CS-452/552 Introduction to Cloud Computing

Storage Virtualization

Data Storage Systems

Data can be stored in various places in different manners

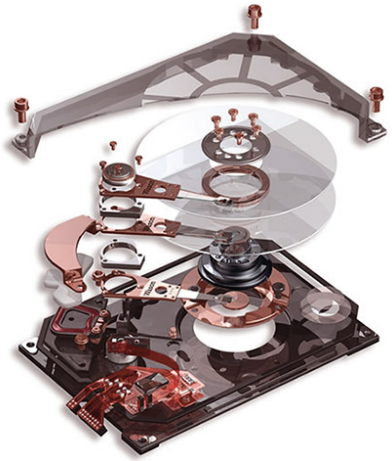
--- Hardware: CPU registers, caches, main memory and persistent storage

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

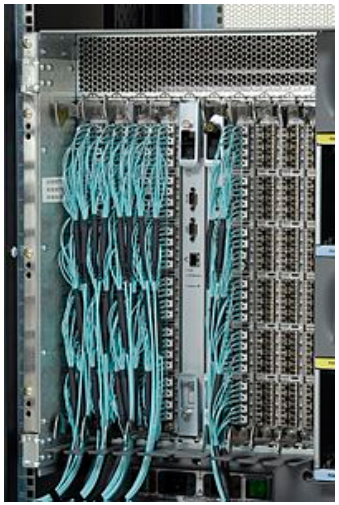
Storage I/O system within a single host

Persistent Storage media

