OMG, NPIV!

Virtualizing Fibre Channel with Linux and KVM

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Outline

- Introduction to Fibre Channel and NPIV
- Fibre Channel and NPIV in Linux and QEMU
- A new NPIV interface for virtual machines
- virtio-scsi 2.0?

What is Fibre Channel?

- High-speed (1-128 Gbps) network interface
- Used to connect storage to server (“SAN”)

FC-4	Application protocols: FCP (SCSI), FC-NVMe
FC-3	Link services (FC-LS): login, abort, scan…
FC-2	Signaling protocols (FC-FS): link speed, frame definitions …
FC-1	Data link (MAC) layer
FC-0	PHY layer

Ethernet NIC vs. Fibre channel HBA

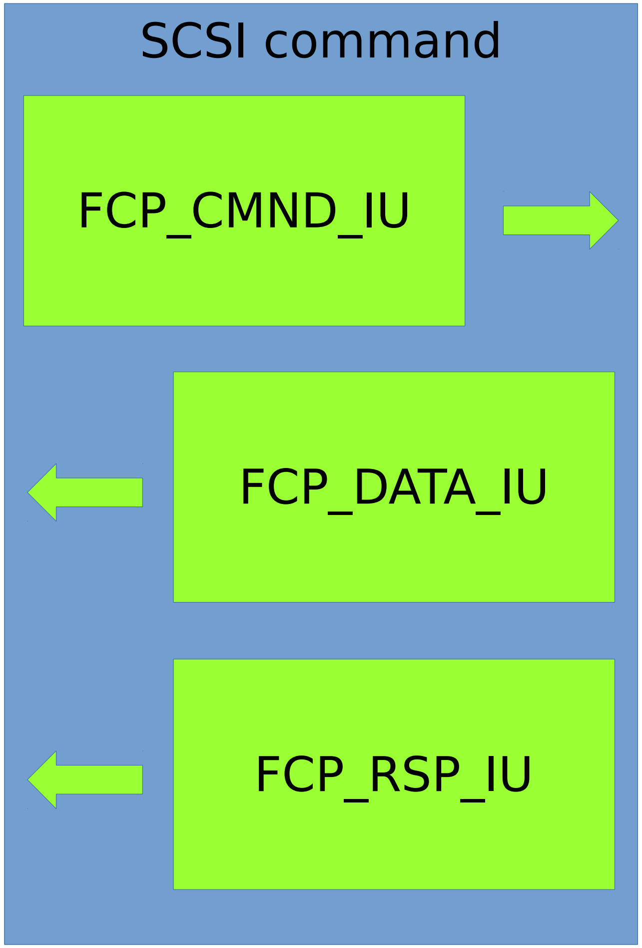
- Buffer credits: flow control at the MAC level
- HBAs hide the raw frames from the driver
- IP-address equivalent is dynamic and mostly hidden
- Devices (ports) identified by World Wide Port Name (WWPN) or World Wide Node Name (WWNN)
  - Similar to Ethernet MAC address
  - But: not used for addressing network frames
  - Also used for access control lists (“LUN masking”)

Fibre channel HBA vs. Ethernet NIC

MAC address	WWPN/WWNN	World Wide Port/Node Name (2x64 bits)
IP address	Port ID	24-bit number
DHCP	FLOGI	Fabric login (usually placed inside switch)
Zeroconf	Name server	Discover other active devices

Initiator	Client
Target	Server
PLOGI	Port login: prepare communication with a target
PRLI	Process login: select protocol (SCSI, NVMe,…), optionally establish connection

FC command format

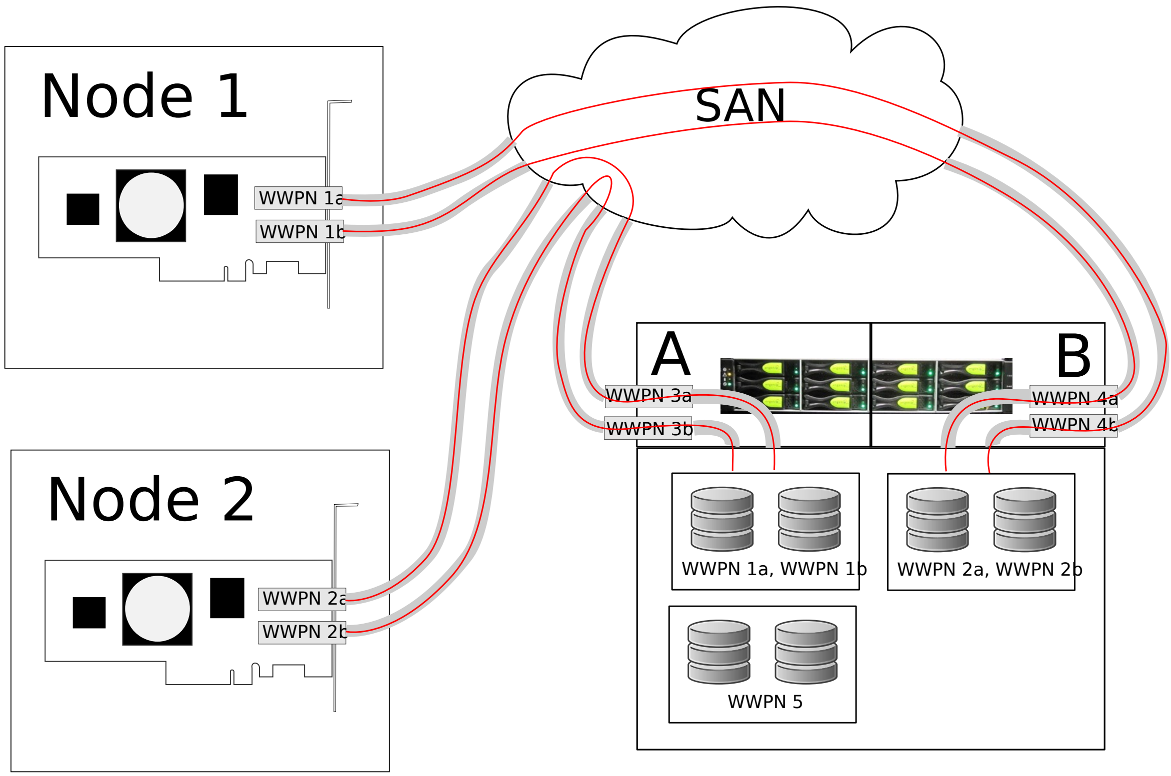


- FC-4 protocols define commands in terms of sequences and exchanges
- The boundary between HBA firmware and OS driver depends on the h/w
- No equivalent of “tap” interfaces

