CS-452/552 Introduction to Cloud Computing

Storage Virtualization

Data Storage Systems

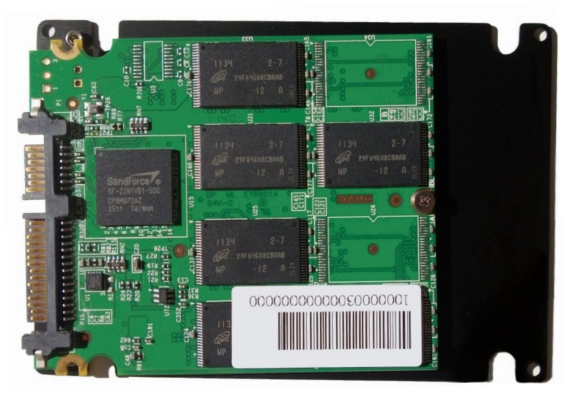
Data can be stored in various places in different manners

--- Hardware: CPU registers, caches, main memory and persistent storage

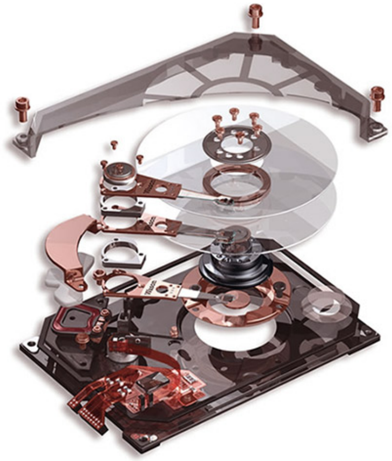
--- Software: File systems, object storage, databases (SQL databases and No-SQL databases.