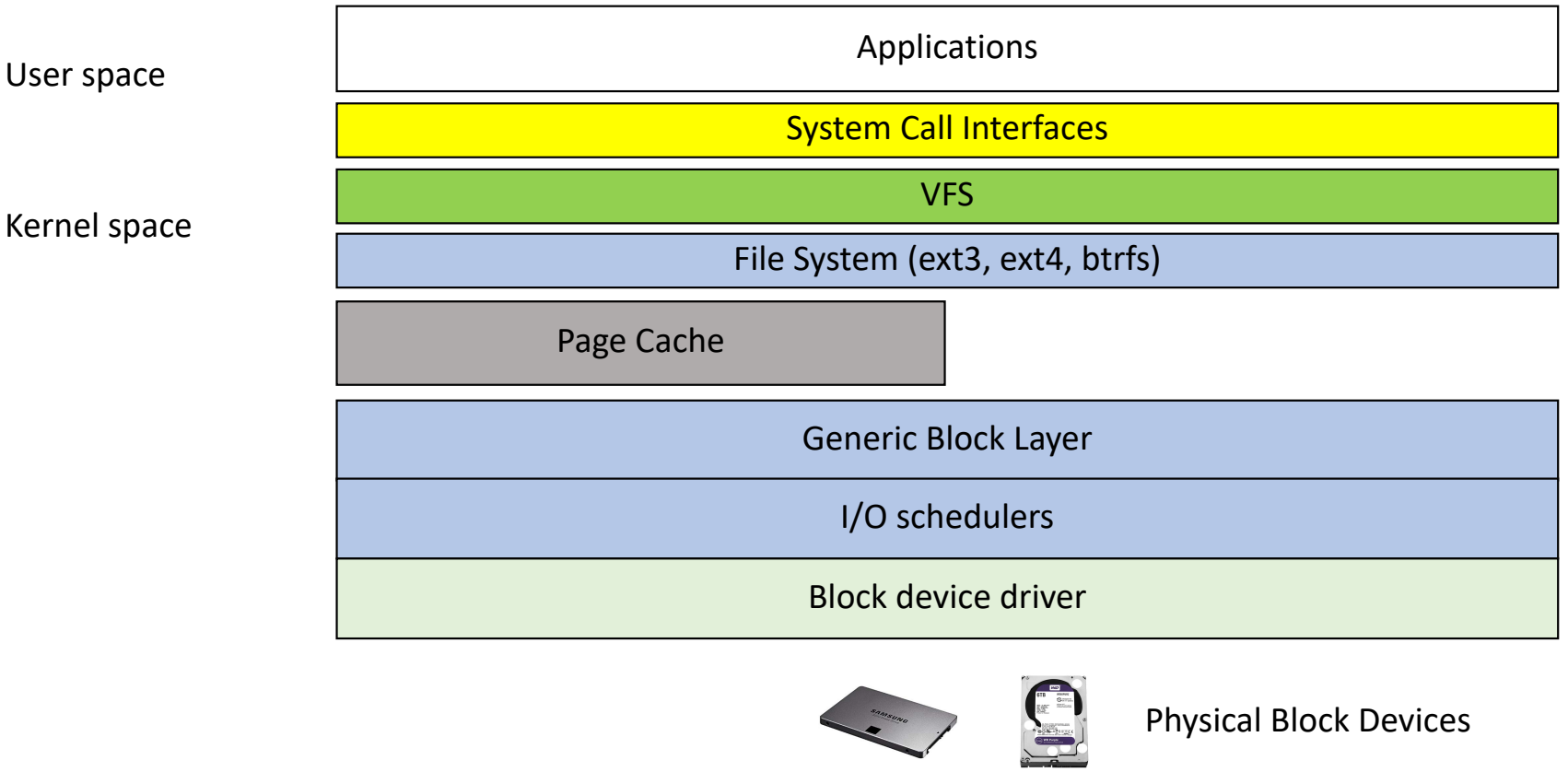
FLASH



HDD OR DISK DRIVE

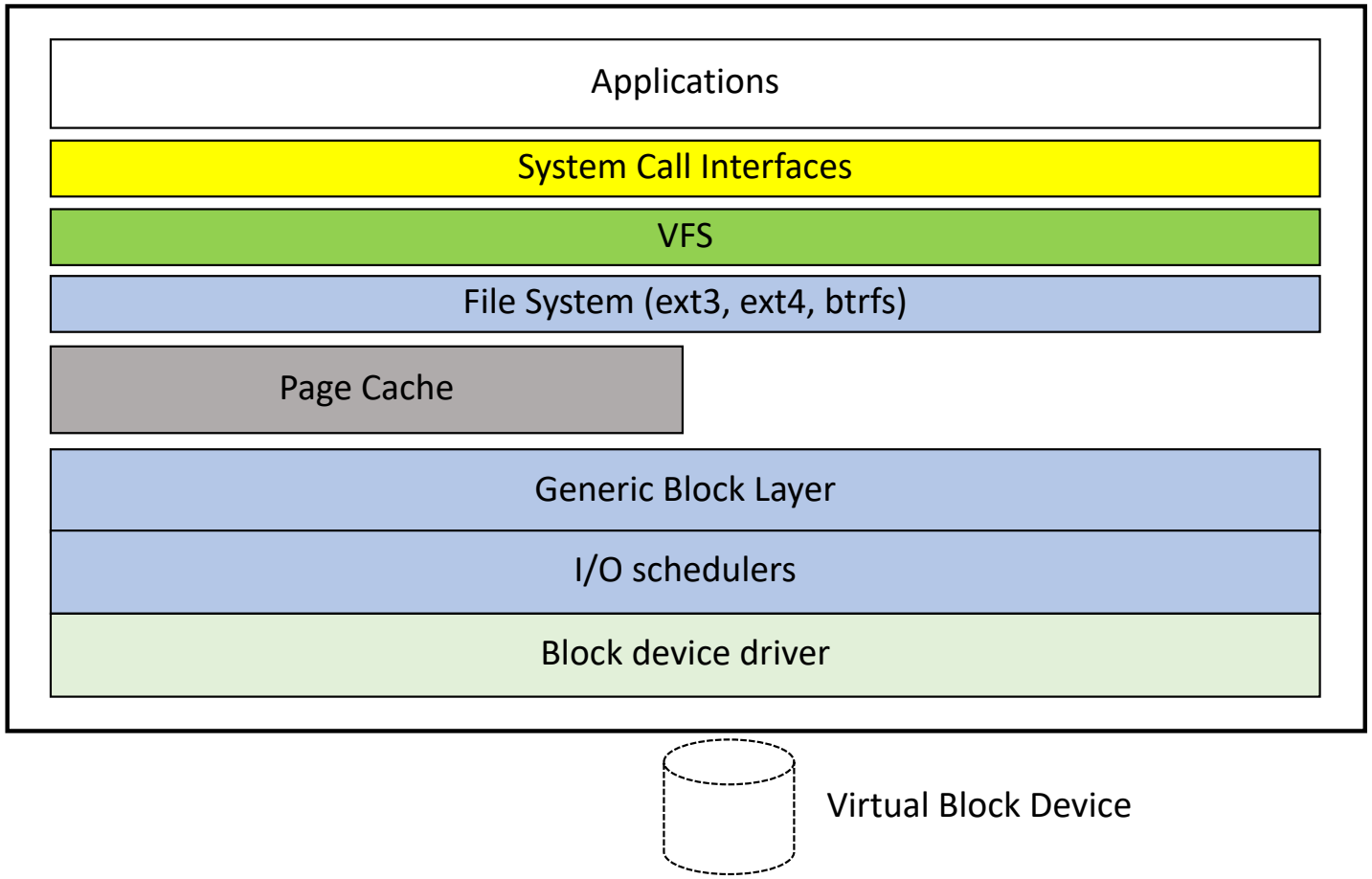


I/O layers within a single host

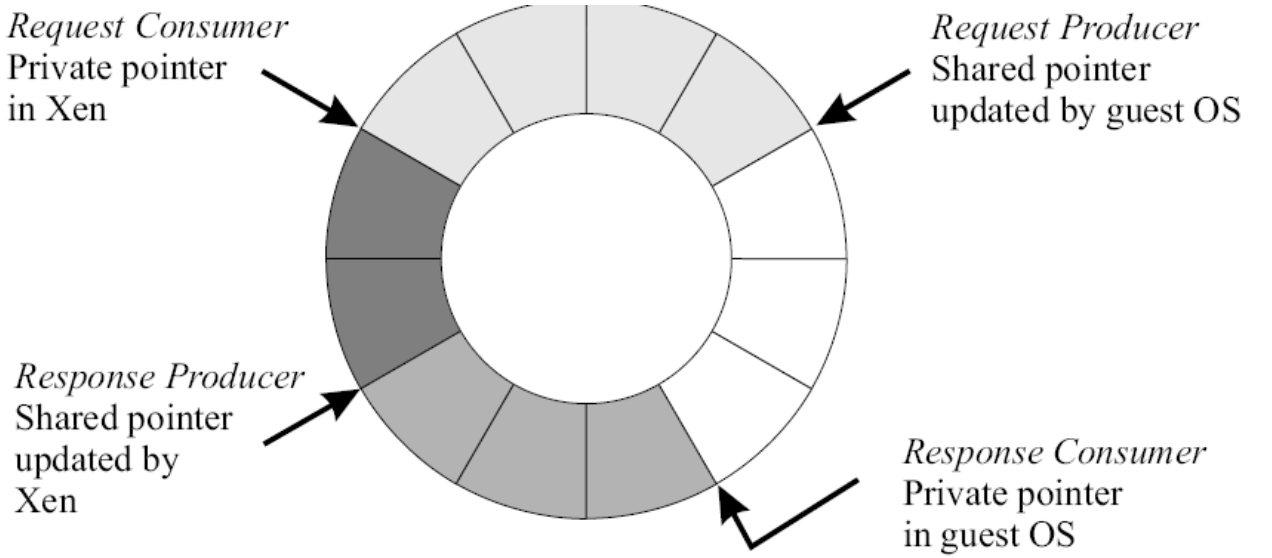


I/O layers within a VM

