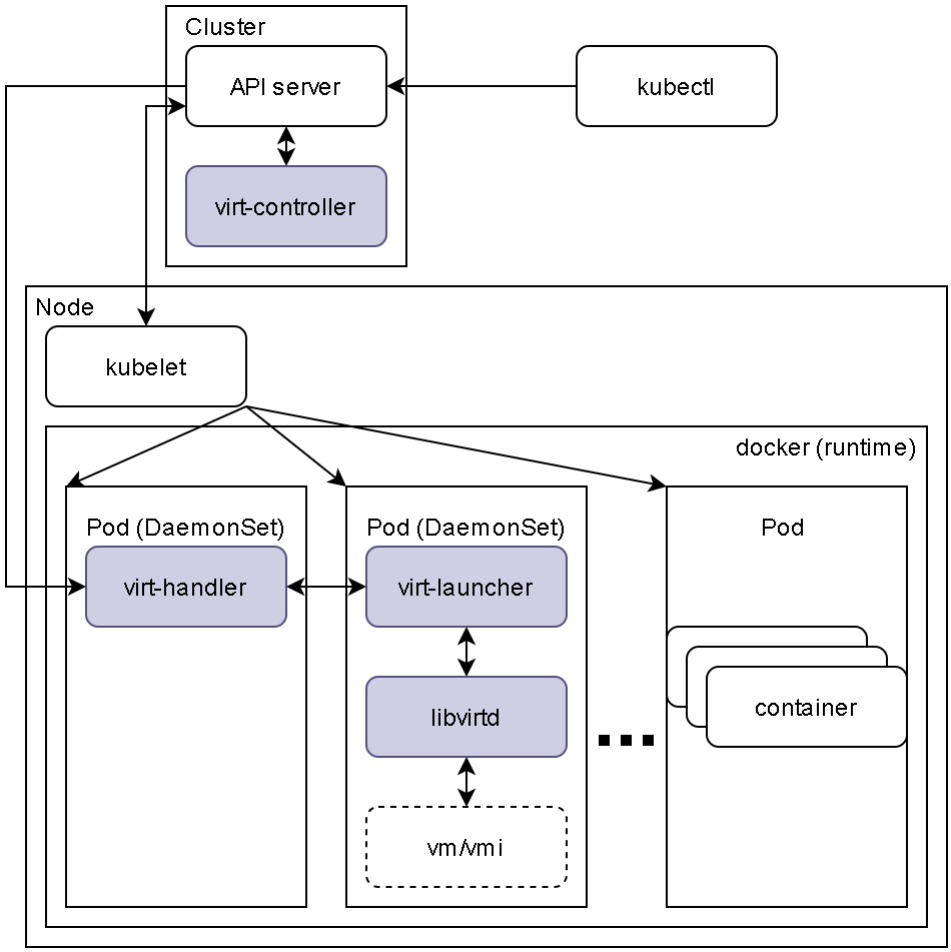
QAT enabling in Kubevirt

Kubevirt

What is Kubevirt?

KubeVirt is a Kubernetes CRD(Custom Resource Definitions) implement. It is a virtual machine management add-on for Kubernetes. The aim is to provide a common ground for virtualization solutions on top of Kubernetes.

In details, KubeVirt technology addresses the needs of development teams that have adopted or want to adopt Kubernetes but possess existing Virtual Machine-based workloads that cannot be easily containerized. So KubeVirt extends Kubernetes by adding additional virtualization resource types (especially the VM/VMI type) through Kubernetes's Custom Resource Definitions API. By using this mechanism, the Kubernetes API can be used to manage these VM resources alongside all other resources Kubernetes provides. The resources themselves in Kubernetes are not enough to launch virtual machines. For this to happen, the functionality and business logic needs to be added to the cluster. Scheduling, networking, and storage are all delegated to Kubernetes, while KubeVirt provides the virtualization functionality. The functionality is not added to Kubernetes itself, but rather added to a Kubernetes cluster by running additional controllers and agents on an existing cluster. And these necessary controllers and agents are all provided by KubeVirt.



