Kubevirt设计文档

(2019版本)

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# 引言

## 背景

研发基于Kubernetes的虚拟机管理系统，复用Kubernetes的API设计规范，支持虚拟机生命周期管理。

* **规范性**：支持Kubernetes API规范；
* **兼容性**：支持Pod的反亲和等高级能力；
* **高可用**：支持高可用

## 编写目的

1. 确定软件的全部需求和软件组成模块，确定各模块的功能和用户接口。
2. 作为研发工作基础，并以此作为具体API设计的依据和基础。
3. 作为测试工作基础，用于制定相关测试计划等。

## 读者对象

本设计说明书的适用读者，一般为：设计及开发者和相关的测试人员。

## 文档书写约定

无。

## 术语定义

* Kubervirt-controller：将VM封装为Pod模型
* Libvirt：虚拟机生命周期管理工具，也是OpenStack用于管理虚拟机的工具。
* XML：XML是一种文件格式描述文件，是Libvirt的标准输入，不同的XML可以描述不同的虚拟机管理需求，并通过Libvirt进行实施。
* YAML：XML是一种文件格式描述文件，是Kubernetes的标准输入

# 运行环境

## 硬件环境

最少需要3台物理机，主机节点最低配置为4 CPU和8GB 内存，运行虚拟机的节点最低配置为4CPU和8GB内存

|  |  |  |
| --- | --- | --- |
| **服务器** | **最低配置** | **生产配置** |
| Kubevirt管理节点 | 基本环境：2CPU，4GB内存，40GB存储 | 4CPU，6GB内存，100GB存储 |
| 资源监测：1CPU，2GB内存，40GB存储 | 4CPU，6GB内存，100GB存储 |
| 日志分析：1CPU，2GB内存，40GB存储 | 4CPU，6GB内存，100GB存储 |
| Kubevirt  运行节点 | KVM虚拟机：4CPU，8GB内存 | 32CPU，64GB内存 |

## 软件环境

|  |  |  |
| --- | --- | --- |
| **分类** | **名称** | **版本** |
| 操作系统 | CentOS/RHEL | >7.2 |
| 容器 | Docker | >18.03 |
| 虚拟机 | KVM（libvirt） | > 2.10 |
| 集群 | Kubernetes | >1.14 |
| CNI网络适配 | Flannel | >0.10 |
| 网络方案 | Openvswitch | >2.10 |
| KV数据库 | Ectd | >3.2.24 |
| 资源监测 | Prometheus | >2.8 |
| 日志分析 | Fluentd(EFK) | >1.4 |

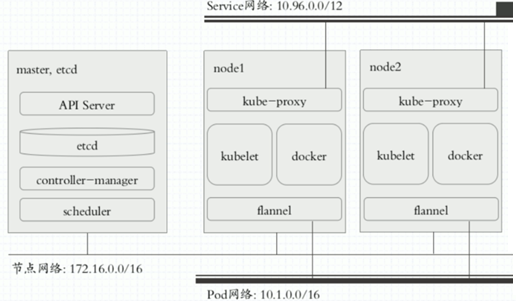
## 部署关系

|  |  |
| --- | --- |
| **分类** | **名称** |
|  | CentOS/RHEL |
| Docker |
| Flannel |
| Kubernetes |
| Openvswitch |
| Ectd |
| Prometheus |
| Kubevirt运行节点 | KVM（libvirt） |
| Docker |
| Flannel |
| Openvswitch |
| Prometheus |

# 部署架构

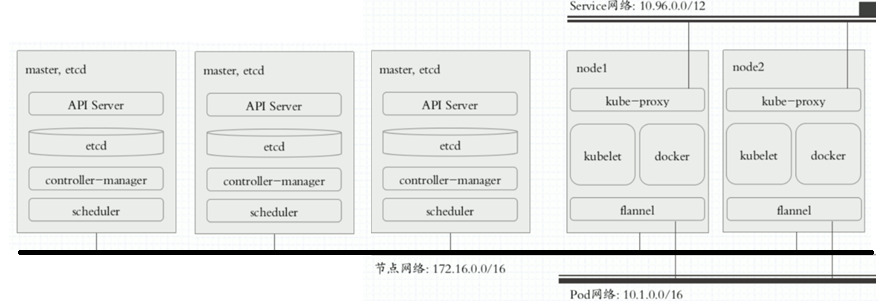
## 开发部署架构

最少部署需要3台物理机，一台主机节和两台运行节点



## 生产部署架构

最少部署需要5台物理机，三台主机节和两台运行节点



## 注意事项

其它具体资源需求的测算方法：

1. 如果存储是是SAN环境，做共享存储依赖gfs2, ocfs2,VMFS等集群文件系统，则Kubernetes Node集群运行节点最大规模为16台。因为超过16台规模会存在性能问题，如果采用glusterfs, ceph等分布式文件系统，则不存在该问题。
2. 每一个应用容器需要监测5个指标，故大约需要监测2500个指标，如果采用zabbix方案，其监测8000个指标会存在性能问题。此外，Zabbix使用Mysql数据库，但Mysql一个数据表大约超过100万数据会有性能问题。那么500个应用对应的该数据表一个月产生5万条数据，大概20个月会产生100万条记录。因此，需要按年对历史数据进行清理。

# 整体架构

## Kubernetes运行机理

  图1给出了Kubernetes的三个主要组件（计算资源视角），kube-apiserver、kube-scheduler和kubelet。其中，kube-apiserver和kube-scheduler运行在master结点，kubelet运行在salve节点。master与slave节点是一对多关系。

