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Device-passthrough Framework Refactoring – Modernized DMA Isolation Framework for Passthrough Devices

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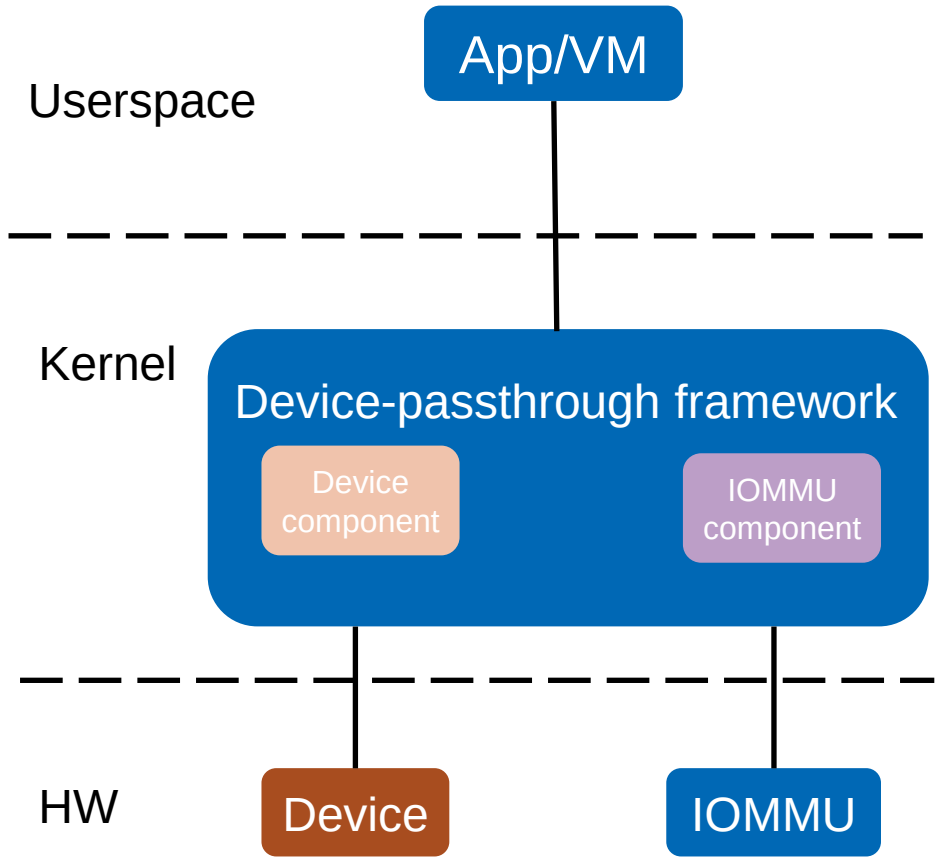
Agenda

- Backgrounds
  - Device Passthrough Recap
  - VFIO Recap
  - Challenges today
- IOMMU FD Proposal
  - Basic concepts for IOMMU FD proposal
  - Basic flow of IOMMU FD model
- Efforts for Adapting passthrough frameworks to IOMMU FD
- Q&A

Device Passthrough Recap

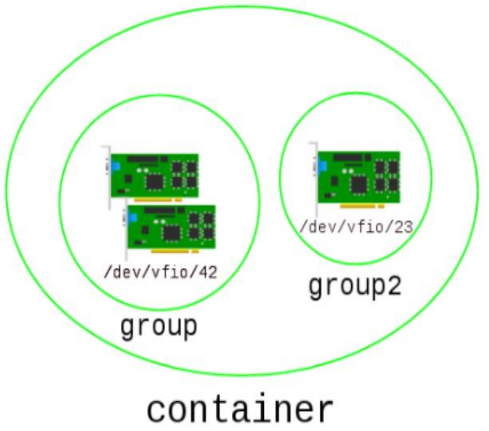
- Device passthrough
  - A way to gain BareMetal I/O performance in virtualization
  - A multi-layer userspace driver in Linux
- Device-passthrough framework
  - Device component
    - Handle the device access like PCI configuration space r/w, BAR mmap, interrupts, etc.;
    - Example: vfio-pci, vfio-platform;
  - IOMMU component
    - Handle the DMA isolation affairs;
    - Example: vfio iommu type1 driver;
  - Typical Device-passthrough Frameworks
    - VFIO, vDPA;



Device frameworks have their own iommu components today!

