VDUSE – vDPA Device in Userspace

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Agenda

- Background
- Design & Implementation
- Status & Future Work

Background

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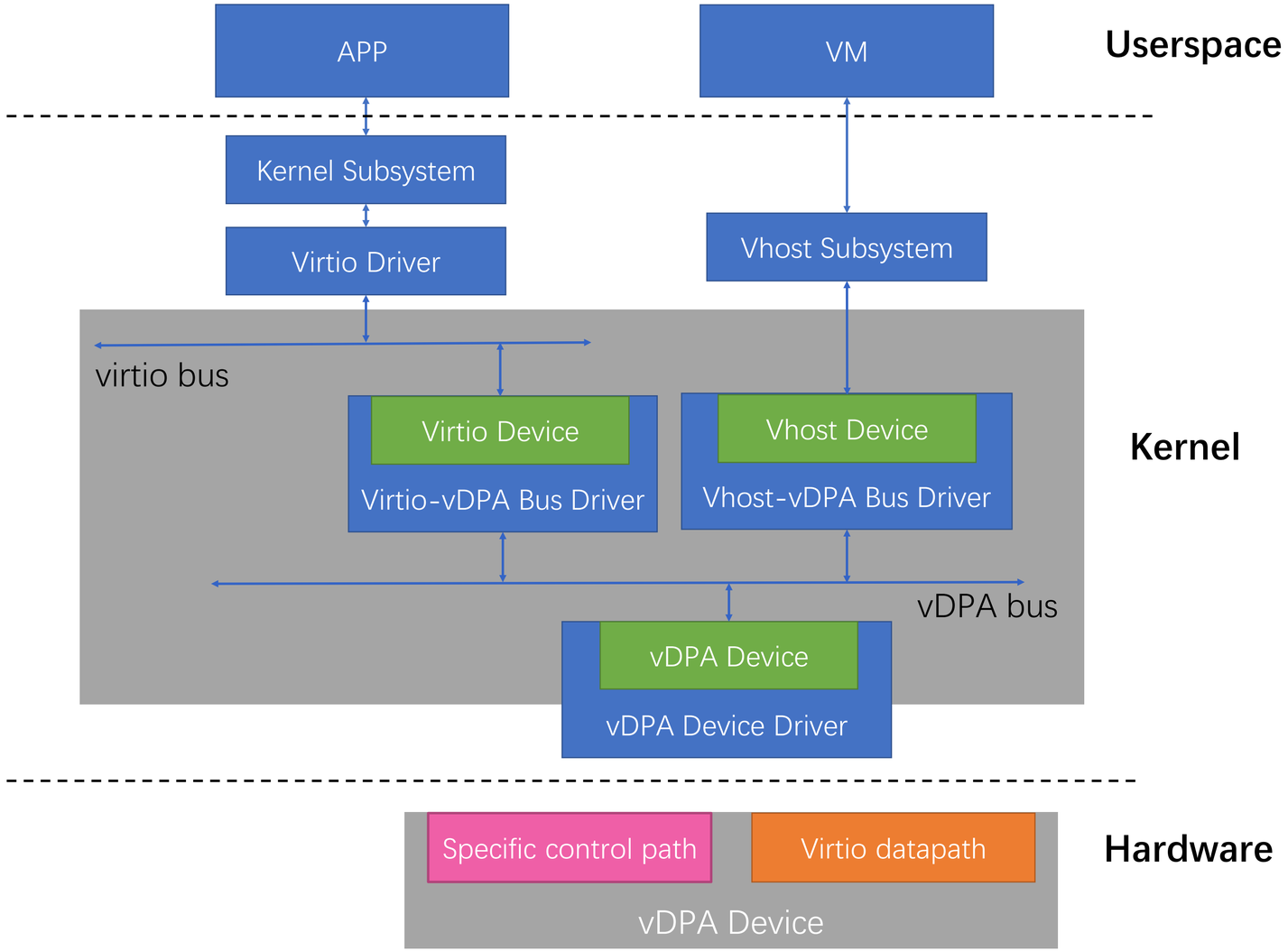
vDPA Overview