    首先看图1中红线部分，slave节点注册到kube-apiserver，使得kube-apiserver能获取全局资源的信息。其次看蓝线部分，当有容器进行发布时，kube-scheduler会从kube-apiserver获取全局slave节点状态和待部署的容器列表，然后输出调度决策，即“容器-salve节点”关系，并重新注册到kube-apiserver。最后看黑线部分，kubelet会基于当前主机标识，从kube-apiserver获取待部署的容器列表，并实施对其生命周期管理。同时，kubelet会周期性获取salve节点状态（CPU个数是否变化、磁盘是否有空间）和容器实际状态列表，重新注册给kube-apiserver。而kube-apiserver如果一定周期未能获取某个slave节点上kubelet的消息，则说明该slave节点失效。同样，如果容器因未知原因宕机，也可在周期时间内被kube-apiserver感知。

       总体而言，Kubernetes是一个事件驱动的体系结构，且组件之间（kube-apiserver、kube-scheduler和kubelet）通过Yaml格式进行通信交互。此外，Kubernetes运行的前提是Pod模型，也就是说，只有容器封装为Pod形式，kube-scheduler才会工作，并驱动kubelet工作。

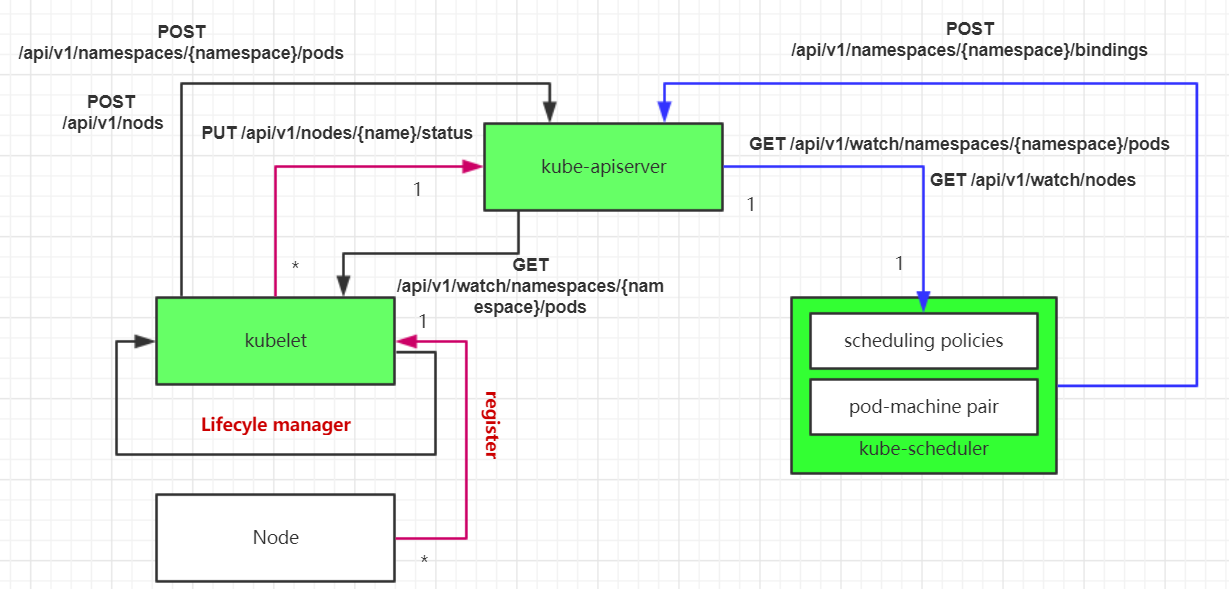


图1 Kubernetes运行机理

## 本项目设计

       因此，我们的设计原则依然是最大化复用Kubernetes能力，特别是它的轻量级和高可靠的优势，提供Kubernetes支持多种部署模型的方案（Pod、VM），我们的架构如图3所示（已经完成原型验证）。

       我们已经重构Kube-Scheduler，使其支持VM部署模型（应对Kubevirt面临的第1个问题）。同时，我们打算实现Virtlet用于管理VM的生命周期（对应于Kubelet管理容器的生命周期），Virtlet实现图1中两个接口：1. Get VMs接口，实现对VM的生命周期管理（应对Kubevirt面临的第2个问题）；2.实现Post status接口，将VM的实时状态汇报给kube-apiserver（应对Kubevirt面临的第3个问题）。

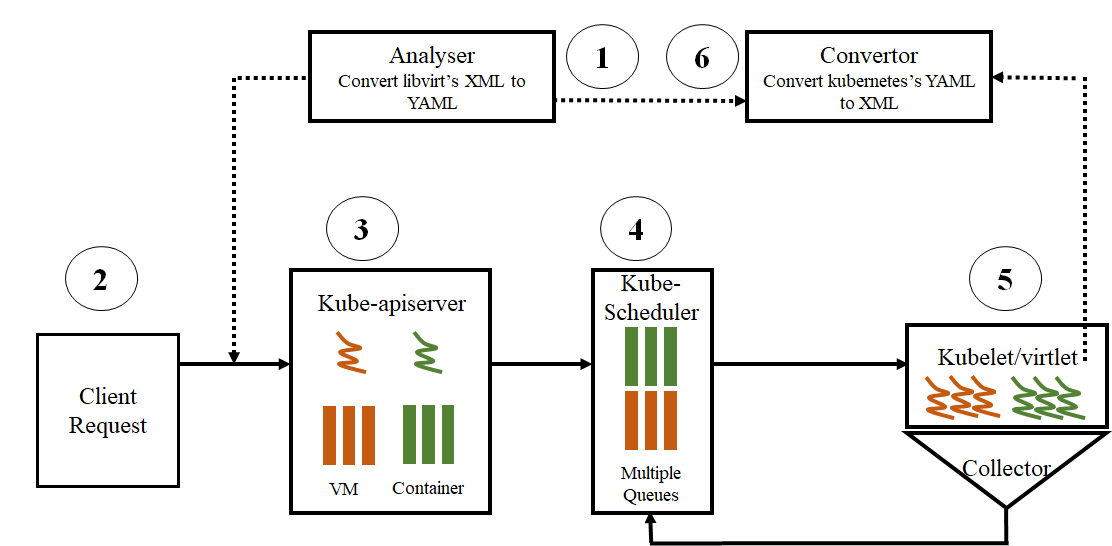


图3 Aladdin设计原理

     此外，我们也试图从理论层面回答，Aladdin是否能替换OpenStack？以及能替代OpenStack哪些功能？我们发现，OpenStack的主要功能包括计算、网络和存储资源管理能力，其中除了高级网络功能（如路由等），其它大部分能力均基于开源软件libvirt实现(<https://libvirt.org/>)，那么问题就转变成Aladdin方案对libvirt的支持程度。