VFIO Recap

- A secure userspace driver framework
- Key concepts
  - Group FD
    - Get from /dev/vfio/iommu_group_id
    - Group is the smallest granularity for DMA isolation.
      - Relates to ACS, topology etc.
  - Container FD
    - Get from /dev/vfio/vfio
    - Provides an iommu context for userspace to program iommu
  - Device FD
    - Get via group fd after setting the corresponding group to a container
    - Provides device access



Container and Group[1]

```
container_fd = open("/dev/vfio/vfio", O_RDWR);
group_fd = open("/dev/vfio/42", O_RDWR);
ioctl(group_fd, VFIO_GROUP_SET_CONTAINER, &container_fd);
ioctl(container_fd, VFIO_SET_IOMMU, VFIO_TYPE1_IOMMU);
device_fd = ioctl(group_fd, VFIO_GROUP_GET_DEVICE_FD, name);
ioctl(container_fd, VFIO_IOMMU_MAP_DMA, &dma_map);
```

[1] http://events17.linuxfoundation.org/sites/events/files/slides/An%20Introduction%20to%20PCI%20Device%20Assignment%20with%20VFIO%20-%20Williamson%20-%202016-08-30_0.pdf

VFIO Recap (Cont.)

- Supported device types
  - PCI device, platform device, software-based mdev, hardware-based mdev (ADI), etc.
- Supported features in vfio iommu type1
  - DMA map/unmap
    - meta data management, page pinning, and related accounting
  - dirty bitmap retrieving
  - dynamic vaddr update, etc.

Challenges for Supporting new IOMMU Features

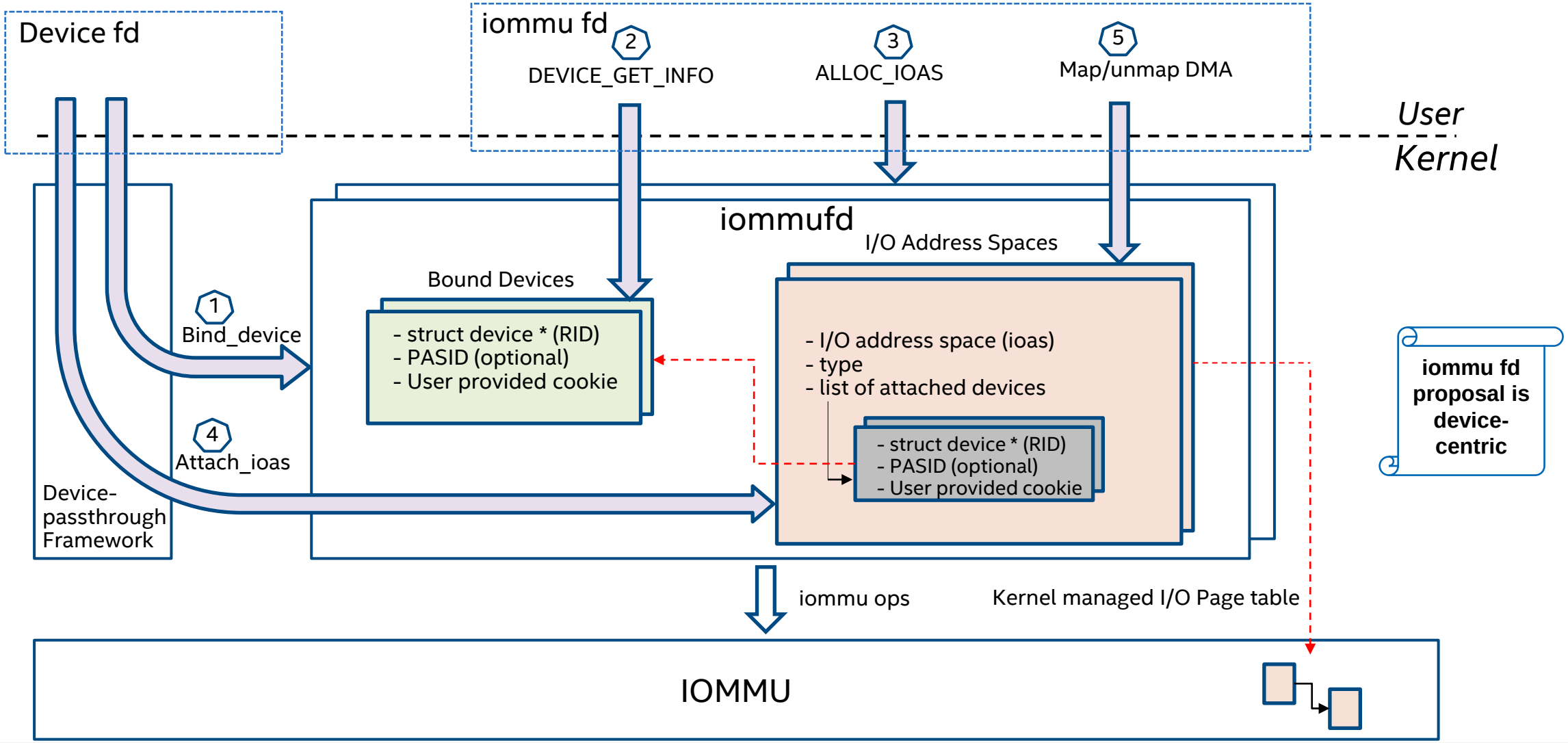
- Subdevice passthrough
  - Needs to support PASID (Process Address Space ID)/SSID (Sub-Stream ID)
- SVA virtualization
  - Needs to support user-provisioned I/O page table (nested on a hypervisor managed I/O page table),
- I/O page table dirty bit
- I/O page faults