FC Port addressing

- FC Ports are addressed by WWPN/WWNN or FCID
- Storage arrays associate disks (LUNs) with FC ports
- SCSI command are routed from *initiator* to *target* to *LUN*
  - Initiator: FC port on the HBA
  - Target: FC port on the storage array
  - LUN: (relative) LUN number on the storage array

FC Port addressing



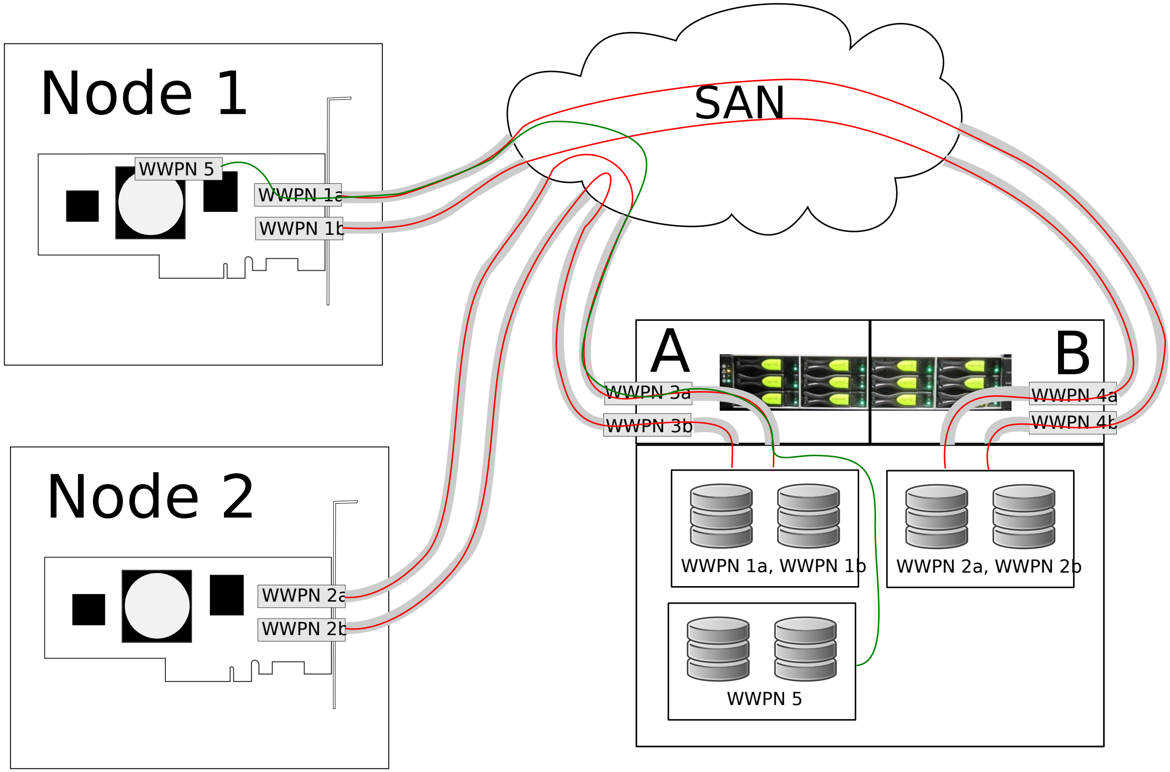
FC Port addressing

- Resource allocation based on FC Ports
- FC Ports are located on FC HBA
- But: VMs have to share FC HBAs
- Resource allocation for VMs not possible

NPIV: N_Port_ID virtualization

- Multiple FC_IDs/WWPNs on the same switch port
  - WWPN/WWNN pair (N_Port_ID) names a vport
  - Each vport is a separate initiator
- Very different from familiar networking concepts
  - No separate hardware (unlike SR-IOV)
  - Similar to Ethernet macvlan
  - Must be supported by the FC HBA