Storage I/O system within a single host

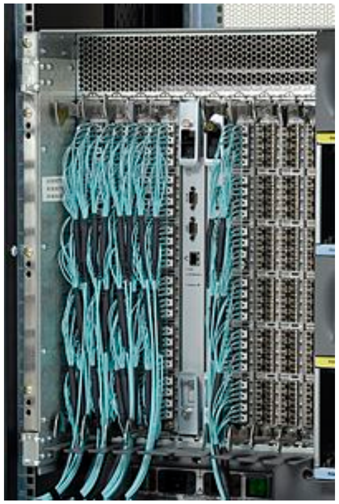
Persistent Storage media

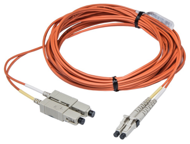


FLASH

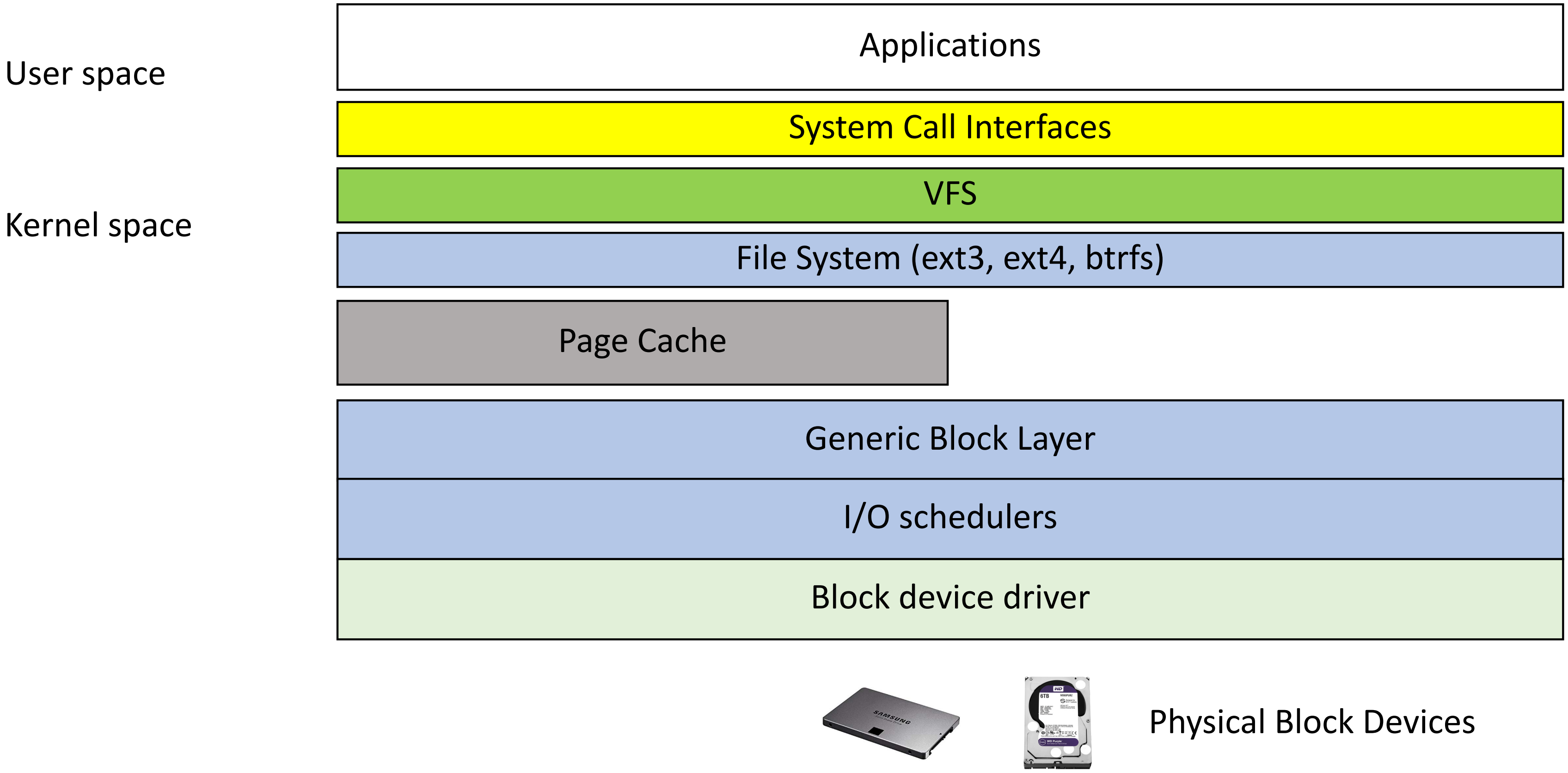


HDD OR DISK DRIVE





I/O layers within a single host



User space

Kernel space

Applications

System Call Interfaces

VFS

File System (ext3, ext4, btrfs)

Page Cache

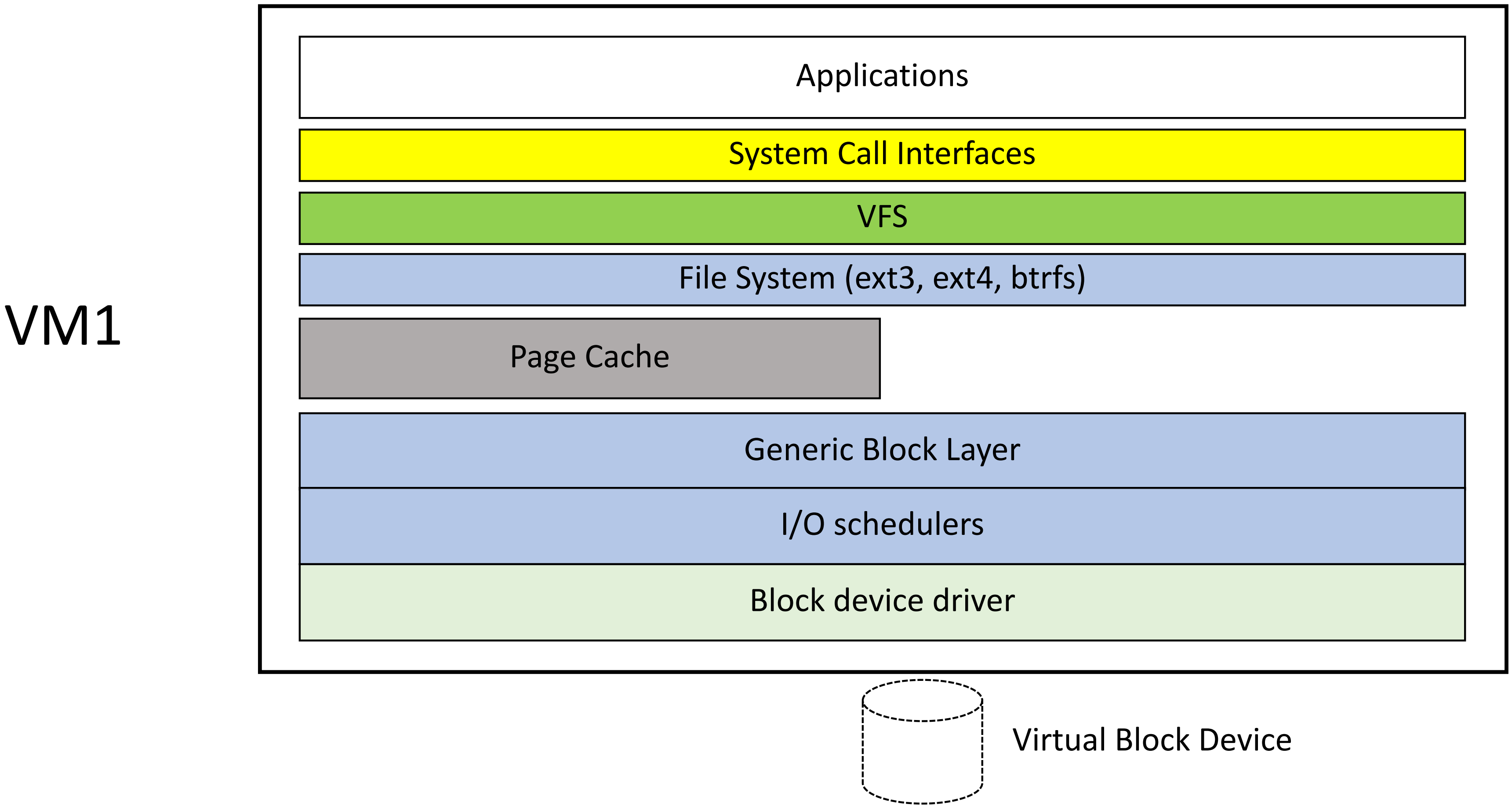
Generic Block Layer

I/O schedulers

Block device driver

Physical Block Devices

I/O layers within a VM



VM1

Applications

System Call Interfaces

VFS

File System (ext3, ext4, btrfs)