Not scale to develop the new iommu features for each device-passthrough framework

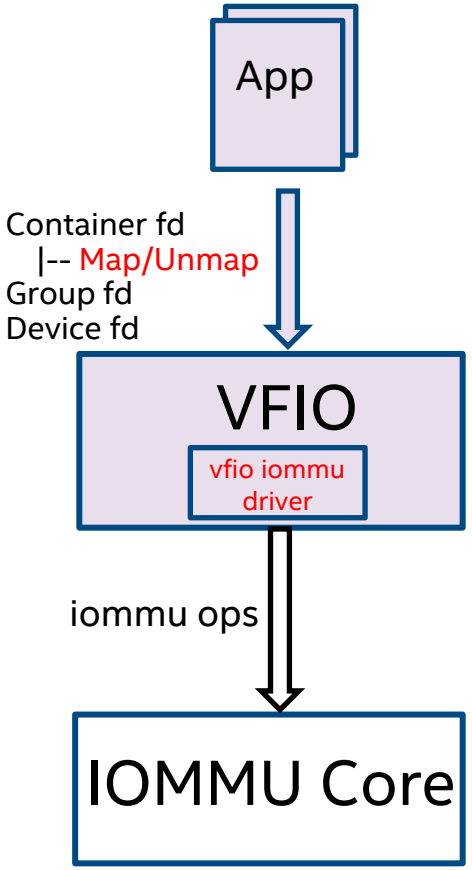
IOMMU FD Based DMA Isolation Framework

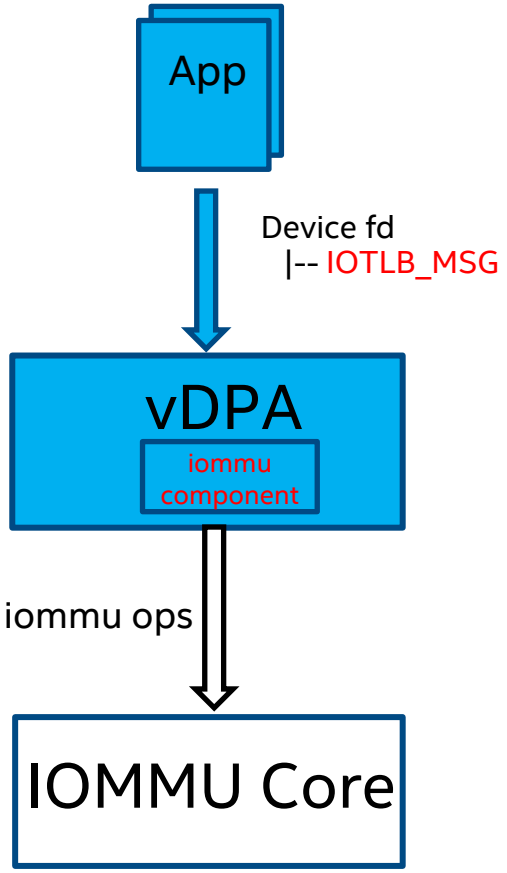
- IOMMU FD
  - Got per /dev/iommu opening
  - The container holding multiple I/O address spaces
  - Support the iommu operations (e.g., DMA map/unmap) from userspace
- IOAS
  - An iommufd-local software handle representing an I/O address space
  - Allocated via iommufd
- Protocols with device-passthrough frameworks
  - Bind/unbind device to iommufd
  - Attach/detach selected IOAS to device
- Device types to support
  - PCI device, platform device, software-based mdev, hardware-based mdev (ADI), etc.