NPIV: N_Port_ID virtualization



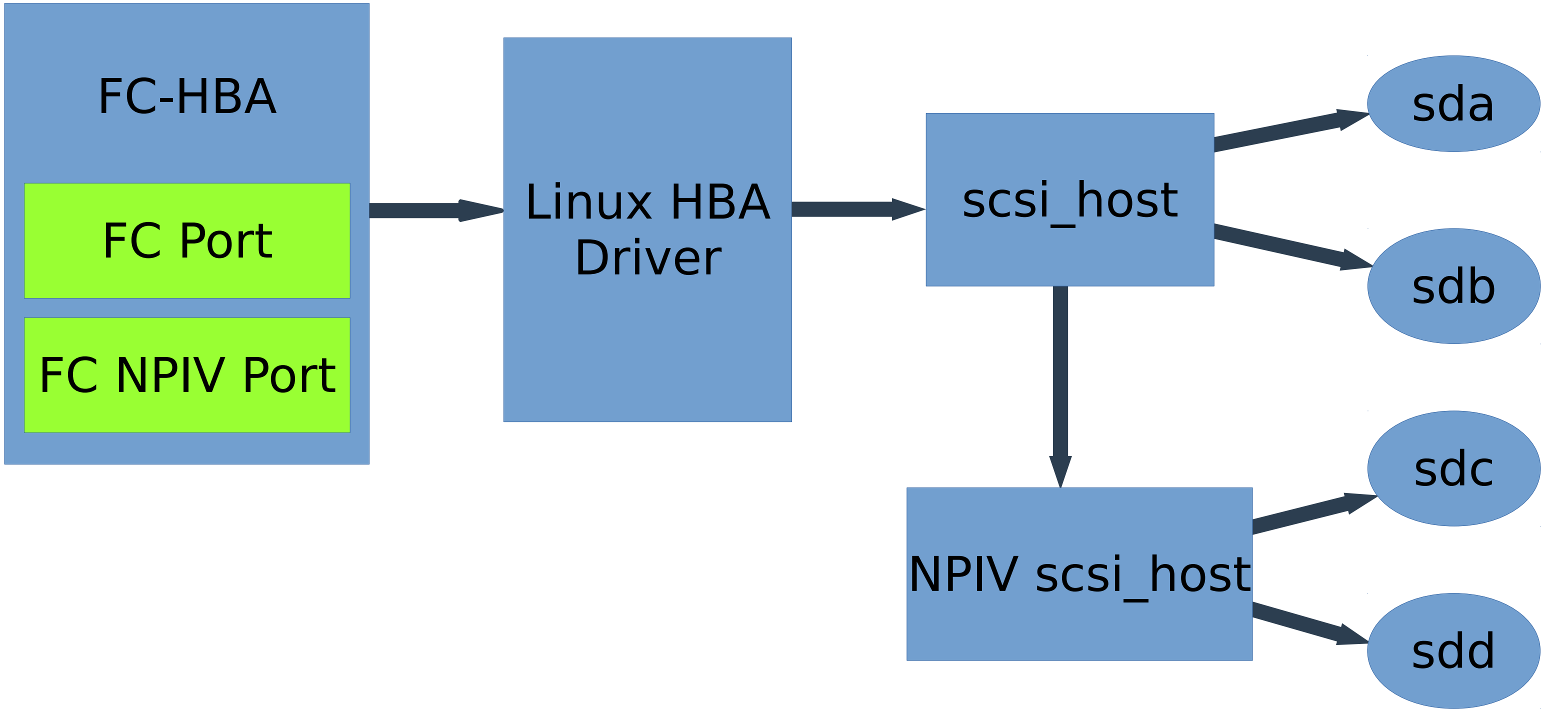
NPIV and virtual machines

- Each VM is a separate initiator
  - Different ACLs for each VM
  - Per-VM persistent reservations
- The goal: map each FC port in the guest to an NPIV port on the host.

NPIV in Linux

- FC HBA (ie the PCI Device) can support several FC Ports
  - Each FC Port is represented as an fc_host (visible in /sys/class/fc_host)
  - Each FC NPIV Port is represented as a separate fc_host
- Almost no difference between regular and virtual ports

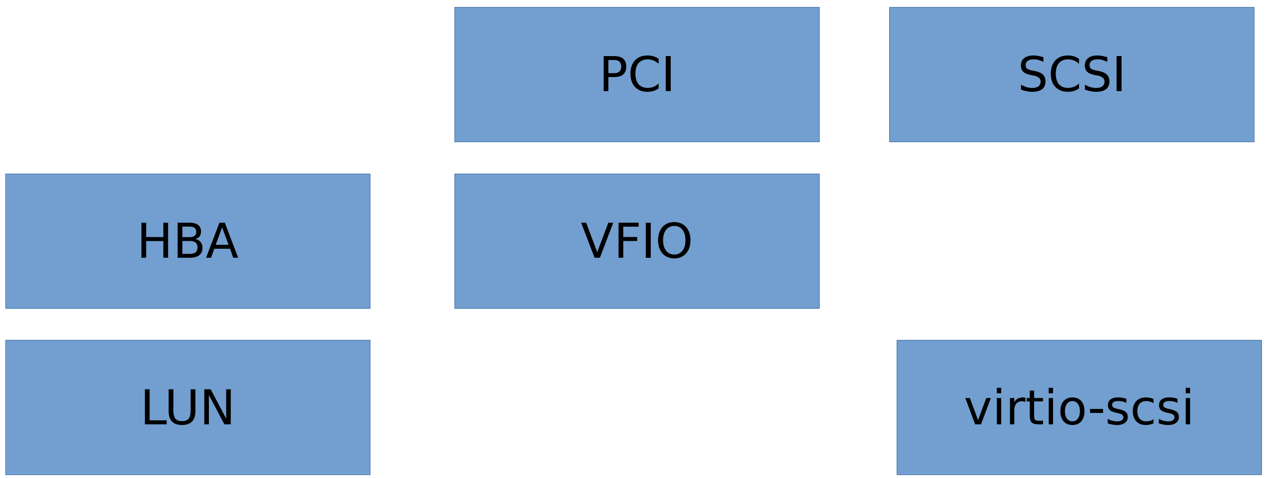
NPIV in Linux



QEMU does not help...

- PCI device assignment
  - Uses the VFIO framework
  - Exposes an entire PCI device to the guest
- Block device emulation
  - Exposes/emulates a single block device
  - virtio-scsi allows SCSI command passthrough
- Neither is a good match for NPIV
  - PCI devices are shared between NPIV ports
  - NPIV ports presents several block devices

NPIV passthrough and KVM



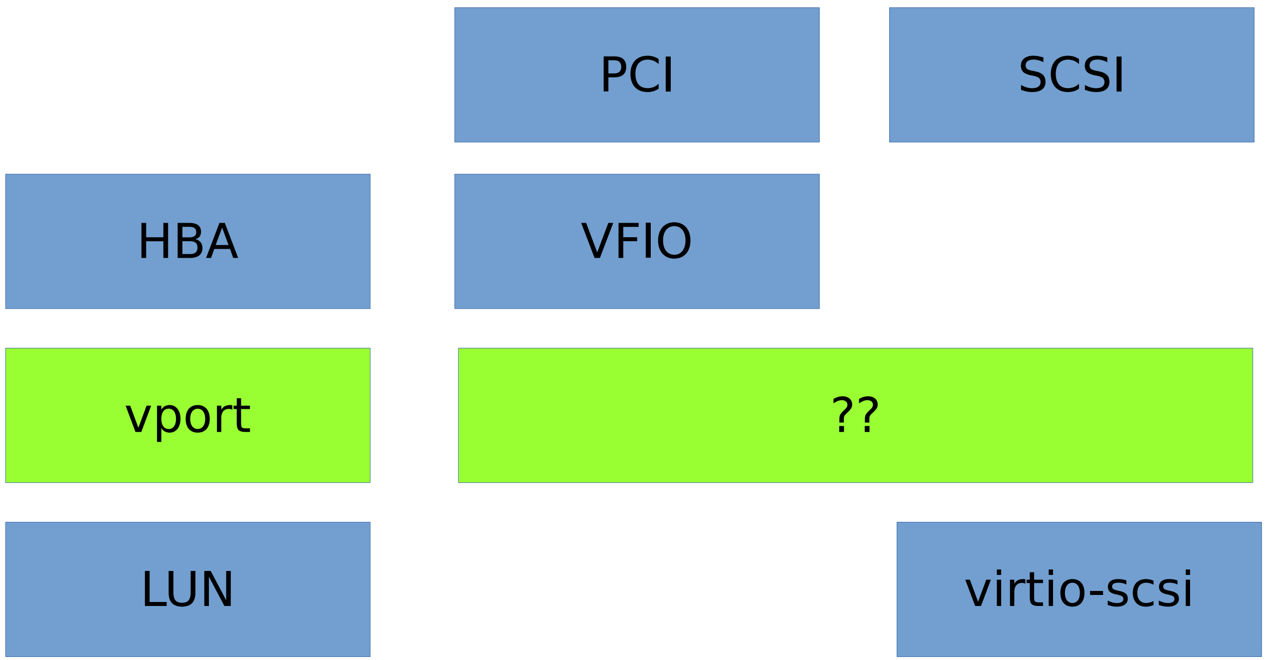
LUN-based NPIV passthrough

- Map all devices from a vport into the guest
- New control command to scan the FC bus
- Handling path failure
  - Use existing hot-plug/hot-unplug infrastructure
  - Or add new virtio-scsi events so that /dev/sdX doesn’t disappear

LUN-based NPIV passthrough

- Assigned NPIV vports do not “feel” like FC
  - Bus rescan in the guest does not map to LUN discovery in the host
  - New LUNs not automatically visible in the VM
- Host can scan LUN for partitions, mount file systems, etc.