Page Cache

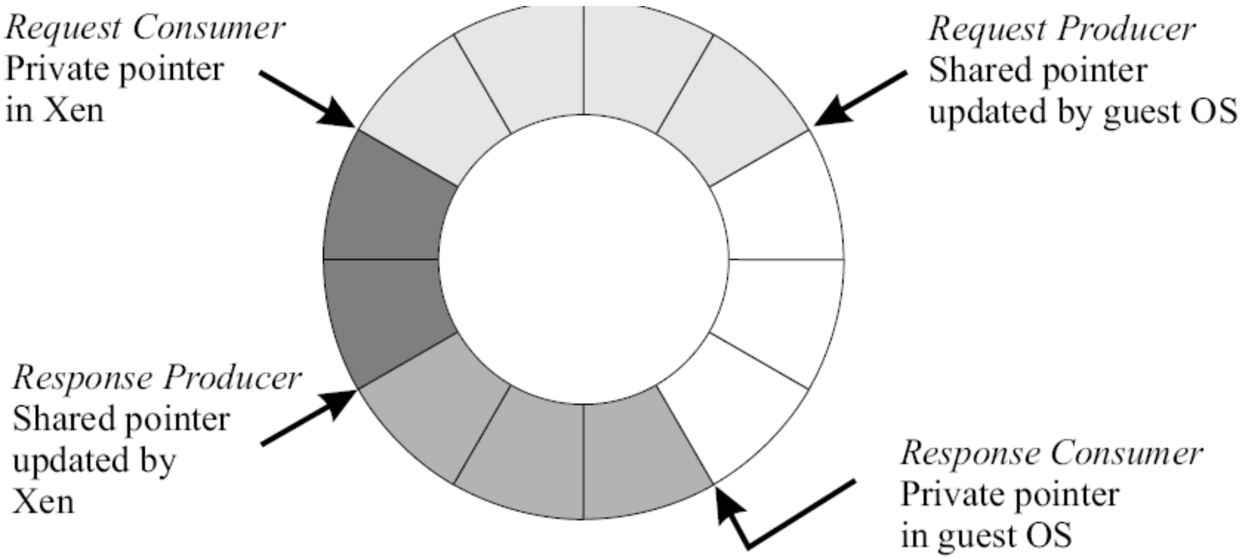
Generic Block Layer

I/O schedulers

Block device driver

Virtual Block Device

I/O Rings



Request Consumer
Private pointer
in Xen

Request Producer
Shared pointer
updated by guest OS

Response Producer
Shared pointer
updated by
Xen

Response Consumer
Private pointer
in guest OS