KubeVirt delivers three things to provide the new functionality:

1. New types - Custom Resource Definition (CRD) - are added to the Kubernetes API
2. Controllers for cluster wide logic associated with new types
3. Daemons for node specific logic associated with new types

Once all three steps have been completed, you are able to create new objects (VM/VMI) in Kubernetes and the new controllers take care to get the VMIs scheduled on some host, and a daemon - the virt-handler is taking care of a host alongside the kubelet to launch the VMI and configure it until it matches the required state.

Benifits

More specifically, the technology provides a unified development platform where developers can build, modify, and deploy applications residing in both Application Containers as well as Virtual Machines in a common, shared environment. Teams with a reliance on existing virtual machine-based workloads are empowered to rapidly containerize applications. With virtualized workloads placed directly in development workflows, teams can decompose them over time while still leveraging remaining virtualized components as is comfortably desired.

- Leverage KubeVirt and Kubernetes to manage virtual machines for impractical-to-containerize apps.
- Combine existing virtualized workloads with new container workloads on the one platform.
- Support development of new microservice applications in containers that interact with existing virtualized applications.
- ...

Components

- VM/VMI
  VM/VMI definitions are kept as custom resource definitions inside the Kubernetes API server. The VM/VMI definition is defining all properties of the Virtual machine itself.
- virt-api-server
  It is a Http API server which serves as the entry point for all virtualization related flows and it is responsible for defaulting and validation of the provided VM/VMI CRDs. The API Server is taking care to update the virtualization related custom resource definition.
- virt-controller
  From a high-level perspective, the virt-controller has all the cluster wide virtualization functionality. This controller is responsible for monitoring the VM/VMI (CRDs) and managing the associated pods. It will make sure to create and manage the life-cycle of the pods associated to the VM/VMI objects.

- virt-handler
  Every host needs a single instance of virt-handler. It can be delivered as a DaemonSet. The virt-handler is also reactive and watching for changes of the VM/VMI object. Once detected, it will perform all necessary operations to change a VM/VMI to meet the required state. This behavior is similar to the choreography between the Kubernetes API Server and the kubelet. The main areas which virt-handler has to cover are:
    1. Keep a cluster-level VM/VMI spec in sync with a corresponding libvirt domain.
    2. Report domain state and spec changes to the cluster.
    3. Invoke node-centric plugins which can fulfill networking and storage requirements defined in VM/VMI specs.
- virt-launcher
  One pod is created for every VM/VMI object. This pod's primary container runs the virt-launcher. Kubernetes or the kubelet is not running the VM /VMIs itself. Instead a daemon on every host in the cluster will take care to launch a VM/VMI process for every pod which is associated to a VM /VMI object whenever it is getting scheduled on a host.
    1. The main purpose of the virt-launcher Pod is to provide the cgroups and namespaces, which will be used to host the VM/VMI process. The virt-handler signals virt-launcher to start a VM/VMI by passing the VM/VMI's CRD object to virt-launcher.
    2. The virt-launcher then uses a local libvirtd instance within its container to start the VM/VMI.
    3. The virt-launcher monitors the VM/VMI process and terminates once the VM/VMI has exited.
- libvirtd
  An instance of libvirtd is present in every VM/VMI pod. virt-launcher uses libvirtd to manage the life-cycle of the VM/VMI process.
- ...

VM Pod Lifecycle

- The virt-controller and the virt-handler listen on node status through the watch interface provided by api-server
- A new VMI definition similar with a plain pod is posted to the kubelet
- The K8s API Server validates the input and creates a VMI custom resource definition (CRD) object.
- The virt-controller observes the creation of the new VMI object and creates a corresponding pod.
- Kubernetes schedules the pod on a host.
- The virt-controller observes that a pod for the VMI got started and updates the nodeName field in the VMI object.
- The virt-handler (DaemonSet) observes that a VMI got assigned to the host where it is running on.
- The virt-handler is using the VMI Specification and signals the creation of the corresponding domain using a libvirtd instance in the VMI's pod.
- A client deletes the VMI object through the virt-api-server.
- When Kubernetes runtime attempts to shutdown the virt-launcher pod before the VM/VMI has exited, the virt-launcher forwards signals from Kubernetes to the VM/VMI process and attempts to hold off the termination of the pod until the VM/VMI has shutdown successfully.
- The virt-handler observes the deletion and turns off the domain.