Can we do better?



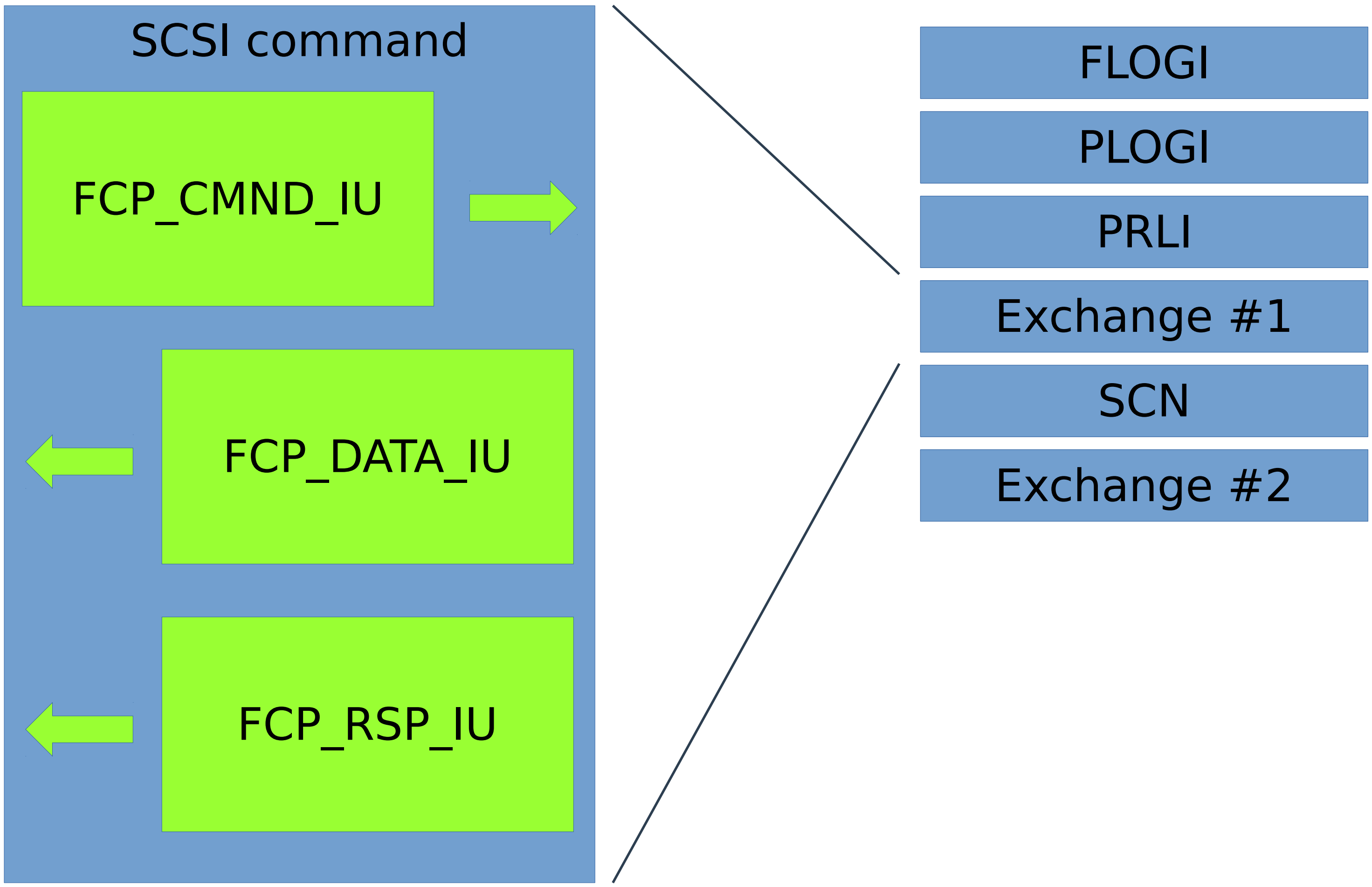
Mediated device passthrough

- Based on VFIO
- Introduced for vGPU
- Driver virtualizes itself, and the result is exposed as a PCI device
  - BARs, MSIs, etc. are partly emulated, partly passed-through for performance
  - Typically, the PCI device looks like the parent
- One virtual N_Port per virtual device