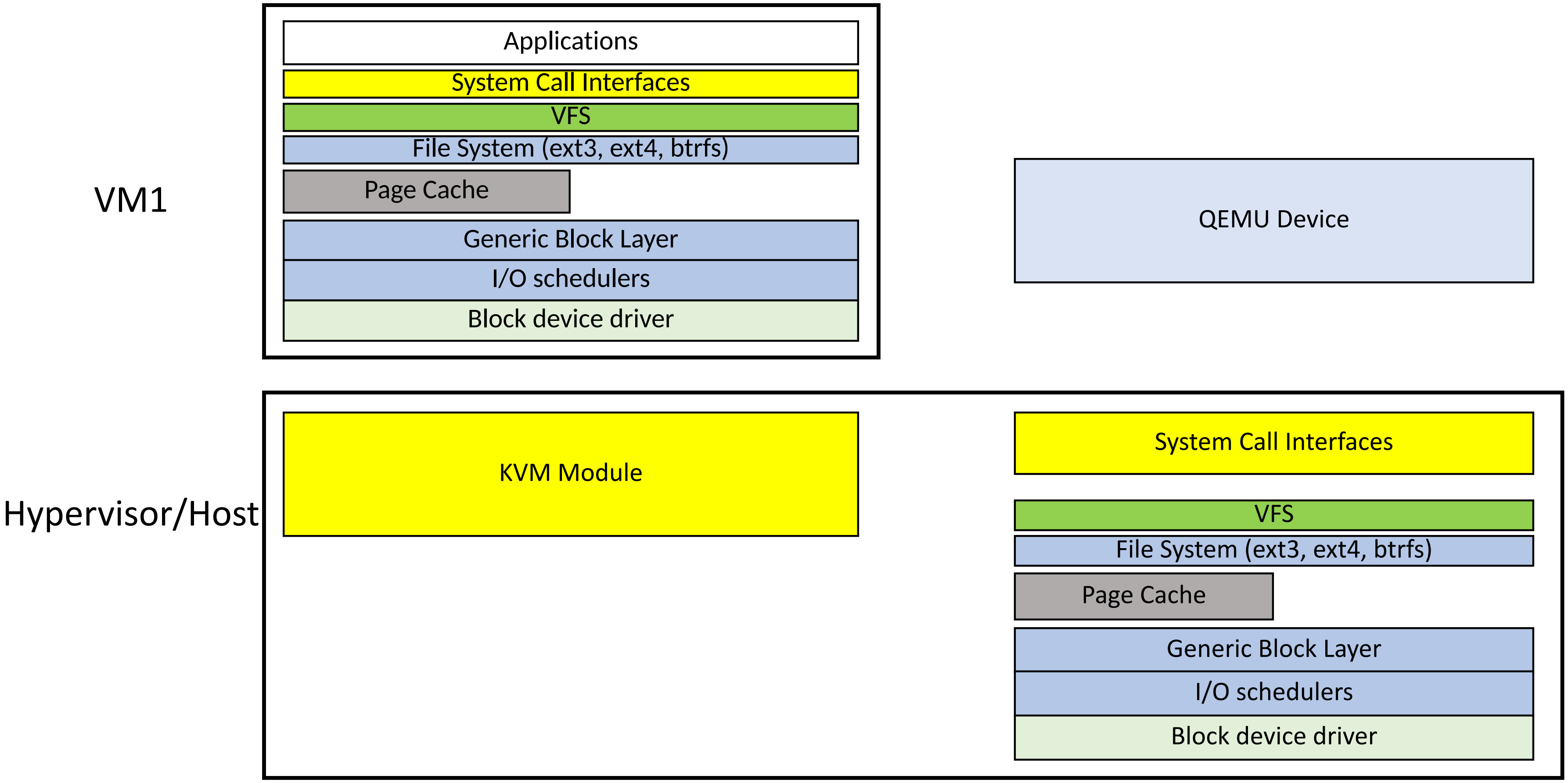
░ **Request queue** - Descriptors queued by the VM but not yet accepted by Xen

▓ **Outstanding descriptors** - Descriptor slots awaiting a response from Xen

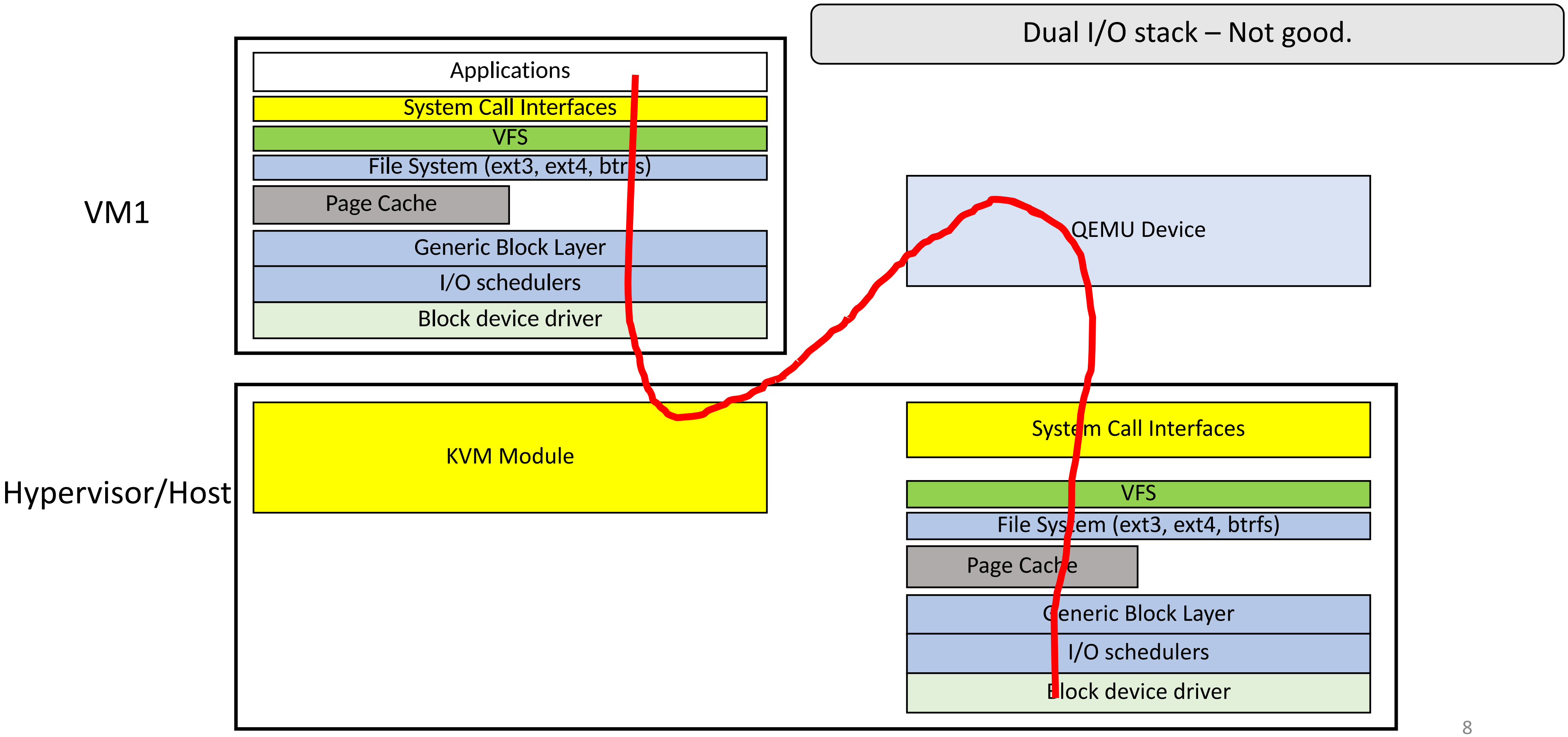
▒ **Response queue** - Descriptors returned by Xen in response to serviced requests