      我们采用程序分析的方法，以libvirt提供的SDK作为输入，还原出libvirt可以支持的所有xml，我们发现其与官方文档一致（<https://libvirt.org/format.html>）。如图3所示第1步骤，我们将其转化为yaml格式，供前端调用，具体格式参见附件1。

     用户请求该参数（参见附件1），并指定相关操作（参见附件2）后，Virtctl会将其转化为xml格式，并根据用户指定的操作(参见附件2），执行 virsh [command] [xml]进行VM生命周期管理。

    因此，从理论上，OpenStack基于libvirt从事所有管理功能，本方法均能支持。

# Kube-Controller设计

Kubernetes是主流的容器管理平台，Pod是其基本管理单元，也是高级属性，如亲和，反亲和的基础。在本文，Controller的作用是将Kind为VirtualMachine的Yaml/JSON转化为Kind为Pod的容器，用以指导整个生命周期管理。



整个流程如上图所示，首先是监听器Listener，用于监听VirtualMachine资源，监听该资源只存在两种可能，一种是ADDED，一种是DELETE状态。

ADDED状态：新建Pod对象（注意这个对象会在Scheduler后被删除，在此处的目的是复用Kubernetes已有调度的核心和高级能力，如亲和等）。对于一个Pod对象，有三个关键的属性必须要设置：

* Metadata的Name：我们的规则是放在“default”下，建议一个vm2pod\_开头，并拼接VirtualMachine的Metadata中Name字段；
* Image属性：这里指定默认值fake
* Resource属性：将VirtualMachine的资源需求相应的添加。注意：这个属性非常关键，否则可能引起调度器超分资源，引起宕机事故。

在拼接完Pod对象后，则执行创建Pod操作，该操作可能出现两种结果，一种是成功，则程序执行完成。否则，执行删除Pod操作。

DELETED状态：如果是Delete操作，则首先执行查询操作，看看该VM及其对应的Pod是否存在，如果不存在，则完成执行流程。如果存在，则删除。

# Kubevirt-Executor设计

|  |
| --- |
|  |

图1 Kubevirt Executor架构设计

上图为Kubevirt Executor的架构设计图。由两个组件Virtctl和Virtlet组成。Virtctl主要实现了包括虚拟机、镜像、快照、存储和网络的生命周期管理。 Virtctl主要包括以下功能模块：

Listener：监听器，用于监听Kubernetes API事件，当Client端调用请求触发事件时能够及时响应；

Unpacker：处理器，用于分析调用请求类型，并处理调用请求中的数据；

Configurations: 程序的配置文件，维护系统支持的请求列表；

Invoker：执行器，用于执行本地命令或调用Libvirt API；

Write-back: 结果写回器，将XML结果转换成Json格式并写回API服务器。

Virtlet主要负责周期性监测虚拟机状态与宿主机资源，并报告给API服务器以维护集群状态的正确性。Virtlet主要包括以下功能模块：

Event Handler: 虚拟层事件的处理器，通过Libvirt Event Loop监听虚拟层的事件（如虚拟机后台删除），当事件被触发时，通过消息推送机制汇报给Virtlet，保障系统一致性；

Host Cycler: 宿主机资源的监听器，通过系统命令周期性采集宿主机可用资源，并将结果推送给Virtlet；

Daemon: 守护进程，后台运行的Virtlet进程；

Reporter: 状态报告器，将状态以Json格式汇报给API服务器。

# API模式的设计

## 组成要素

|  |
| --- |
| apiVersion: cloudplus.io/v1alpha3  kind: VirtualMachine  metadata:  name: testvmi-nocloud  spec:  domain: {}  lifecycle:  command: {}  image: string  nodeName: string |

上表为虚拟机生命周期管理的Yaml格式。根据Kubernetes规范，Spec下可以自定义。因此，生命生命周期管理主要集中在Spec下，包括：

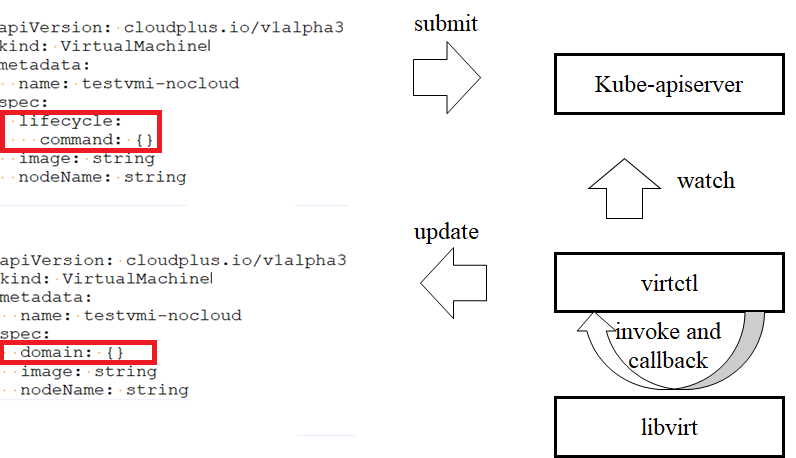
* image：用于标识虚拟机是从哪个镜像出来的
* nodeName：用于表示虚拟机部署在哪台物理机上
* domain: 运行时虚拟机可使用libvirt的virsh dumpxml命令查询其具体描述。由于虚拟机描述为xml格式，需要将其转化为yaml格式，见附件2和附件3。
* lifecycle：用于表示对虚拟机进行怎么样的操作，command为具体操作名或者其别名。