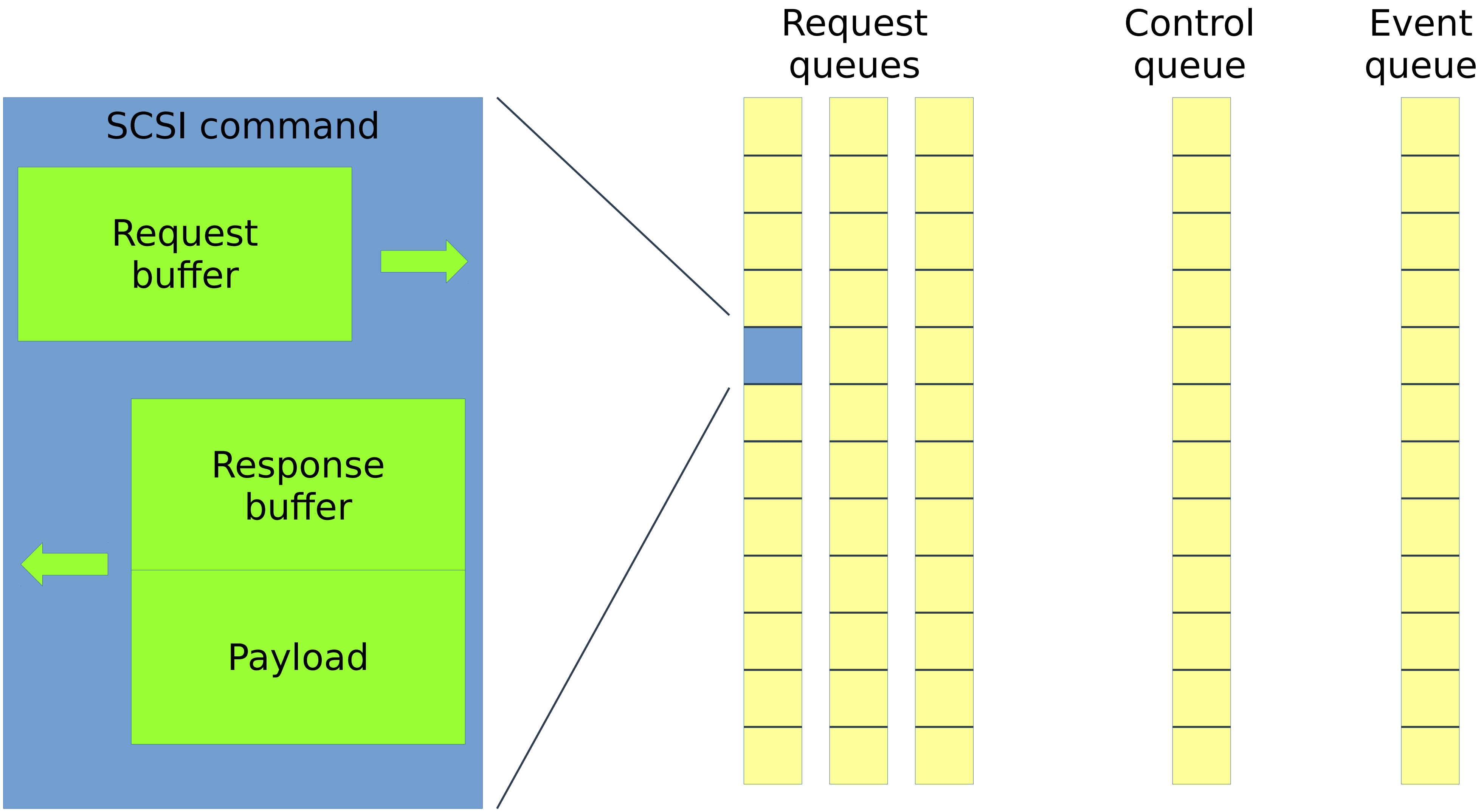
Mediated device passthrough

- Advantages:
  - No new guest drivers
  - Can be implemented entirely within the driver
- Disadvantages:
  - Specific to each HBA driver
  - Cannot stop/start guests across hosts with different HBAs
  - Live migration?

What FC looks like



What virtio-scsi looks like



vhost

- Out-of-process implementation of virtio
  - A vhost-scsi device represents a SCSI target
  - A vhost-net device is connected to a tap device
- The vhost server can be placed closer to the host infrastructure
  - Example: network switches as vhost-user-net servers
  - How to leverage this for NPIV?

Initiator vhost-scsi

- Each vhost-scsi device represents an initiator
- Privileged ioctl to create a new NPIV vport
  - WWPN/WWNN → vport file descriptor
  - vport file descriptor compatible with vhost-scsi
- Host driver converts virtio requests to HBA requests
- Devices on the vport will *not* be visible on the host

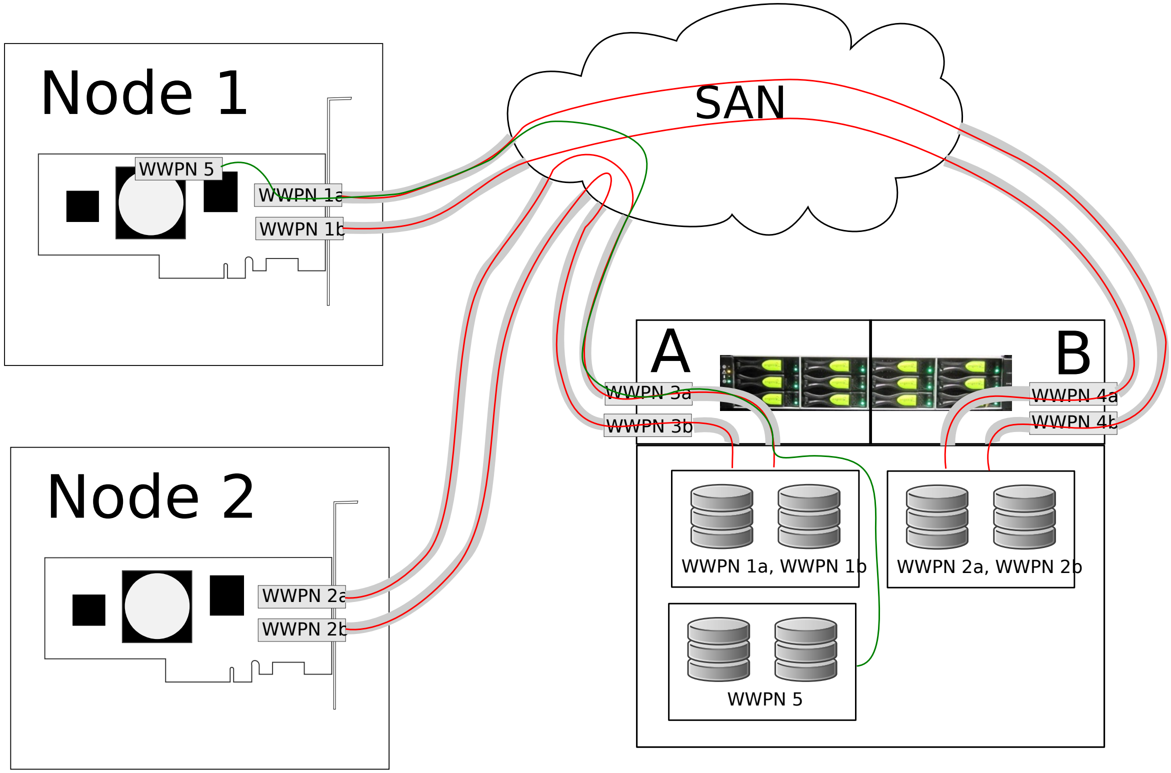
Initiator vhost-scsi

- Advantages:
  - Guests are unaware of the host driver
  - Simpler to handle live migration (in principle)
- Disadvantages:
  - Need to be implemented in each host driver (around a common vhost framework)
  - Guest driver changes likely necessary (path failure etc.)