□ **Unused descriptors**

I/O layers in Virtualization



I/O layers in Virtualization



Dual I/O stack – Not good.

VM1

Applications

System Call Interfaces

VFS

File System (ext3, ext4, btrfs)

Page Cache

Generic Block Layer

I/O schedulers

Block device driver

QEMU Device

Hypervisor/Host

KVM Module

System Call Interfaces

VFS

File System (ext3, ext4, btrfs)

Page Cache

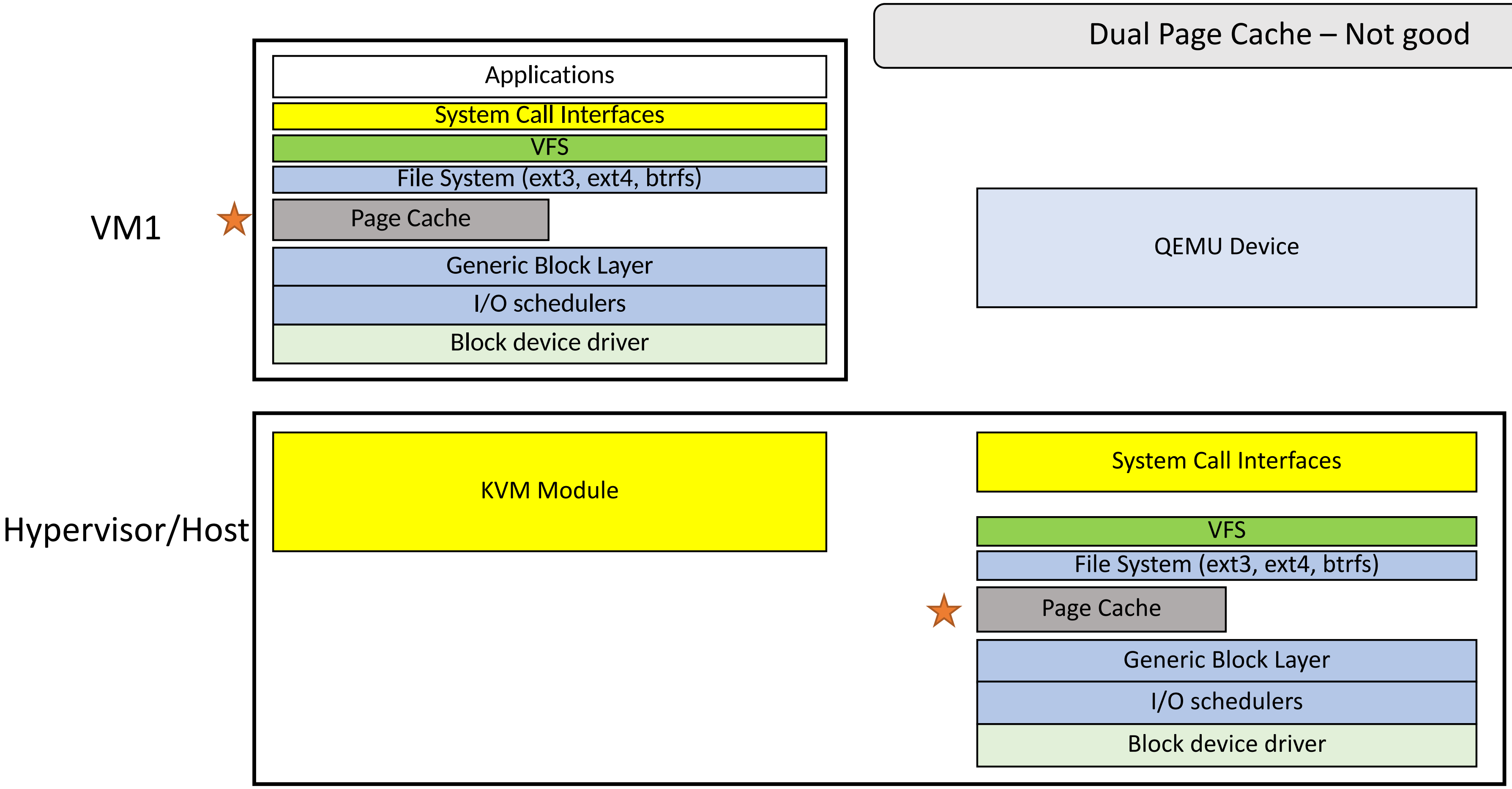
Generic Block Layer

I/O schedulers

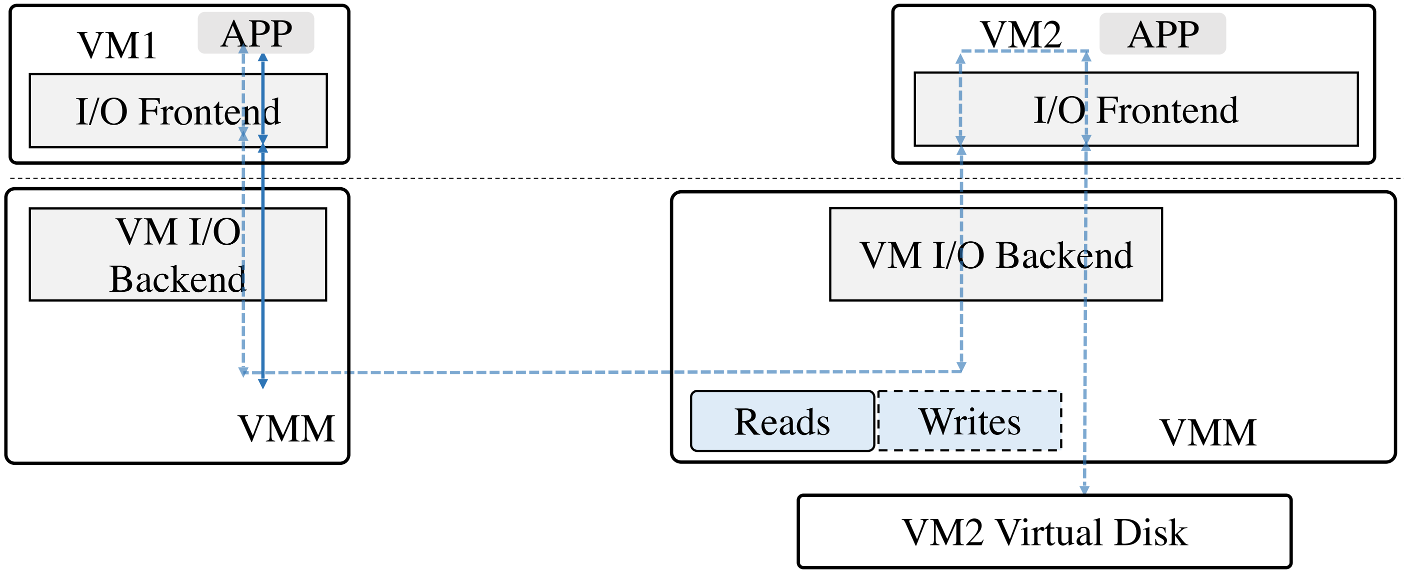
Block device driver

I/O layers in Virtualization

Dual Page Cache – Not good

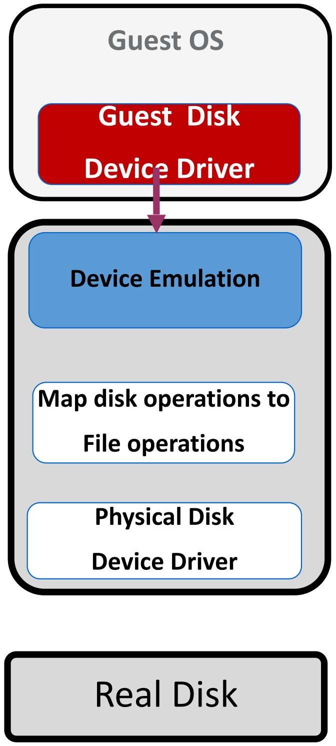


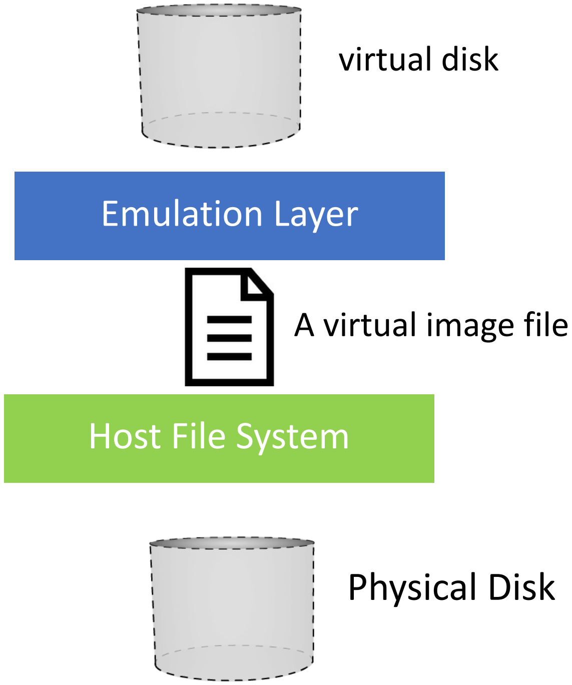
I/O Data Plane Redundancy



Multiple data copying steps for data communication between two VMs. Not good!