## 主要约束

1. 通过kubectl get vm [name] –o yaml查看虚拟机状态，如果有lifecycle字段，说明虚拟机尚未完成相关处理
2. Image字段初始化后禁止修改
3. nodeName是由调度器决定的，该值为空说明虚拟机无法运行在任何物理机上
4. domain字段与libvirt的<domain.xml>一一对应
5. lifecycle字段不能出现多条command，如果出现多条，仅第一条生效

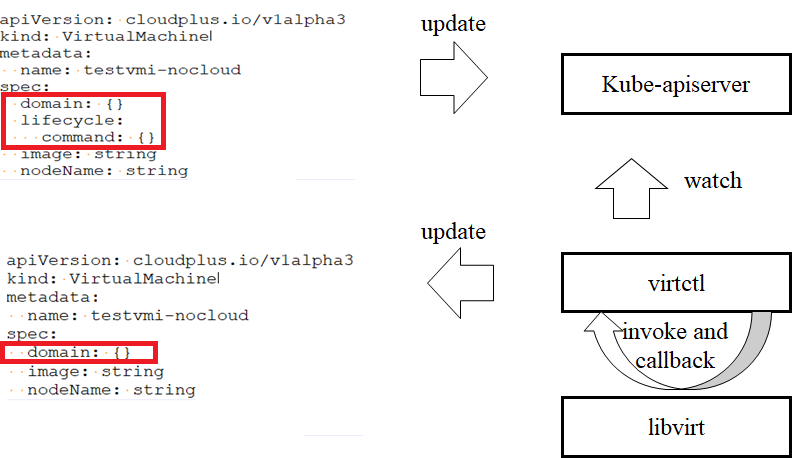
### 虚拟机创建阶段

在虚拟机创建和启动阶段，domain信息为空，其它三个字段均由数值，当lifecycle执行生效后，删除lifecycle字段，并填充domain字段，如图所示。



### 虚拟机热插拔设备阶段

该阶段，四个字段均有数值，当lifecycle执行生效后，删除lifecycle字段，更新相应的domain字段，如图所示。



### Virtctl失效恢复过程

Virtctl在失效恢复过，会重新获取所有的VM列表，此时应检查VM的属性中是否包含lifecycle字段。如果未包含，则说明该虚拟机已经被处理过，无需重新处理。

# Lifecycle的设计

对libvirt的支持，本文支持附件1中所有指令，如下表所示，其对应的是virsh blockresize [domain] [path] –size [size]指令

|  |
| --- |
| {  "blockresize": {  "domain": "string",  "path": "string",  "\_\_size": "string"  }  } |

因此，该JSON（或YAML）的Key表示指令名，value是参数列表。注意，这里的参数有两种情况需要考虑：

* 参数的key不是以下划线开头，说明该参数可直接输入，如domain和path
* 参数的key是以下划线开头，说明需要显示说明参数，如—size [size]

# 附件1 Libvirt常用指令

Virsh

attach-device attach device from an XML file

attach-disk attach disk device

attach-interface attach network interface

autostart autostart a domain

blkdeviotune Set or query a block device I/O tuning parameters.

blkiotune Get or set blkio parameters

blockcommit Start a block commit operation.

blockcopy Start a block copy operation.

blockjob Manage active block operations

blockpull Populate a disk from its backing image.

blockresize Resize block device of domain.

change-media Change media of CD or floppy drive

cpu-stats show domain cpu statistics

create create a domain from an XML file

define define (but don't start) a domain from an XML file

desc show or set domain's description or title

destroy destroy (stop) a domain

detach-device detach device from an XML file

detach-device-alias detach device from an alias

detach-disk detach disk device

detach-interface detach network interface

domfsfreeze Freeze domain's mounted filesystems.

domfsthaw Thaw domain's mounted filesystems.

domfsinfo Get information of domain's mounted filesystems.

domfstrim Invoke fstrim on domain's mounted filesystems.

domid convert a domain name or UUID to domain id

domif-setlink set link state of a virtual interface

domiftune get/set parameters of a virtual interface

domjobabort abort active domain job

domjobinfo domain job information

domname convert a domain id or UUID to domain name

domrename rename a domain

dompmsuspend suspend a domain gracefully using power management functions

dompmwakeup wakeup a domain from pmsuspended state

domuuid convert a domain name or id to domain UUID

domxml-from-native Convert native config to domain XML

domxml-to-native Convert domain XML to native config

dump dump the core of a domain to a file for analysis

dumpxml domain information in XML

edit edit XML configuration for a domain

inject-nmi Inject NMI to the guest

iothreadinfo view domain IOThreads

iothreadpin control domain IOThread affinity

iothreadadd add an IOThread to the guest domain

iothreaddel delete an IOThread from the guest domain

send-key Send keycodes to the guest

send-process-signal Send signals to processes

lxc-enter-namespace LXC Guest Enter Namespace

managedsave managed save of a domain state

managedsave-remove Remove managed save of a domain

managedsave-edit edit XML for a domain's managed save state file

managedsave-dumpxml Domain information of managed save state file in XML

managedsave-define redefine the XML for a domain's managed save state file

memtune Get or set memory parameters

metadata show or set domain's custom XML metadata

migrate migrate domain to another host

migrate-setmaxdowntime set maximum tolerable downtime

migrate-getmaxdowntime get maximum tolerable downtime

migrate-compcache get/set compression cache size

migrate-setspeed Set the maximum migration bandwidth

migrate-getspeed Get the maximum migration bandwidth

migrate-postcopy Switch running migration from pre-copy to post-copy

numatune Get or set numa parameters

qemu-attach QEMU Attach

qemu-monitor-command QEMU Monitor Command

qemu-agent-command QEMU Guest Agent Command

reboot reboot a domain

reset reset a domain

restore restore a domain from a saved state in a file

resume resume a domain

save save a domain state to a file

save-image-define redefine the XML for a domain's saved state file

save-image-dumpxml saved state domain information in XML

save-image-edit edit XML for a domain's saved state file

schedinfo show/set scheduler parameters

screenshot take a screenshot of a current domain console and store it into a file

