` FeatureGate
- request N GPUs

NVIDIA GPUs

```
spec:
  containers:
  - name: demo
    ...
    resources:
      requests:
                alpha.kubernetes.io/nvidia-gpu: 2
```

NVIDIA GPUs

- deprecated by device plugins

Device Plugins

- since Kubernetes 1.8
- shortened to DPI(s)
- gated behind `DevicePlugins` FeatureGate
- gRPC server(s) that exposes available resources
  - Register, Allocate, ListAndWatch

Device Plugins

- one gRPC server per tracked resource

```
9 func (dpm *DevicePluginManager) Run() {
8         for _, plugin := range dpm.plugins {
7             go plugin.Run()
6         }
5
4         <-dpm.stopCh
3         dpm.stop()
2 }
```

```
9 func (dpm *DevicePluginManager) Run() {
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6         }
5
4         <-dpm.stopCh
3         dpm.stop()
2 }
```

fancy starting 50+ gRPC servers?

```
$ sh kubectl.sh get nodes --show-all -o json | grep -A 10 alloca
            "allocatable": {
                "cpu": "4",
                "hugepages-1Gi": "0",
                "hugepages-2Mi": "0",
                "memory": "12181600Ki",
                "mpolednik.github.io/102b_0522": "1",
                "mpolednik.github.io/111d_8018": "3",
                "mpolednik.github.io/8086_10c9": "2",
                "mpolednik.github.io/8086_10e8": "4",
                "mpolednik.github.io/8086_244e": "1",
                "mpolednik.github.io/8086_2c70": "1",
...
```

```
apiVersion: v1
kind: Pod
metadata:
  name: nginx-apparmor
spec:
  containers:
                .
  - name: nginx
    image: nginx
    resources:
      requests:
        mpolednik.github.io/8086_10e8: 1
      limits:
        mpolednik.github.io/8086_10e8: 1
```

Device Plugins

- flexible
  - allows the node to advertise any resource
    - /dev/kvm is a device too!
  - and mount it into a container (not pod!)
- still in development
  - Deallocate gRPC endpoint?

KubeVirt

KubeVirt

- (not only) pet VMs in Kubernetes
- uses CRD (custom resource definition)
  - and several custom services
- based on libvirt

kubectl (user commands)

Node

kubelet

docker (runtime)