Virtualize Storage Device





- Virtual disk is stored as
  - a file in the host file system
  - or partition on physical disk
- Operations to the block device is emulated by QEMU
- Guest issues block reads & writes
- QEMU converts them to file operations on the virtual disk file

Virtual Disk Image Type Matters!

- A “pre-allocated” disk image (1 virtual to 1 physical block)
  - A 10 GB disk image reserves 10 GB of disk space, regardless of whether the virtual machine guests uses 1 GB or 10 GB (allocated at creation time)
- An “extensible” disk image, useful for growing on demand
  - From the VM point of view, it sees a full size disk, but the hypervisor is actually lying to the VM, and is allocating the disk blocks on the HOST side on demand

Disk images - pros / cons

- A “pre-allocated” disk image
  - Pros: Fast
  - Cons: Uses all space
- An extensible disk image
  - Pros: Less space
  - Cons: A bit overhead, fragmentation
- It depends on what we are trying to achieve: system design tradeoff

VM Creation and Virtual Disk Images

- Assume that each virtual machine (VM) needs a disk image. If we are only going to create a single VM, it’s easy:
  - Create VM
    - (1) create disk image
    - (2) attach ISO image (installation) to start VM
    - (3) install operating system
    - (4) Done!

- What if we want to install 2 VMs ? We could probably install a second time. What about when we have to build 5 ? 40 ? And do this very often (e.g., cloud service vendors)?
  - How do you increase the efficiency of such VM creation?

Two Concrete Techniques

- Raw disks (“pre-allocated”)
  - Byte-for-byte disk image, byte 0 = byte 0 of the disk

- QEMU-KVM’s “QCOW2” (Qemu Copy On Write, v.2) format (extensible)
  - Grow-on-demand
  - Compression support
  - Encryption support
  - Copy-on-write!

What is Copy-on-Write?

- Traditionally (e.g., raw disks):
  - When programs inside the guest VM write to the virtual disk, the changes are written to the disk image in place.

- Copy-on-write:
  - Write delta and store somewhere else (don’t modify the original copy)

Use of CoW

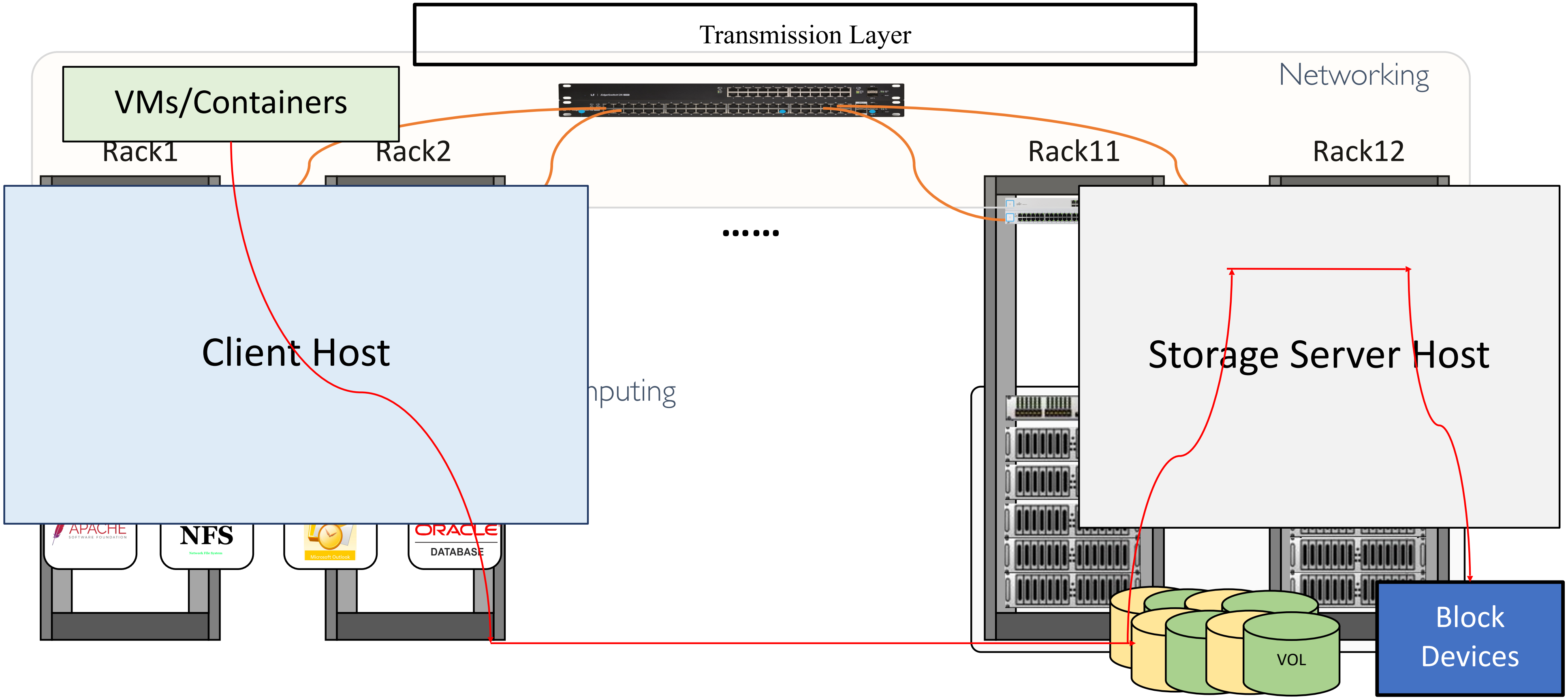
- A new disk image, originates from a “master” image as a backing file.
  - E.g, qemu-img create -o backing_file=master_image.qcow2 -f guest1.qcow2 10G