set-lifecycle-action change lifecycle actions

set-user-password set the user password inside the domain

setmaxmem change maximum memory limit

setmem change memory allocation

setvcpus change number of virtual CPUs

shutdown gracefully shutdown a domain

start start a (previously defined) inactive domain

suspend suspend a domain

ttyconsole tty console

undefine undefine a domain

update-device update device from an XML file

vcpucount domain vcpu counts

vcpuinfo detailed domain vcpu information

vcpupin control or query domain vcpu affinity

emulatorpin control or query domain emulator affinity

guestvcpus query or modify state of vcpu in the guest (via agent)

setvcpu attach/detach vcpu or groups of threads

domblkerror Show errors on block devices

domblkinfo domain block device size information

domblkstat get device block stats for a domain

domcontrol domain control interface state

domif-getlink get link state of a virtual interface

domifaddr Get network interfaces' addresses for a running domain

domifstat get network interface stats for a domain

dominfo domain information

dommemstat get memory statistics for a domain

domstate domain state

domtime domain time

iface-bridge create a bridge device and attach an existing network device to it

iface-define define an inactive persistent physical host interface or modify an existing persistent one from an XML file

iface-destroy destroy a physical host interface (disable it / "if-down")

iface-dumpxml interface information in XML

iface-edit edit XML configuration for a physical host interface

iface-mac convert an interface name to interface MAC address

iface-name convert an interface MAC address to interface name

iface-start start a physical host interface (enable it / "if-up")

iface-unbridge undefine a bridge device after detaching its slave device

iface-undefine undefine a physical host interface (remove it from configuration)

nwfilter-define define or update a network filter from an XML file

nwfilter-dumpxml network filter information in XML

nwfilter-edit edit XML configuration for a network filter

nwfilter-undefine undefine a network filter

nwfilter-binding-create create a network filter binding from an XML file

nwfilter-binding-delete delete a network filter binding

nwfilter-binding-dumpxml network filter information in XML

net-autostart autostart a network

net-create create a network from an XML file

net-define define an inactive persistent virtual network or modify an existing persistent one from an XML file

net-destroy destroy (stop) a network

net-dhcp-leases print lease info for a given network

net-dumpxml network information in XML

net-edit edit XML configuration for a network

net-info network information

net-name convert a network UUID to network name

net-start start a (previously defined) inactive network

net-undefine undefine a persistent network

net-update update parts of an existing network's configuration

net-uuid convert a network name to network UUID

nodedev-create create a device defined by an XML file on the node

nodedev-destroy destroy (stop) a device on the node

nodedev-detach detach node device from its device driver

nodedev-dumpxml node device details in XML

nodedev-reattach reattach node device to its device driver

nodedev-reset reset node device

secret-define define or modify a secret from an XML file

secret-dumpxml secret attributes in XML

secret-get-value Output a secret value

secret-set-value set a secret value

secret-undefine undefine a secret

snapshot-create Create a snapshot from XML

snapshot-create-as Create a snapshot from a set of args

snapshot-current Get or set the current snapshot

snapshot-delete Delete a domain snapshot

snapshot-dumpxml Dump XML for a domain snapshot

snapshot-edit edit XML for a snapshot

snapshot-info snapshot information

snapshot-parent Get the name of the parent of a snapshot

snapshot-revert Revert a domain to a snapshot

find-storage-pool-sources-as find potential storage pool sources

find-storage-pool-sources discover potential storage pool sources

pool-autostart autostart a pool

pool-build build a pool

pool-create-as create a pool from a set of args

pool-create create a pool from an XML file

pool-define-as define a pool from a set of args

pool-define define an inactive persistent storage pool or modify an existing persistent one from an XML file

pool-delete delete a pool

pool-destroy destroy (stop) a pool

pool-dumpxml pool information in XML

pool-edit edit XML configuration for a storage pool

pool-info storage pool information

pool-name convert a pool UUID to pool name

pool-refresh refresh a pool

pool-start start a (previously defined) inactive pool

pool-undefine undefine an inactive pool

pool-uuid convert a pool name to pool UUID

vol-clone clone a volume.

vol-create-as create a volume from a set of args

vol-create create a vol from an XML file

vol-create-from create a vol, using another volume as input

vol-delete delete a vol

vol-download download volume contents to a file

vol-dumpxml vol information in XML

vol-info storage vol information

vol-key returns the volume key for a given volume name or path

vol-name returns the volume name for a given volume key or path

vol-path returns the volume path for a given volume name or key

vol-pool returns the storage pool for a given volume key or path

vol-resize resize a vol

vol-upload upload file contents to a volume

vol-wipe wipe a vol

virt-install Create a new virtual machine from specified install media

virt-clone Duplicate a virtual machine, changing all the unique host side configuration like MAC address, name, etc.