QAT

Brief Introduction

Intel QuickAssist Technology is developed by Intel and runs on the Intel Architecture to provide security and compression acceleration capabilities to improve performance and efficiency. It will offload the workloads like cryptography and compression from the CPU to hardware. Server, networking, big data, and storage applications use Intel QuickAssist to offload compute-intensive operations, such as:

- Symmetric cryptography functions, including cipher operations and authentication operations
- Public key functions, including RSA, Diffie-Hellman, and elliptic curve cryptography,
- Compression and decompression functions, including DEFLATE

It has made great benefits in many areas, such as Hadoop Acceleration, OpenSSL Integration, SDN and NFV Solutions Boost and so on.

–4G LTE and 5G encryption algorithm offload for mobile gateways and infrastructure.

–VPN traffic acceleration, with up to 50 Gbps crypto throughput and support for IPsec and SSL acceleration.

–Compression/decompression up to 24 Gbps throughput.

–I/O virtualization using PCI-SIG Single-Root I/O Virtualization (SR-IOV).

Handware

- Chipset: Intel® C6xx Series Chipsets
- PCIE: Intel® QuickAssist Adapter 89xx
- SoC: Intel Atom® Processor C3000 Series (Denverton NS) / Rangeley

Features

- QAT provides security (encryption) HW acceleration and compression HW acceleration
- QAT makes use of a set of APIs to abstract out the hardware, so the same application can run on multiple generations of QAT hardware
- Customers can also make use of patches that QAT has provided to popular open source software, so they can minimize or eliminate their effort to learn the API

With above support, QAT makes it easier for developers to integrate the accelerators in their designs and thus decrease the development time. And it can increase business flexibility by offering solutions that best fit the changing business requirements. It also frees up the valuable cycles on processors and allows it to perform value-added functionality.

What's more, QAT provides a uniform means of communication between accelerators, applications, and acceleration technologies. Due to this, the resources are managed more productively. Then It can boost application throughput, by reducing the demand on the platform and maximizing the CPU utilization.

Gaps

First of all, in a Kubernetes cluster, if we need utilize the QAT card and assign its vf to a container, we will compile the QAT driver on the host and deploy the QAT device plugin. After the QAT device plugin register successfully, a *ListAndWatch* function is for the Kubelet to Discover the devices and their properties as well as notify of any status change (devices become unhealthy). The list of devices is returned as an array of all devices description information (ID, health status) of the resource. Kubelet records this resource and its corresponding number of devices to *node.status.capacity/allocable* and updates it to apiserver.

In this way, when creating a plain pod, fields such as *intel.com/qat* can be added to spec.containers.resource.limits/requests: "1" to inform Kubernetes to schedule the pod to nodes with more than one *intel.com/qat* resource allowance. When the pod is to run, Kubelet will call device plugin *allocate* function. Device plugin may do some initialization operations, such as QAT configuration or QRNG initialization. If initialization is successful, this function will return how to config the device assigned to the pod when the container is created, and this configuration will be passed to the container runtime as a parameter used to run container.

This workflow runs well in Kubernetes, but Kubevirt doesn't support for it. Because Kubevirt is a CRD implenment and it fails to process the pod-type configuration in its yaml file. It has its own api server and controller to verify the CRD definition and create a corresponding pod. Thie means we can not assign a QAT vf to the Kubevirt VM by adding spec.containers.resource.limits/requests: "1" with QAT resource name to the VMI configuration file. So the gaps in Kubevirt to enable QAT may be following items:

1. Need create corresponding custom resource to hold QAT device.
2. QAT feature should be optional and can be configured through a configmap.
3. When assign a QAT vf to VM, Kubevirt need mount the required pci device to it.
4. Do ordinary device passthrough to assign it
5. Change virt-api to verify an approved VMI pod with QAT
6. Example yaml file to create VMI with QAT
7. Test cases

Integration

CRD Definition

Kubevirt use the feature of Kubernetes name Dynamic Admission Control and create Kubevirt API through a ValidatingAdmissionWebhook. This feature allows KubeVirt to dynamically register an HTTPS webhook with Kubernetes at KubeVirt install time. After registering the custom webhook, all requests related to KubeVirt API objects are forwarded from the Kubernetes API server to our HTTPS endpoint for validation. If our endpoint rejects a request for any reason, the object will not be persisted into etcd and the client receives our response outlining the reason for the rejection.