vDPA
- Virtio Data Path Acceleration

vDPA Device
- Virtio compatible datapath
- Vendor specific control path

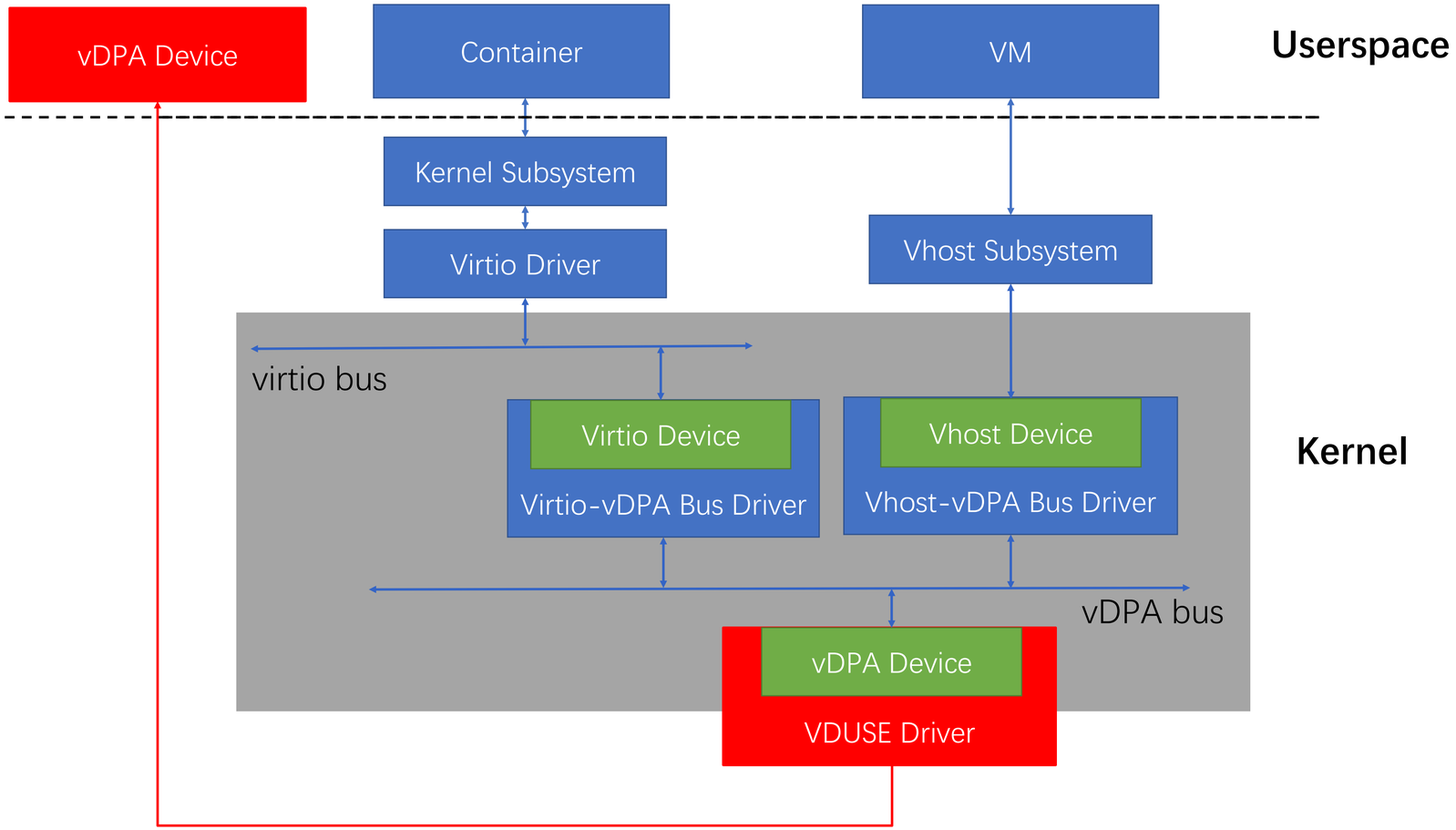
vDPA Kernel Subsystem
- vDPA Bus
- vDPA Device (Abstraction)
- vDPA Bus Driver, including virtio-vDPA and vhost-vDPA