Pod

virt-handler

libvirtd

Pod

virt-launcher

VM

Pod

container

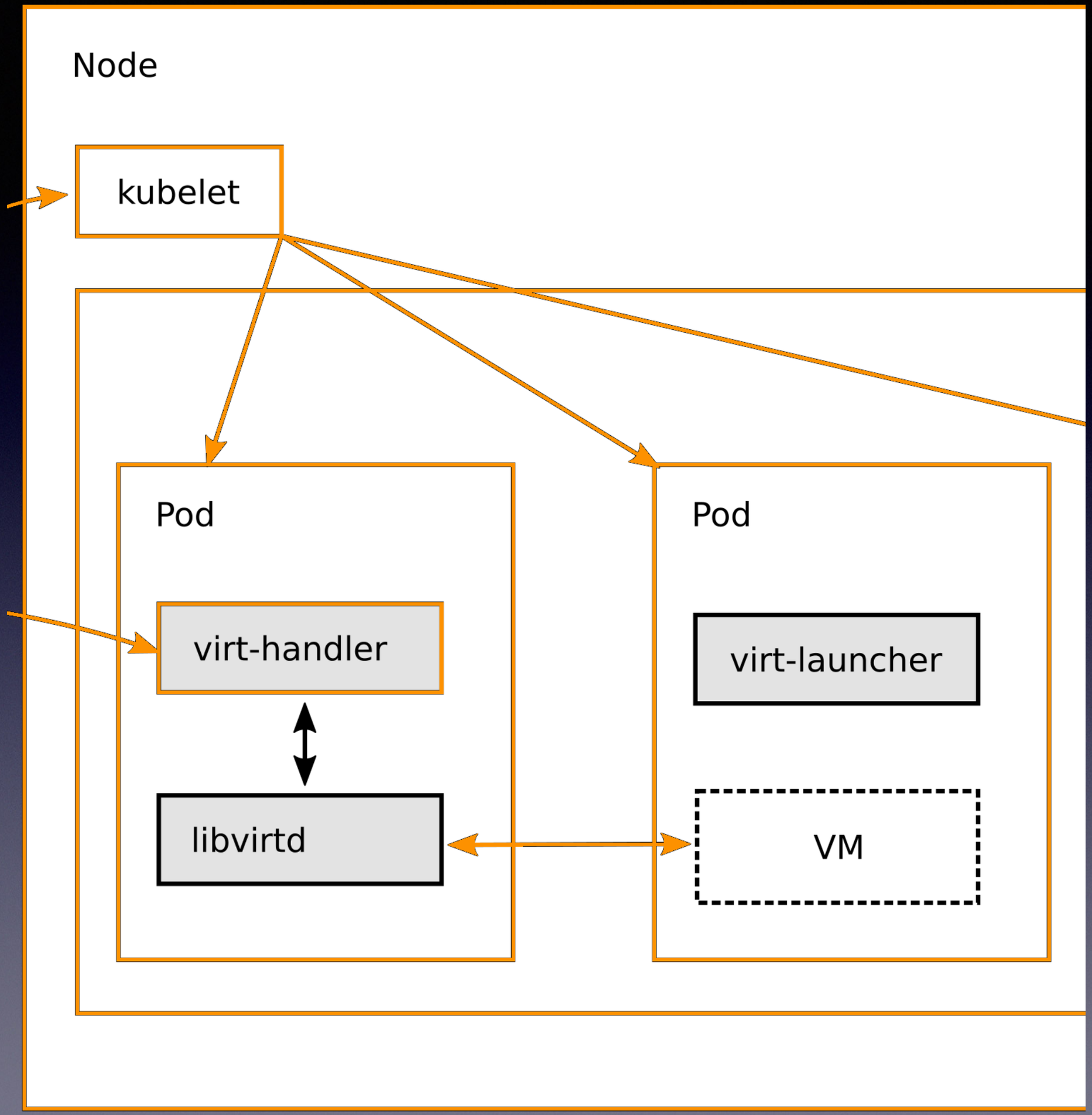
API Server

Virt Controller

Cluster components

KubeVirt component

Kubernetes component


Node
kubelet
Pod
virt-handler
libvirtd
Pod
virt-launcher
VM

Devices in KubeVirt

- mix of both worlds
  - Kubernetes assignment for devices
    - VFIO within the (docker) container
- requires custom DPI
- + VM spec to POD spec translation

VFIO DPI

https://github.com/kubevirt/kubernetes-device-plugins (WIP)

VFIO DPI

- ensure vfio-pci is loaded
- enumerates /sys/bus/pci/devices
- for each device found
  - get vendor ID, device ID, IOMMU group
  - report it back to Kubelet (via gRPC API)

VFIO DPI

- the missing parts:
  - IOMMU group awareness (report conflicting groups as unhealthy? + DPI topology)
  - device deallocation (inotify VFIO endpoint?)
  - edge case handling (Kubelet dies, device plugin dies)

Bridging VMs and pods

What We Have (idea)

```
spec:
  domain:
    devices:
      ...
      passthrough:
      - type: pci
        vendor: 1000
        device: 1000
      ...
  memory:
```

What We Need (reality)

```
spec:
  containers:
  - name: demo
    ...
    resources:
      requests:
        mpolednik.github.io/1000_1000: 1
      limits:
        mpolednik.github.io/1000_1000: 1
```

VFIO Initializer

- https://github.com/mpolednik/k8s-vfio-initializer-plugin (WIP)
- transform VM requirements to pod
  - in Kubernetes-native way
- probably not needed after all

That's it!*

* almost

Is that really all?

- which devices inside pod belong to the VM?
  - remember libvirt addressing?
  - mount
    - /sys
    - /sys/bus/pci/devices/${device_address}
    - something else?

Devices in KubeVirt

- proposal @ https://github.com/kubevirt/kubevirt/pull/593
- DPI @ https://github.com/kubevirt/kubernetes-device-plugins
- Initializer @ https://github.com/mpolednik/k8s-vfio-initializer-plugin
- comments & suggestions welcome!

Summary

- VMs in Kubernetes are real!
- and so is device assignment

Questions?

Thank you!
Slides & Blog @ https://mpolednik.github.io/