So to enable QAT in Kubevirt, it is necessray to create related segments to the validation service and add the QAT feature Gate verified method.

- Add necessary information to swagger.json which is an add on for kubenetes API used in Kubevirt

```
...

"qats": {
   "description": "Whether to assign a QAT vf device to the vmi.\n+optional",
   "type": "array",
   "items": {
      "$ref": "#/definitions/v1.QAT"
   }
},

...

"v1.QAT": {
   "required": [
      "name",
      "deviceName"
   ],
   "properties": {
      "deviceName": {
         "type": "string"
      },
      "name": {
         "description": "Name of the QAT device as exposed by a device plugin",
         "type": "string"
      }
   }
},
```

- Add Feature Gate to webhook validation service to config it in configmap

```
...

if spec.Domain.Devices.QATs != nil && !config.QATPassthroughEnabled() {
    causes = append(causes, metav1.StatusCause{
        Type: metav1.CauseTypeFieldValueInvalid,
        Message: fmt.Sprintf("QAT feature gate is not enabled in kubevirt-config"),
        Field: field.Child("QATs").String(),
    })
}

...
```

...

Non-privileged

To meet the Kubernetes and Kubevirt community specifications, the pod should be non-privileged. So we should mount the assigned QAT pci device to the VM through the interfaces Kubevirt provided.

```
if util.IsQATVMI(vmi) {
    for _, qat := range vmi.Spec.Domain.Devices.QATs {
        requestResource(&resources, qat.DeviceName)
    }
}
```

This will call the Kubevirt to mount necessary resources for QAT into the VM, such as /sys/devices/.

PCI passthrough

Fundamentally, Kubevirt create a Kubernetes CRD to hold some resource configurations that fit a libvrit instance. So actually to assign a QAT vf into a VM is to create a libvirt and insert the specific device into hostdev block. (In libvirt, hostdev label means a plain host device assignment with all its limitations)

```
<hostdev mode='subsystem' type='pci' managed='yes'>
    <driver name='vfio'/>
    <source>
      <address domain='0x0000' bus='0x3d' slot='0x02' function='0x2'/>
    </source>
    <alias name='hostdev0'/>
    <address type='pci' domain='0x0000' bus='0x00' slot='0x04' function='0x0'/>
</hostdev>
```

So when a QAT vf resource is required, I call the Kubevirt method to get the device id of the assigned QAT and integrate it into libvirt domain.

```
// Append HostDev to libvirt DomXML if QAT is required
if util.IsQATVMI(vmi) {

    qatPCIAddresses := append([]string{}, c.QATDevices...)
    hostDevices, err := createHostDevicesFromPCIAddresses(qatPCIAddresses)
    if err != nil {
        log.Log.Reason(err).Error("Unable to parse PCI addresses")
    } else {
        domain.Spec.Devices.HostDevices = append(domain.Spec.Devices.HostDevices, hostDevices...)
    }
}

...
```

Example

Based on the Kubevirt official example VMI file, to make use of my QAT version, after building its docker images and uploading to docker, we should open the QAT feature gate through configmap.

```
apiVersion: v1
kind: ConfigMap
metadata:
    name: kubevirt-config
    namespace: kubevirt
    labels:
        kubevirt.io: ""
data:
    feature-gates: "QAT"
```

And the key point of QAT VMI:

```
...

spec:
   domain:
      devices:
         qats:
            - deviceName: qat.intel.com/generic
              name: qat1

...
```

Conclusion

The patch now has not been merged into the Kubevirt Project and is in review now. (PR: https://github.com/kubevirt/kubevirt/pull/2980)