What is VDUSE

Based on vDPA subsystem, a framework to implement userspace vDPA Device

Provide an unified userspace approach for both VM and container workloads



Why Userspace

DEVELOPMENT LIFECYCLE

MAINTAINABILITY

FLEXIBILITY

Design & Implementation

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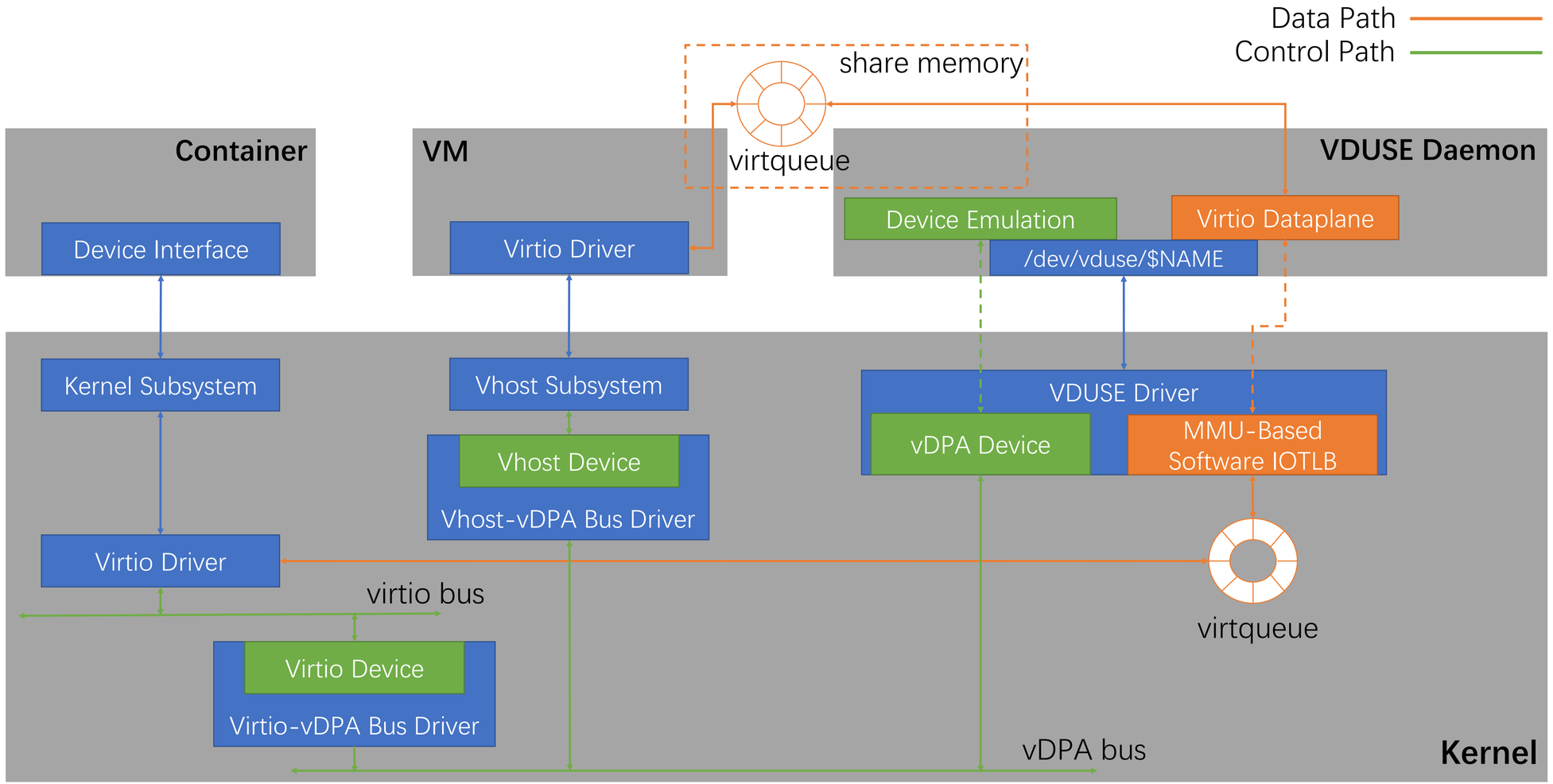
Architecture Overview