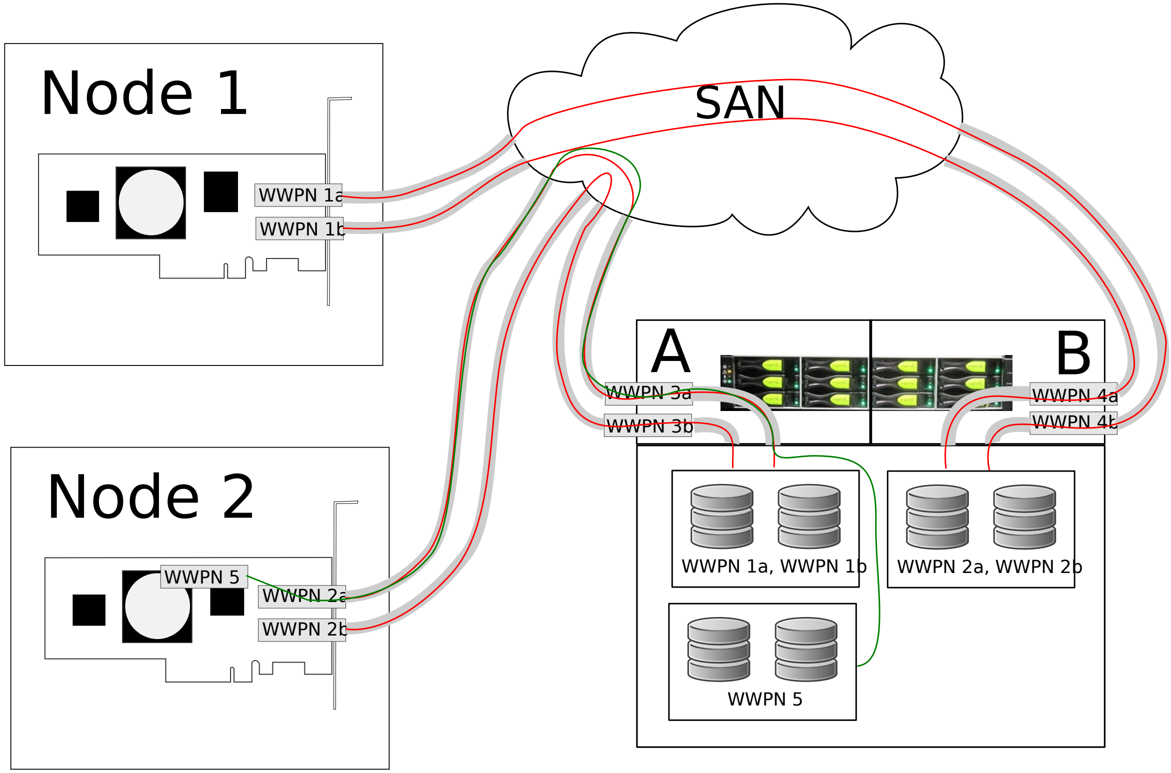
Live migration

- WWPN/WWNN are unique (per SAN)
- Can log into the SAN only once
- For live migration both instances need to access the same devices at the same time
- Not possible with single WWPN/WWNN

Live migration



Live migration



Live migration

- Solution #1: Use “generic” temporary WWPN during migration
- Temporary WWPN has to have access to all devices; potential security issue
- Temporary WWPN has to be scheduled/negotiated between VMs

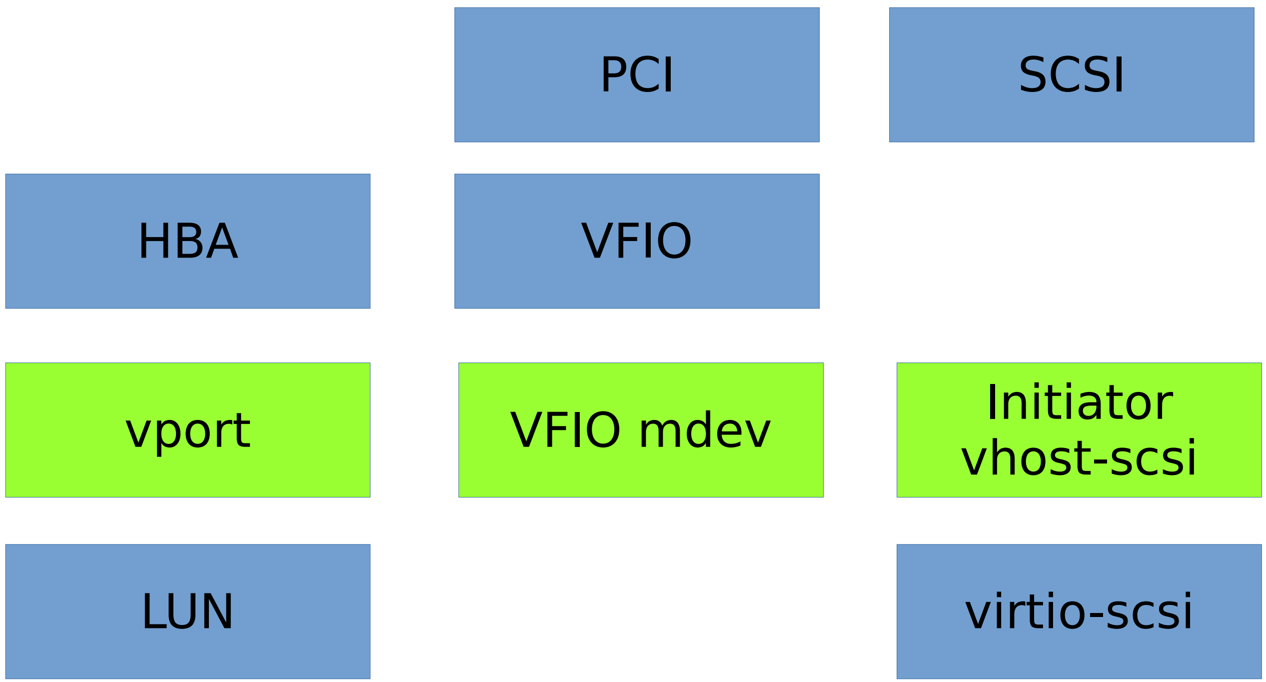
Live migration

- Solution #2: Use individual temporary WWPNs
- Per VM, so no resource conflict with other VMs
- No security issue as the temporary WWPN only has access to the same devices as the original WWPN
- Additional management overhead; WWPNs have to be created and registered with the storage array