- Initially, the size of
  - guest1.qcow2 is 0 bytes.
  - backing file (master_image.qcow2) is (say) 10 GiB.

- For writes, KVM will write the changes to the guest1.qcow2. The file master image.qcow2 is never written to.

- For reads, KVM will read the block from the master image.qcow2 or guest1.qcow2 (whichever is latest).

Cloud Block Storage System

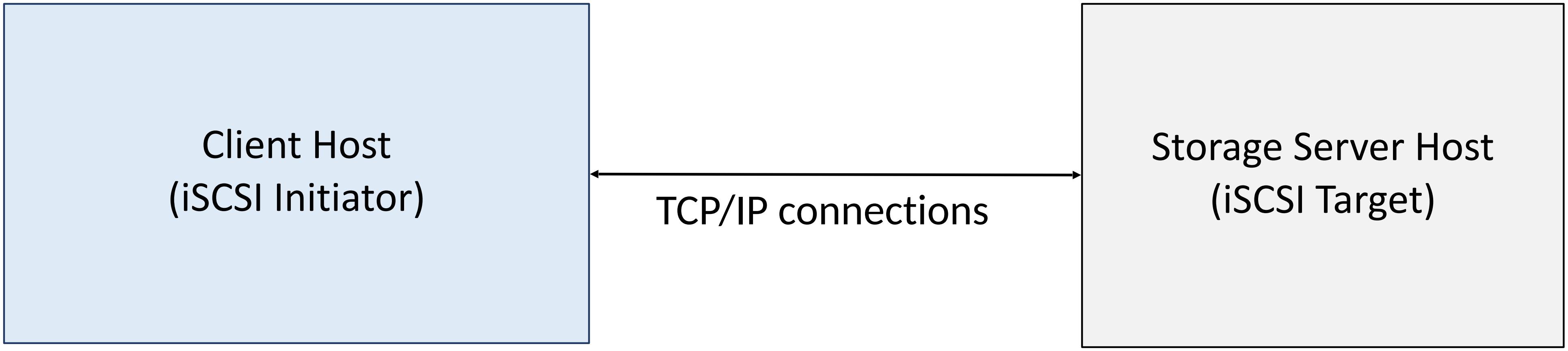


Storage Area Network (SAN)

- Dedicated high-speed network interconnects and presents shared pools of storage devices to servers. (e.g., Fibre Channel)
- Light-weight solution: Protocols: iSCSI – Reuse Ethernet Network (by encapsulating SCSI commands into IP packets that don't require an FC connection)

iSCSI

- iSCSI is a Storage Area Network (SAN) protocol that allows for SCSI command transmission over a TCP/IP network
- iSCSI allows for the sharing of I/O devices over a long distance.
- iSCSI maintains the SCSI notion of an Initiator and Target device



Client Host
(iSCSI Initiator)

TCP/IP connections

Storage Server Host
(iSCSI Target)

Data Deduplication

- Duplicate data is deleted leaving, only one copy of the data to be stored.

- Compare new data block to existing data blocks.
  - If contents of new block are unique then store it in the disk.
  - But if it is a duplicate of existing blocks then don’t store again but create a reference.

- Only one unique instance of the data is retained on storage media (e.g., disk). Redundant data is replaced with a pointer to the unique data copy.

Deduplication Methods

- In-line deduplication:
  - Hash calculations are created as the data is entered in real time.
  - If the target device identifies a block that has already been stored then it simply references to the existing block.

- Pros: Inline deduplication significantly reduces the raw disk capacity needed in the system since the full, not-yet-deduplicated data set is never written to disk

- Cons: However, “because hash calculations and lookups takes so long, data writes can be slower thereby reducing the backup throughput of the device.”

- What is off-line deduplication?