Control Path

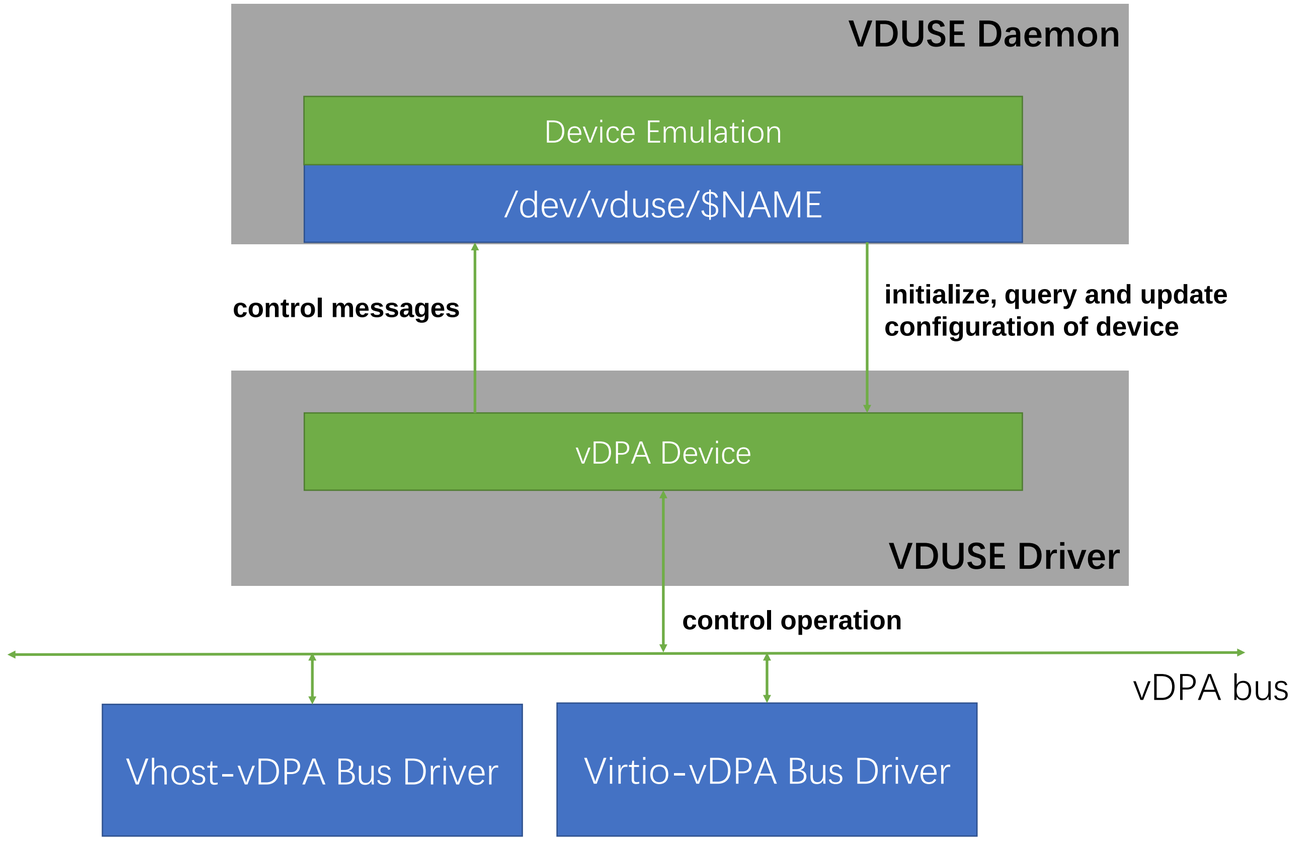
Mostly handled in kernel

Some ioctls is introduced to initialize, query and update configuration of device, e.g.

- Initialize virtio features
- Update configuration space
- Query virtqueue information

Message mechanism is used to forward some control messages from vDPA Bus Driver to userspace, e.g.