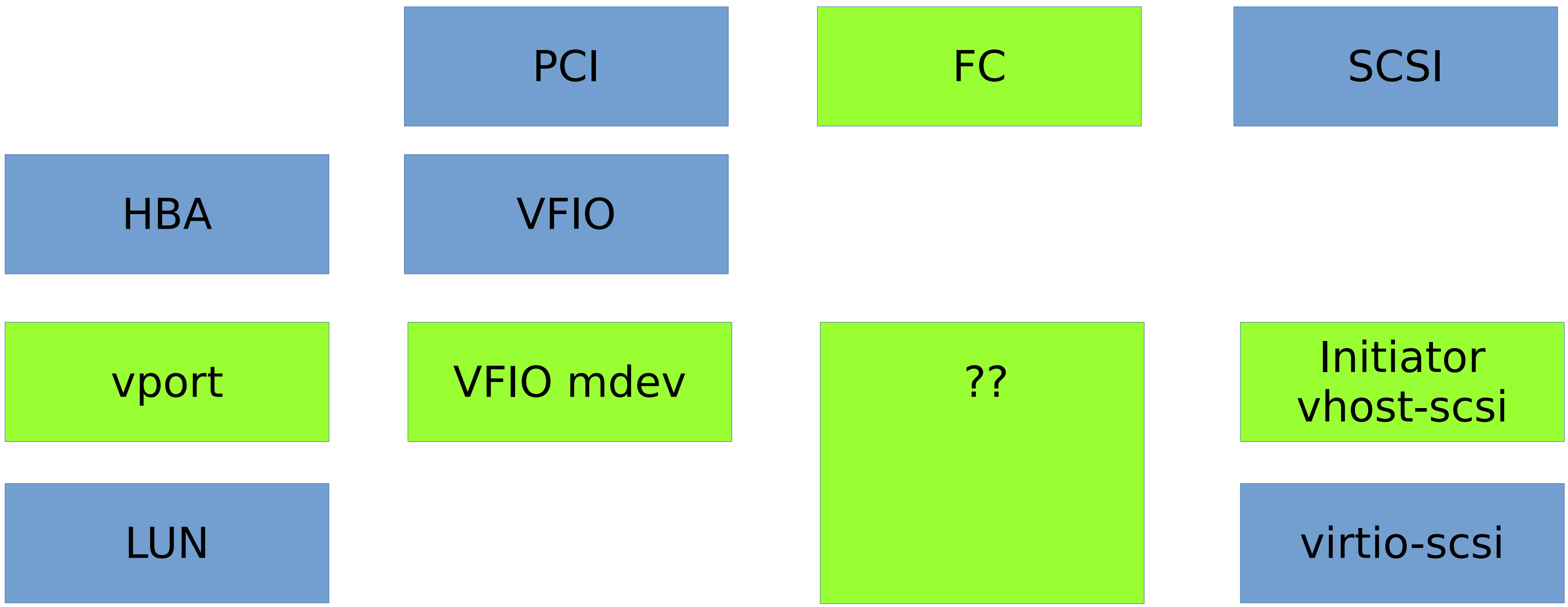
Live migration: multipath to the rescue

- Register two WWPNs for each VM; activate multipathing
- Disconnect the lower WWPN for the source VM during migration, and the higher WWPN for the target VM.
- Both VMs can access the disk; no service interruption
- WWPNs do not need to be re-registered.

Is it better?


PCI
SCSI
HBA
VFIO
vport
VFIO mdev
Initiator
vhost-scsi
LUN
virtio-scsi

Can we do *even* better?



virtio-scsi 2.0?

- virtio-scsi has a few limitations compared to FCP
  - Hard-coded LUN numbering (8-bit target, 16-bit LUN)
  - One initiator id per virtio-scsi HBA (cannot do “nested NPIV”)
- No support for FC-NVMe