# 附件2 Libvirt XML

[Domain.xml(aka VirtualMachine)](https://libvirt.org/formatdomain.html)

<?xml version="1.0" encoding="utf-8"?>

<domain type="string" id="string">

<name>string</name>

<uuid>string</uuid>

<genid>string</genid>

<title>string</title>

<description>string</description>

<metadata/>

<maxMemory unit="string" slots="string">string</maxMemory>

<memory unit="string" dumpCore="string">string</memory>

<currentMemory unit="string">string</currentMemory>

<blkiotune>

<weight>string</weight>

<device>

<path>string</path>

<weight>string</weight>

<read\_iops\_sec>string</read\_iops\_sec>

<write\_iops\_sec>string</write\_iops\_sec>

<read\_bytes\_sec>string</read\_bytes\_sec>

<write\_bytes\_sec>string</write\_bytes\_sec>

</device>

<device>

<path>string</path>

<weight>string</weight>

<read\_iops\_sec>string</read\_iops\_sec>

<write\_iops\_sec>string</write\_iops\_sec>

<read\_bytes\_sec>string</read\_bytes\_sec>

<write\_bytes\_sec>string</write\_bytes\_sec>

</device>

</blkiotune>

<memtune>

<hard\_limit unit="string">string</hard\_limit>

<soft\_limit unit="string">string</soft\_limit>

<min\_guarantee unit="string">string</min\_guarantee>

<swap\_hard\_limit unit="string">string</swap\_hard\_limit>

</memtune>

<memoryBacking>

<hugepages>

<page size="string" unit="string" nodeset="string"/>

<page size="string" unit="string" nodeset="string"/>

</hugepages>

<nosharepages/>

<locked/>

<source type="string"/>

<access mode="string"/>

<allocation mode="string"/>

<discard/>

</memoryBacking>

<vcpu placement="string" cpuset="string" current="string">string</vcpu>

<vcpus>

<vcpu id="string" enabled="string" hotpluggable="string" order="string"/>

<vcpu id="string" enabled="string" hotpluggable="string" order="string"/>

</vcpus>

<iothreads>string</iothreads>

<iothreadids>

<iothread id="string"/>

<iothread id="string"/>

</iothreadids>

<cputune>

<shares>string</shares>

<period>string</period>

<quota>string</quota>

<global\_period>string</global\_period>

<global\_quota>string</global\_quota>

<emulator\_period>string</emulator\_period>

<emulator\_quota>string</emulator\_quota>

<iothread\_period>string</iothread\_period>

<iothread\_quota>string</iothread\_quota>

<vcpupin vcpu="string" cpuset="string"/>

<vcpupin vcpu="string" cpuset="string"/>

<emulatorpin cpuset="string"/>

<iothreadpin iothread="string" cpuset="string"/>

<iothreadpin iothread="string" cpuset="string"/>

<vcpusched vcpus="string" scheduler="string" priority="string"/>

<vcpusched vcpus="string" scheduler="string" priority="string"/>

<iothreadsched iothreads="string" scheduler="string" priority="string"/>

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<cachetune vcpus="string">

<cache id="string" level="string" type="string" size="string" unit="string"/>

<cache id="string" level="string" type="string" size="string" unit="string"/>

<monitor level="string" vcpus="string"/>

<monitor level="string" vcpus="string"/>

</cachetune>

<cachetune vcpus="string">

<cache id="string" level="string" type="string" size="string" unit="string"/>

<cache id="string" level="string" type="string" size="string" unit="string"/>

<monitor level="string" vcpus="string"/>

<monitor level="string" vcpus="string"/>

</cachetune>

<memorytune vcpus="string">

<node id="string" bandwidth="string"/>

<node id="string" bandwidth="string"/>

</memorytune>

<memorytune vcpus="string">

<node id="string" bandwidth="string"/>

<node id="string" bandwidth="string"/>

</memorytune>

</cputune>

<numatune>

<memory mode="string" nodeset="string" placement="string"/>

<memnode cellid="string" mode="string" nodeset="string"/>

<memnode cellid="string" mode="string" nodeset="string"/>

</numatune>

<resource>

<partition>string</partition>

</resource>

<sysinfo type="string">

<bios>

<entry name="string">string</entry>

<entry name="string">string</entry>

</bios>

<system>

<entry name="string">string</entry>

<entry name="string">string</entry>

</system>

<baseBoard>

<entry name="string">string</entry>

<entry name="string">string</entry>

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<entry name="string">string</entry>