- Set device status
- Get virtqueue state



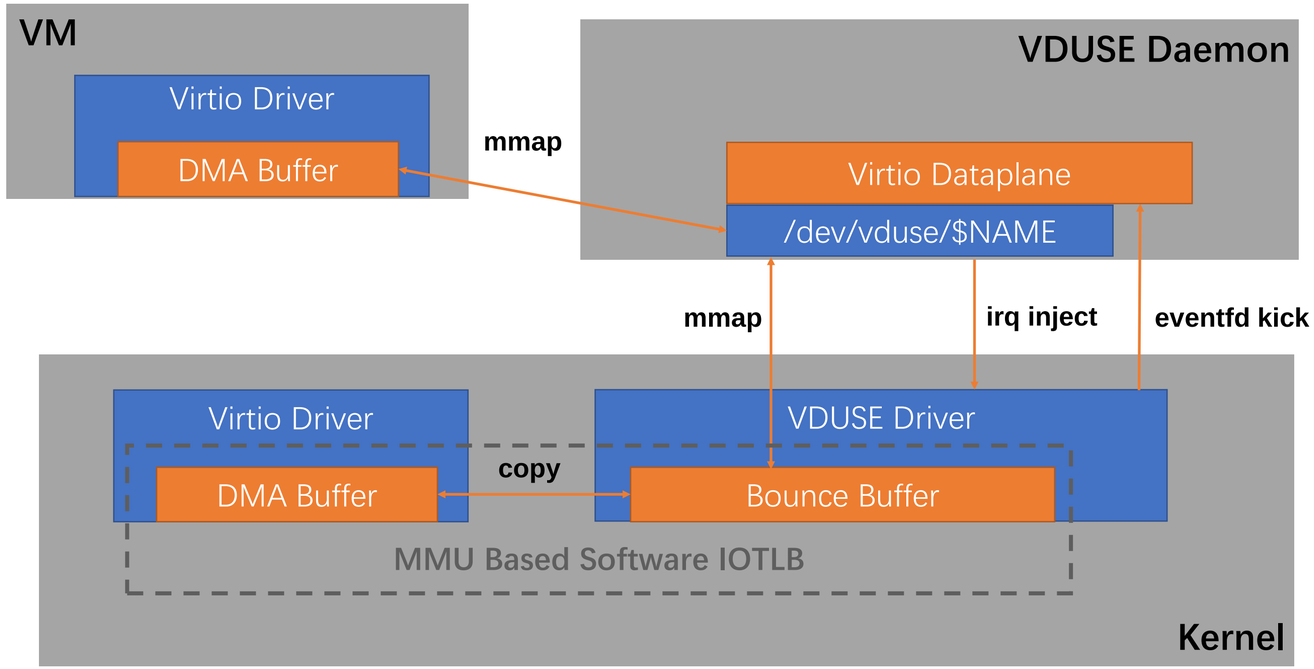
Data Path

The core is how to access the data of DMA buffer in userspace

- In virtio-vdpa cases (Hosts), bounce buffer mechanism is introduced
- In vhost-vdpa cases (VMs), memory is shared

Eventfd is used to receive kick

Ioctl is used to inject irq



How to implement a VDUSE Daemon

Create VDUSE Device

- ioctl(/dev/vduse/control, VDUSE_CREATE_DEV, struct vduse_dev_config)

```
struct vduse_dev_config {
#define VDUSE_NAME_MAX 256
    char name[VDUSE_NAME_MAX]; /* vduse device name, uniquely identify a VDUSE device */
    __u32 vendor_id; /* virtio vendor id */
    __u32 device_id; /* virtio device id */
    __u64 features; /* virtio features */
    __u32 vq_num; /* the number of virtqueues */
    __u32 vq_align; /* the allocation alignment of virtqueue's metadata */
    __u32 reserved[13]; /* for future use, needs to be initialized to zero */
    __u32 config_size; /* the size of the configuration space */
    __u8 config[]; /* the buffer of the configuration space */
};
```

How to implement a VDUSE Daemon

Create VDUSE Device

- ioctl(/dev/vduse/control, VDUSE_CREATE_DEV, struct vduse_dev_config)
- A char device interface (/dev/vduse/$NAME) will be exported to userspace

How to implement a VDUSE Daemon

Create VDUSE Device

- ioctl(/dev/vduse/control, VDUSE_CREATE_DEV, struct vduse_dev_config)
- A char device interface (/dev/vduse/$NAME) will be exported to userspace