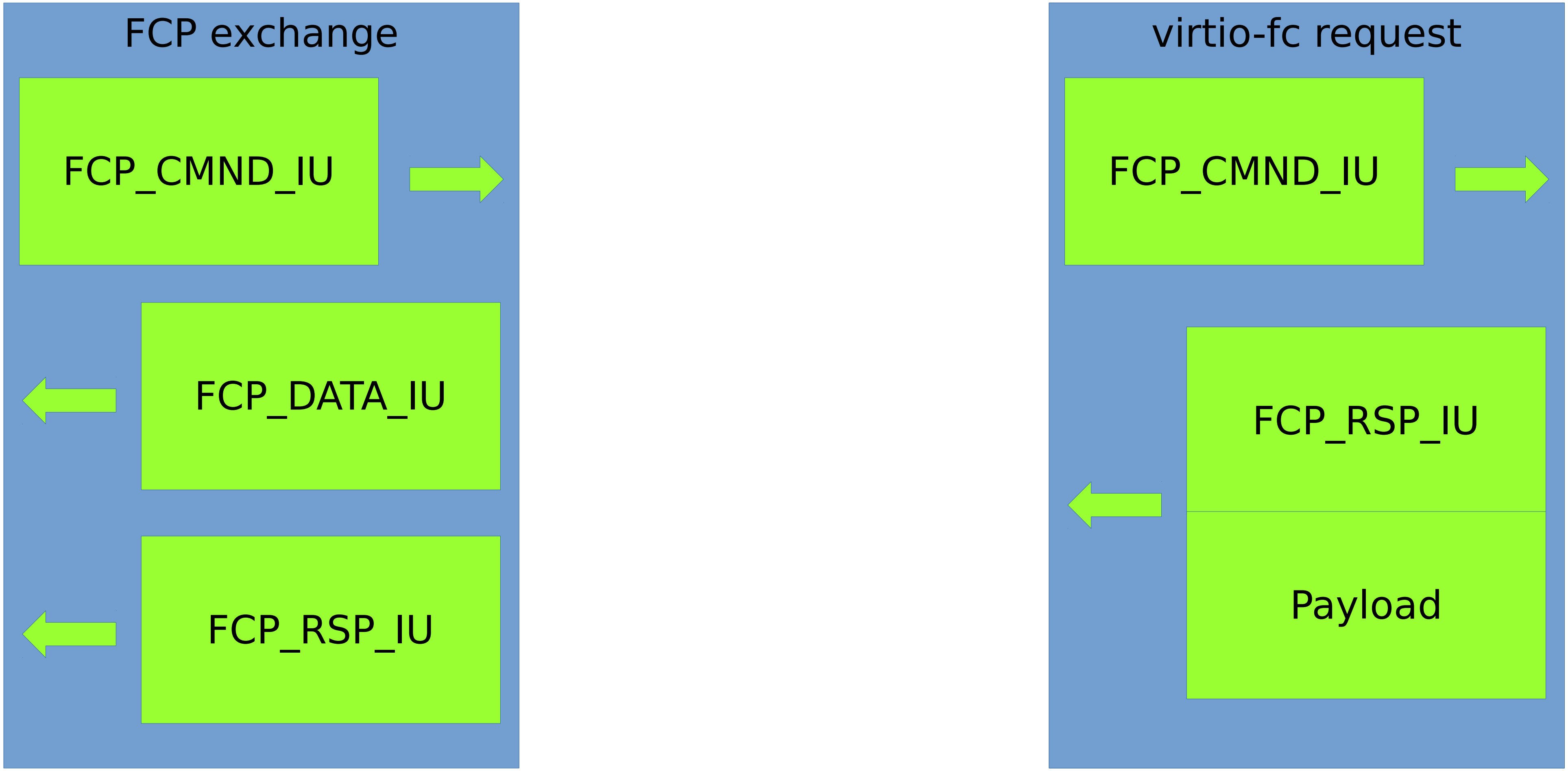
virtio-scsi device addressing

- virtio-scsi uses a 64-bit *hierarchical LUN*
  - Fixed format described in the spec
  - Selects both a bus (target) and a device (LUN)
- FC uses a 128-bit target (WWNN/WWPN) + 64-bit LUN
- Replace 64-bit LUN with I_T_L nexus id
  - Scan fabric command returns a list of target ids
  - New control commands to map I_T_L nexus
  - Add target id to events

Emulating NPIV in the VM

- FC NPIV port (in the guest) maps to FC NPIV port on the host
- No field in virtio-scsi to store the initiator WWPN
- Additional control commands required:
  - Create vport on the host
  - Scan vport on the host

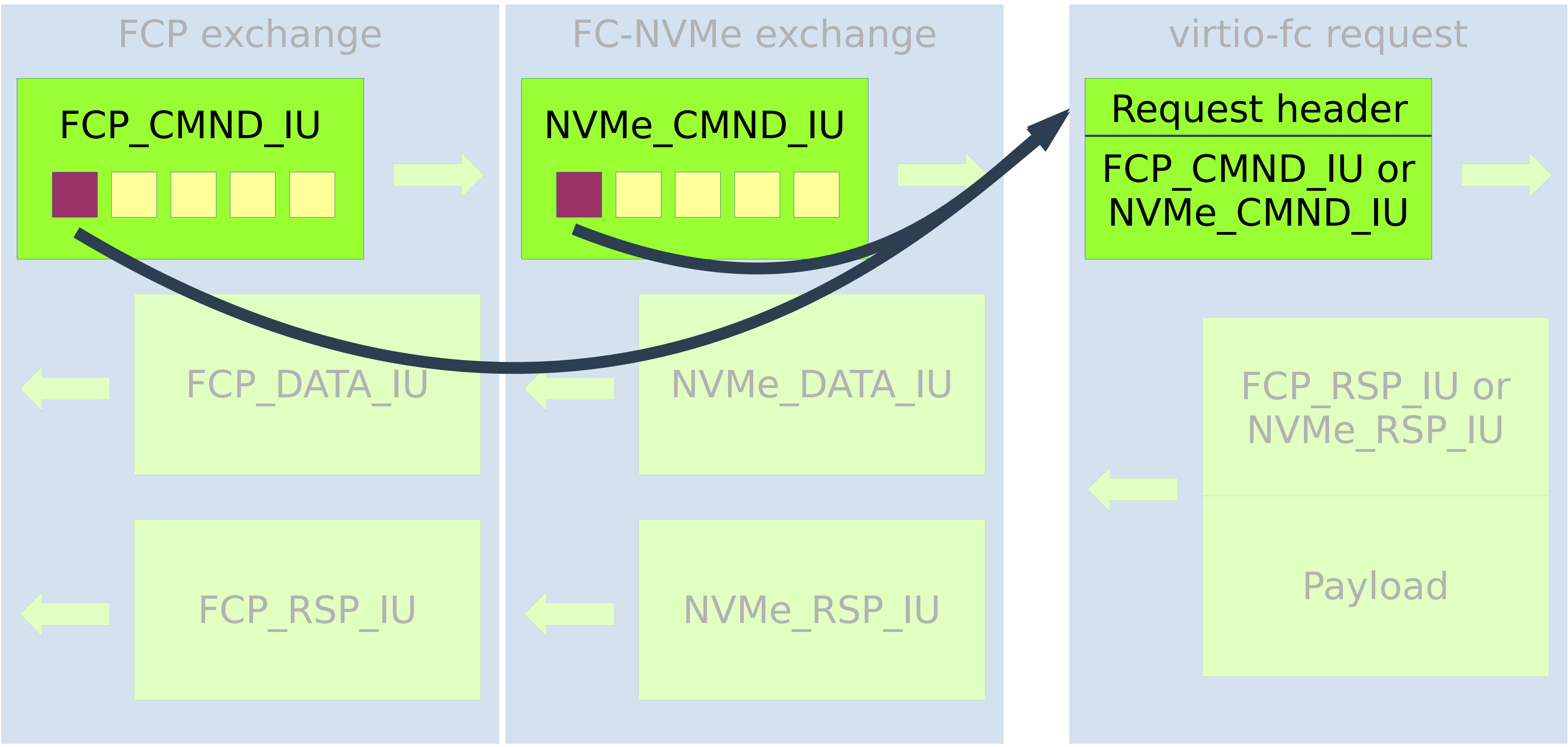
Towards virtio-fc?



Towards virtio-fc

- HBAs handle only “cooked” FC commands; raw FC frames are not visible
- “Cooked” FC frame format different for each HBA
- Additional abstraction needed

Towards virtio-fc?



Towards virtio-fc?

- Not a 1:1 mapping – still a “cooked” frame
  - Simplified compared to FCP and FC-NVMe
  - Remember drivers do not even see raw frames
- Reuse FC definitions to avoid obsolescence
  - Support for NVMe from the beginning
  - Overall IU structure
  - Possibly, PLOGI/FLOGI structure too
- Things learnt from virtio-scsi can be reused

Summary

- “Initiator vhost” as the abstraction for NPIV vports
  - Common framework for Linux + driver code
  - Very few changes required in QEMU and libvirt
- Live migration can be handled at the libvirt and/or guest levels
- Could extend virtio-scsi or go with virtio-fc