</baseBoard>

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</memory>

<memory>

<entry name="string">string</entry>

<entry name="string">string</entry>

</memory>

<oemStrings>

<entry>string</entry>

</oemStrings>

</sysinfo>

<bootloader>string</bootloader>

<bootloader\_args>string</bootloader\_args>

<os>

<type arch="string" machine="string">string</type>

<init>string</init>

<initarg>string</initarg>

<initenv name="string">string</initenv>

<initenv name="string">string</initenv>

<initdir>string</initdir>

<inituser>string</inituser>

<initgroup>string</initgroup>

<loader>strin readonly='string' secure='string' type='string'&gt;</loader>

<nvram>strin template='string'&gt;</nvram>

<kernel>string</kernel>

<initrd>string</initrd>

<cmdline>string</cmdline>

<dtb>string</dtb>

<acpi>

<table type="string">string</table>

<table type="string">string</table>

</acpi>

<boot dev="string"/>

<boot dev="string"/>

<bootmenu enable="string" timeout="string"/>

<bios useserial="string" rebootTimeout="string"/>

<smbios mode="string"/>

</os>

<idmap>

<uid start="string" target="string" count="string"/>

<uid start="string" target="string" count="string"/>

<gid start="string" target="string" count="string"/>

<gid start="string" target="string" count="string"/>

</idmap>

<features>

<pae/>

<acpi/>

<apic eoi="string"/>

<hap state="string"/>

<viridian/>

<privnet/>

<hyperv>

<relaxed state="string"/>

<vapic state="string"/>

<spinlocks retries="string"/>

<vpindex state="string"/>

<runtime state="string"/>

<synic state="string"/>

<stimer state="string"/>

<reset state="string"/>

<vendor\_id value="string"/>

<frequencies state="string"/>

<reenlightenment state="string"/>

<tlbflush state="string"/>

<ipi state="string"/>

<evmcs state="string"/>

</hyperv>

<kvm>

<hidden state="string"/>

</kvm>

<pvspinlock state="string"/>

<pmu state="string"/>

<vmport state="string"/>

<gic version="string"/>

<smm state="string">

<tseg unit="string">string</tseg>

</smm>

<ioapic driver="string"/>

<hpt resizing="string">

<maxpagesize unit="string">string</maxpagesize>

</hpt>

<htm state="string"/>

<nested-hv state="string"/>

<capabilities policy="string">

<audit\_control state="string"/>

<audit\_write state="string"/>

<block\_suspend state="string"/>

<chown state="string"/>

<dac\_override state="string"/>

<dac\_read\_Search state="string"/>

<fowner state="string"/>

<fsetid state="string"/>

<ipc\_lock state="string"/>

<ipc\_owner state="string"/>

<kill state="string"/>

<lease state="string"/>

<linux\_immutable state="string"/>

<mac\_admin state="string"/>

<mac\_override state="string"/>

<mknod state="string"/>

<net\_admin state="string"/>

<net\_bind\_service state="string"/>

<net\_broadcast state="string"/>

<net\_raw state="string"/>

<setgid state="string"/>

<setfcap state="string"/>

<setpcap state="string"/>

<setuid state="string"/>

<sys\_admin state="string"/>

<sys\_boot state="string"/>

<sys\_chroot state="string"/>

<sys\_module state="string"/>

<sys\_nice state="string"/>

<sys\_pacct state="string"/>

<sys\_ptrace state="string"/>

<sys\_rawio state="string"/>

<sys\_resource state="string"/>

<sys\_time state="string"/>

<sys\_tty\_config state="string"/>

<syslog state="string"/>

<wake\_alarm state="string"/>

</capabilities>

<vmcoreinfo state="string"/>

<msrs unknown="string"/>

</features>

<cpu match="string" mode="string" check="string">

<model fallback="string" vendor\_id="string">string</model>

<vendor>string</vendor>

<topology sockets="string" cores="string" threads="string"/>

<cache level="string" mode="string"/>

<feature policy="string" name="string"/>

<feature policy="string" name="string"/>

<numa>

<cell id="string" cpus="string" memory="string" unit="string" memAccess="string" discard="string">

<distances>

<sibling id="string" value="string"/>

<sibling id="string" value="string"/>

</distances>

</cell>

<cell id="string" cpus="string" memory="string" unit="string" memAccess="string" discard="string">

<distances>

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<sibling id="string" value="string"/>

</distances>

</cell>

</numa>

</cpu>

<clock offset="string" basis="string" adjustment="string" timezone="string">

<timer name="string" track="string" tickpolicy="string" frequency="string" mode="string" present="string">

<catchup threshold="string" slew="string" limit="string"/>

</timer>

<timer name="string" track="string" tickpolicy="string" frequency="string" mode="string" present="string">

<catchup threshold="string" slew="string" limit="string"/>

</timer>

</clock>

<on\_poweroff>string</on\_poweroff>

<on\_reboot>string</on\_reboot>

<on\_crash>string</on\_crash>

<pm>

<suspend-to-mem enabled="string"/>

<suspend-to-disk enabled="string"/>

</pm>

<perf>

<event name="string" enabled="string"/>

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</perf>

<devices>

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<disk device="string" rawio="string" sgio="string" snapshot="string" model="string">

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<auth username="string">

<secret type="string" usage="string" uuid="string"/>

</auth>

<source startupPolicy="string" index="string">

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<reservations enabled="string" managed="string">

<source/>

</reservations>

</source>

<backingStore index="string">

<format type="string"/>

<source startupPolicy="string" index="string">

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<reservations enabled="string" managed="string">

<source/>

</reservations>

</source>

</backingStore>

<geometry cyls="string" heads="string" secs="string" trans="string"/>

<blockio logical\_block\_size="string" physical\_block\_size="string"/>

<mirror job="string" ready="string">

<format type="string"/>

<source startupPolicy="string" index="string">

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<reservations enabled="string" managed="string">

<source/>

</reservations>

</source>

</mirror>

<target dev="string" bus="string" tray="string" removable="string"/>

<iotune>

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<write\_iops\_sec\_max\_length>string</write\_iops\_sec\_max\_length>

<size\_iops\_sec>string</size\_iops\_sec>

<group\_name>string</group\_name>

</iotune>

<readonly/>

<shareable/>

<transient/>

<serial>string</serial>

<wwn>string</wwn>

<vendor>string</vendor>

<product>string</product>

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<boot order="string" loadparm="string"/>

<alias name="string"/>

<address/>

</disk>

<disk device="string" rawio="string" sgio="string" snapshot="string" model="string">

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<auth username="string">

<secret type="string" usage="string" uuid="string"/>

</auth>

<source startupPolicy="string" index="string">

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<reservations enabled="string" managed="string">

<source/>

</reservations>

</source>

<backingStore index="string">

<format type="string"/>

<source startupPolicy="string" index="string">

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<reservations enabled="string" managed="string">

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</reservations>

</source>

</backingStore>

<geometry cyls="string" heads="string" secs="string" trans="string"/>

<blockio logical\_block\_size="string" physical\_block\_size="string"/>

<mirror job="string" ready="string">

<format type="string"/>

<source startupPolicy="string" index="string">

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<reservations enabled="string" managed="string">

<source/>

</reservations>

</source>

</mirror>

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<iotune>

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<size\_iops\_sec>string</size\_iops\_sec>