Setup Virtqueues

- ioctl(/dev/vduse/$NAME, VDUSE_VQ_SETUP, struct vduse_vq_config)

```
struct vduse_vq_config {
    __u32 index; /* virtqueue index */
    __u16 max_size; /* the max size of virtqueue */
    __u16 reserved[13]; /* for future use, needs to be initialized to zero */
};
```

How to implement a VDUSE Daemon

Begin processing VDUSE messages from /dev/vduse/$NAME

- The first messages will arrive while attaching the VDUSE device to vDPA bus via VDPA_CMD_DEV_NEW netlink message

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Begin processing VDUSE messages from /dev/vduse/$NAME

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- There are now three types of messages introduced:
  - VDUSE_GET_VQ_STATE: Get the state for virtqueue
  - VDUSE_UPDATE_IOTLB: Notify userspace to update the memory mapping for specified IOVA range
  - VDUSE_SET_STATUS: Set the device status

How to implement a VDUSE Daemon

Start the dataplane processing

- Start after DRIVER_OK status bit is set via the VDUSE_SET_STATUS message

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- Get information of virtqueues
  - ioctl(/dev/vduse/$NAME, VDUSE_VQ_GET_INFO, struct vduse_vq_info)

```
struct vduse_vq_info {
    __u32 index; /* virtqueue index */
    __u32 num; /* the size of virtqueue */
    __u64 desc_addr; /* address of desc area */
    __u64 driver_addr; /* address of driver area */
    __u64 device_addr; /* address of device area */
    union {
        struct vduse_vq_state_split split; /* split virtqueue state */
        struct vduse_vq_state_packed packed; /* packed virtqueue state */
    };
    __u8 ready; /* ready status of virtqueue */
};
```

How to implement a VDUSE Daemon

Start the dataplane processing

- Start after DRIVER_OK status bit is set via the VDUSE_SET_STATUS message

- Get information of virtqueues
  - ioctl(/dev/vduse/$NAME, VDUSE_VQ_GET_INFO, struct vduse_vq_info)

- Map IOVA regions related to virtqueues into userspace
  - ioctl(/dev/vduse/$NAME, VDUSE_IOTLB_GET_FD, struct vduse_iotlb_entry)

```
struct vduse_iotlb_entry {
    __u64 offset; /* the mmap offset on returned file descriptor */
    __u64 start; /* start of the IOVA range: [start, last] */
    __u64 last; /* last of the IOVA range: [start, last] */
#define VDUSE_ACCESS_RO 0x1
#define VDUSE_ACCESS_WO 0x2
#define VDUSE_ACCESS_RW 0x3
    __u8 perm; /* access permission of this region */
};
```

How to implement a VDUSE Daemon

Start the dataplane processing

- Setup the kick eventfd for virtqueues (optional)
  - ioctl(/dev/vduse/$NAME, VDUSE_VQ_SETUP_KICKFD, struct vduse_vq_eventfd)

```
struct vduse_vq_eventfd {
    __u32 index; /* virtqueue index */
#define VDUSE_EVENTFD_DEASSIGN -1
    int fd; /* eventfd, -1 means de-assigning the eventfd */
};
```

How to implement a VDUSE Daemon

Start the dataplane processing

- Setup the kick eventfd for virtqueues (optional)
  - ioctl(/dev/vduse/$NAME, VDUSE_VQ_SETUP_KICKFD, struct vduse_vq_eventfd)

- Listen to the kick eventfd (optional) and consume the available ring
  - The buffer described by the descriptors in the descriptor table should be also mapped into userspace via the VDUSE_IOTLB_GET_FD ioctl before accessing

How to implement a VDUSE Daemon

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- Inject an interrupt for specific virtqueue after the used ring is filled
  - ioctl(/dev/vduse/$NAME, VDUSE_VQ_INJECT_IRQ, __u32)

Status & Future Work

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Status & Future Work

Status

- Kernel patchset v11 posted
  - https://lore.kernel.org/kvm/20210818120642.165-1-xieyongji@bytedance.com/
  - https://github.com/bytedance/linux/tree/vduse

- A userspace daemon example
  - https://github.com/bytedance/qemu/tree/vduse

Future Work

- Userspace library
- More device types support
- Improve performance

THANKS.