Basic Flow of IOMMU FD Proposal

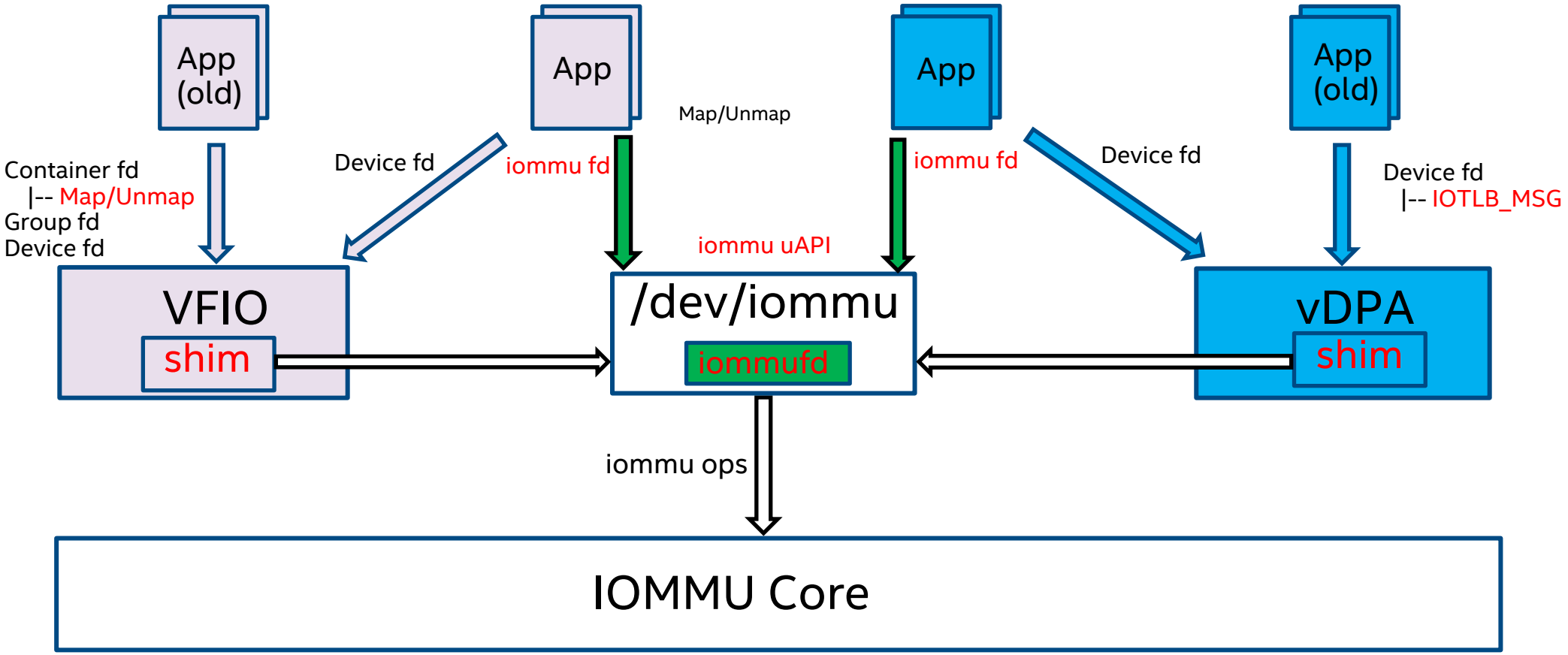


Adapting VFIO/vDPA to IOMMU FD

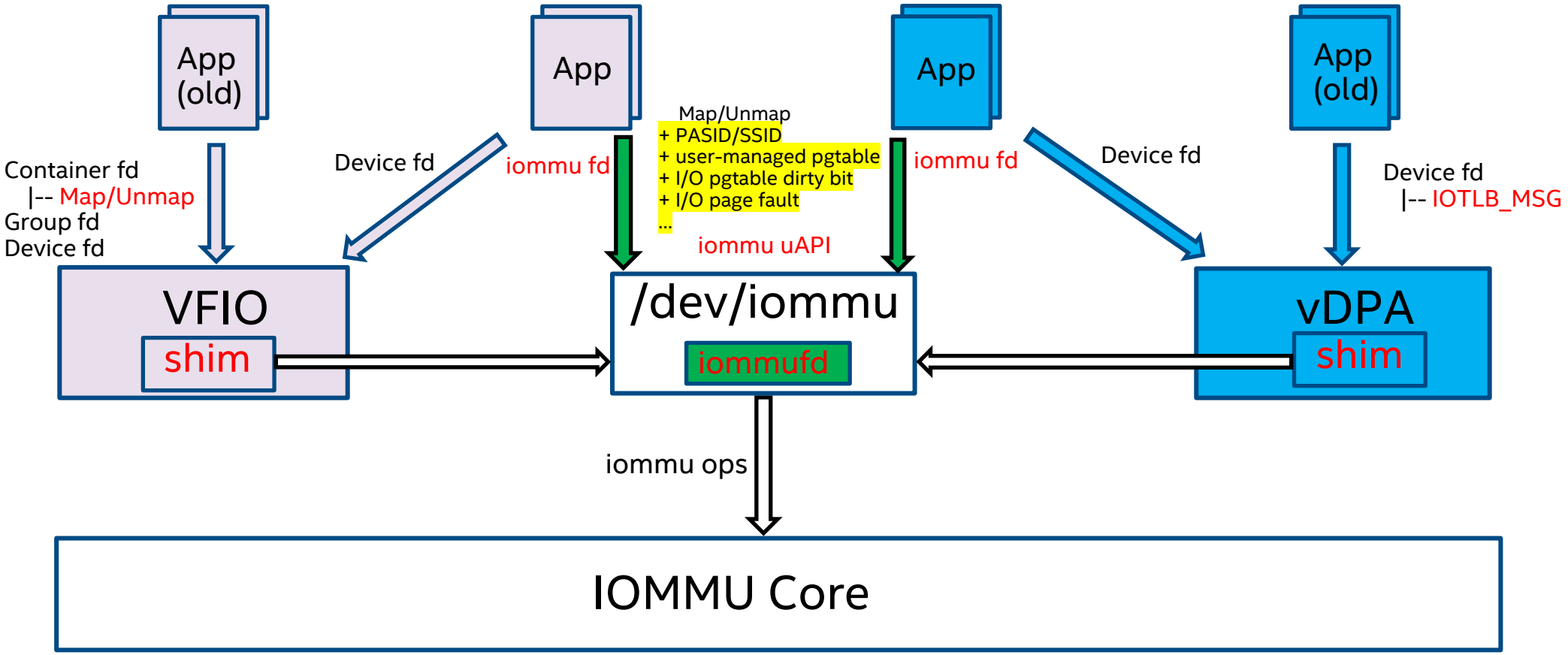




Adapting VFIO/vDPA to IOMMU FD (Cont.)



Adapting VFIO/vDPA to IOMMU FD (Cont.)



Efforts for Adapting VFIO to IOMMU FD

- Introducing device centric interface to VFIO
  - Exposing vfio_device under /dev/vfio/devices/
    - Only allow device access after secure DMA context is setup (done after binding vfio_device to an iommufd)
      - iommufd uses iommu_device_init[exit]_user_dma() for the secure DMA context establishment
  - Allowing co-existence of the legacy group/container interface and the new device-centric interface
    - Userspace can only access device via one of the two interfaces but not both at the same time
- Implementing the protocols defined by iommufd
  - Bind/unbind device to iommu fd
  - Attach/detach ioas to device
- Abstracting the vfio iommu type1 driver to be used by iommufd
  - Features in type1 driver are needed in iommufd
  - over 3000LOC with ~80% related to dma management
- Ensure backward compatibility
  - Existing userspace application should still work

Efforts for Adapting VFIO to IOMMU FD (Cont.)

- Status
  - RFCv1was sent out
    - https://lore.kernel.org/kvm/20210919063848.1476776-1-yi.l.liu@intel.com/#t
    - Team-work across Intel, Nvidia, Redhat, ARM, AMD, etc.
    - Only PCI devices and only basic DMA map/unmap feature supported by iommufd in RFCv1.
    - QEMU part change was not sent out yet
- Helpful links
  - The original discussion inspired iommufd
    - https://lore.kernel.org/linux-iommu/20210330132830.GO2356281@nvidia.com/
  - iommufd uapi proposal discussion
    - https://lore.kernel.org/kvm/BN9PR11MB5433B1E4AE5B0480369F97178C189@BN9PR11MB5433.namprd11.prod.outlook.com/

Summary

- Existing device-passthrough framework implementations doesn't scale as new IOMMU features step in
- IOMMU FD proposal is a unified DMA isolation framework for device-passthrough frameworks
- IOMMU FD model is device-centric, thus requires device-passthrough framework to support device-centric user-interface
- Refactoring device-passthrough frameworks to IOMMU FD creates a good base for supporting new IOMMU features like Scalable IOV, SVM, I/O page table dirty bit, I/O page fault etc.

Q&A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