<group\_name>string</group\_name>

</iotune>

<readonly/>

<shareable/>

<transient/>

<serial>string</serial>

<wwn>string</wwn>

<vendor>string</vendor>

<product>string</product>

<encryption format="string">

<secret type="string" usage="string" uuid="string"/>

</encryption>

<boot order="string" loadparm="string"/>

<alias name="string"/>

<address/>

</disk>

<controller type="string" index="string" model="string">

<driver queues="string" cmd\_per\_lun="string" max\_sectors="string" ioeventfd="string" iothread="string" iommu="string" ats="string"/>

<alias name="string"/>

<address/>

</controller>

<controller type="string" index="string" model="string">

<driver queues="string" cmd\_per\_lun="string" max\_sectors="string" ioeventfd="string" iothread="string" iommu="string" ats="string"/>

<alias name="string"/>

<address/>

</controller>

<lease>

<lockspace>string</lockspace>

<key>string</key>

<target path="string" offset="string"/>

</lease>

<lease>

<lockspace>string</lockspace>

<key>string</key>

<target path="string" offset="string"/>

</lease>

<filesystem accessmode="string" model="string">

<driver type="string" format="string" name="string" wrpolicy="string" iommu="string" ats="string"/>

<source/>

<target dir="string"/>

<readonly/>

<space\_hard\_limit unit="string">string</space\_hard\_limit>

<space\_soft\_limit unit="string">string</space\_soft\_limit>

<alias name="string"/>

<address/>

</filesystem>

<filesystem accessmode="string" model="string">

<driver type="string" format="string" name="string" wrpolicy="string" iommu="string" ats="string"/>

<source/>

<target dir="string"/>

<readonly/>

<space\_hard\_limit unit="string">string</space\_hard\_limit>

<space\_soft\_limit unit="string">string</space\_soft\_limit>

<alias name="string"/>

<address/>

</filesystem>

<interface managed="string" trustGuestRxFilters="string">

<mac address="string"/>

<source/>

<boot order="string" loadparm="string"/>

<vlan trunk="string">

<tag id="string" nativeMode="string"/>

<tag id="string" nativeMode="string"/>

</vlan>

<virtualport>

<parameters/>

</virtualport>

<ip address="string" family="string" prefix="string" peer="string"/>

<ip address="string" family="string" prefix="string" peer="string"/>

<route family="string" address="string" netmask="string" prefix="string" gateway="string" metric="string"/>

<route family="string" address="string" netmask="string" prefix="string" gateway="string" metric="string"/>

<script path="string"/>

<target dev="string"/>

<guest dev="string" actual="string"/>

<model type="string"/>

<driver name="string" txmode="string" ioeventfd="string" event\_idx="string" queues="string" rx\_queue\_size="string" tx\_queue\_size="string" iommu="string" ats="string">

<host csum="string" gso="string" tso4="string" tso6="string" ecn="string" ufo="string" mrg\_rxbuf="string"/>

<guest csum="string" tso4="string" tso6="string" ecn="string" ufo="string"/>

</driver>

<backend tap="string" vhost="string"/>

<filterref filter="string">

<parameter name="string" value="string"/>

<parameter name="string" value="string"/>

</filterref>

<tune>

<sndbuf>string</sndbuf>

</tune>

<link state="string"/>

<mtu size="string"/>

<bandwidth>

<inbound average="string" peak="string" burst="string" floor="string"/>

<outbound average="string" peak="string" burst="string" floor="string"/>

</bandwidth>

<coalesce>

<rx>

<frames max="string"/>

</rx>

</coalesce>

<rom bar="string" file="string" enabled="string"/>

<alias name="string"/>

<address/>

</interface>

<interface managed="string" trustGuestRxFilters="string">

<mac address="string"/>

<source/>

<boot order="string" loadparm="string"/>

<vlan trunk="string">

<tag id="string" nativeMode="string"/>

<tag id="string" nativeMode="string"/>

</vlan>

<virtualport>

<parameters/>

</virtualport>

<ip address="string" family="string" prefix="string" peer="string"/>

<ip address="string" family="string" prefix="string" peer="string"/>

<route family="string" address="string" netmask="string" prefix="string" gateway="string" metric="string"/>

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<backend tap="string" vhost="string"/>

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<sndbuf>string</sndbuf>

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<inbound average="string" peak="string" burst="string" floor="string"/>

<outbound average="string" peak="string" burst="string" floor="string"/>

</bandwidth>

<coalesce>

<rx>

<frames max="string"/>

</rx>

</coalesce>

<rom bar="string" file="string" enabled="string"/>

<alias name="string"/>

<address/>

</interface>

<smartcard>

<source/>

<protocol type="string"/>

<certificate>string</certificate>

<certificate>string</certificate>

<database>string</database>

<alias name="string"/>

<address/>

</smartcard>

<smartcard>

<source/>

<protocol type="string"/>

<certificate>string</certificate>

<certificate>string</certificate>

<database>string</database>

<alias name="string"/>

<address/>

</smartcard>

<serial>

<source/>

<protocol type="string"/>

<target type="string" port="string">

<model name="string"/>

</target>

<log file="string" append="string"/>

<alias name="string"/>

<address/>

</serial>

<serial>

<source/>

<protocol type="string"/>

<target type="string" port="string">

<model name="string"/>

</target>

<log file="string" append="string"/>

<alias name="string"/>

<address/>

</serial>

<parallel>

<source/>

<protocol type="string"/>

<target type="string" port="string"/>

<log file="string" append="string"/>

<alias name="string"/>

<address/>

</parallel>

<parallel>

<source/>

<protocol type="string"/>

<target type="string" port="string"/>

<log file="string" append="string"/>

<alias name="string"/>

<address/>

</parallel>

<console tty="string">

<source/>

<protocol type="string"/>

<target type="string" port="string"/>

<log file="string" append="string"/>

<alias name="string"/>

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# 附件3 Kubernetes YAML

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