VM1



I/O Rings



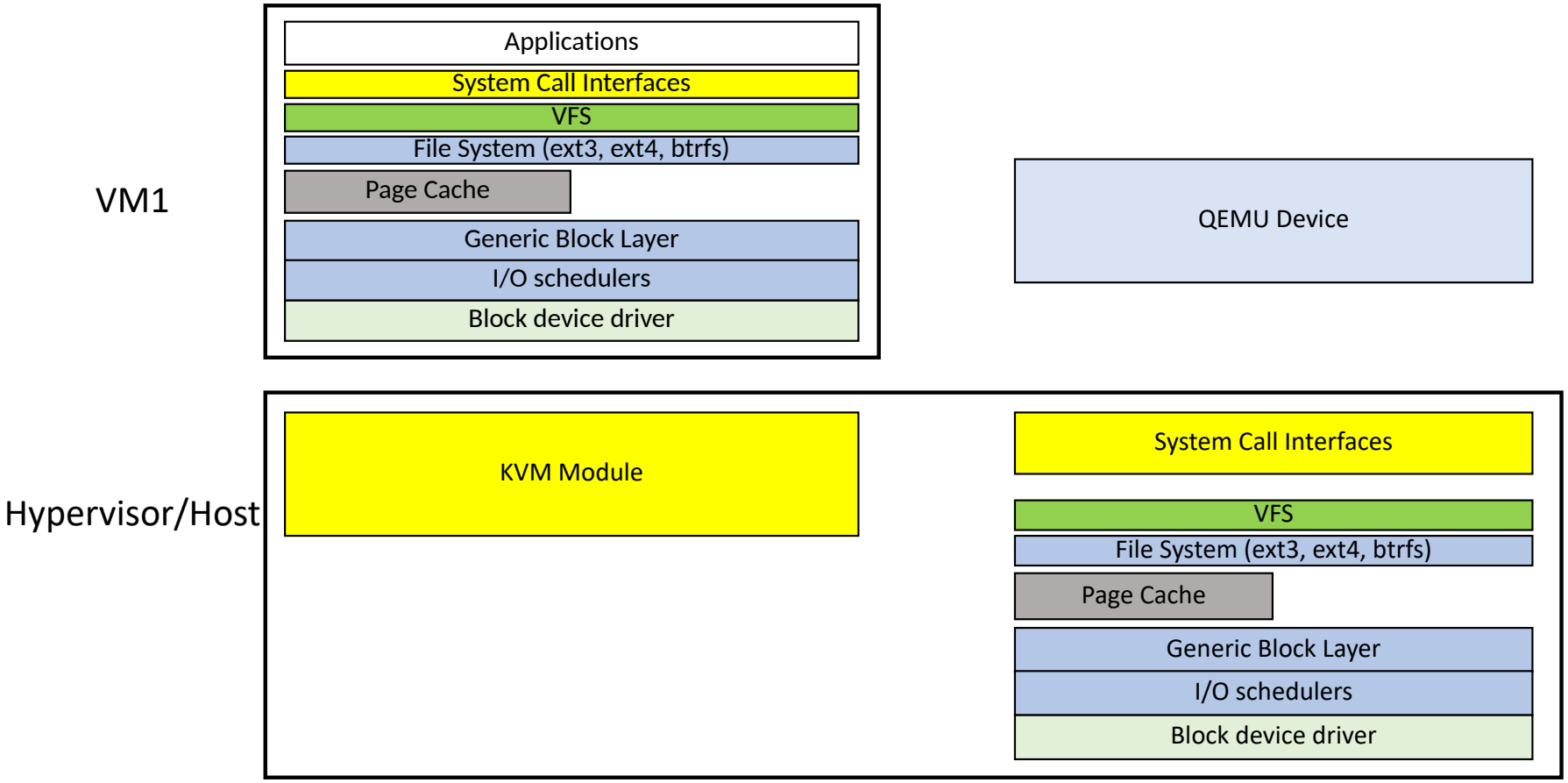
Request queue - Descriptors queued by the VM but not yet accepted by Xen

Outstanding descriptors - Descriptor slots awaiting a response from Xen

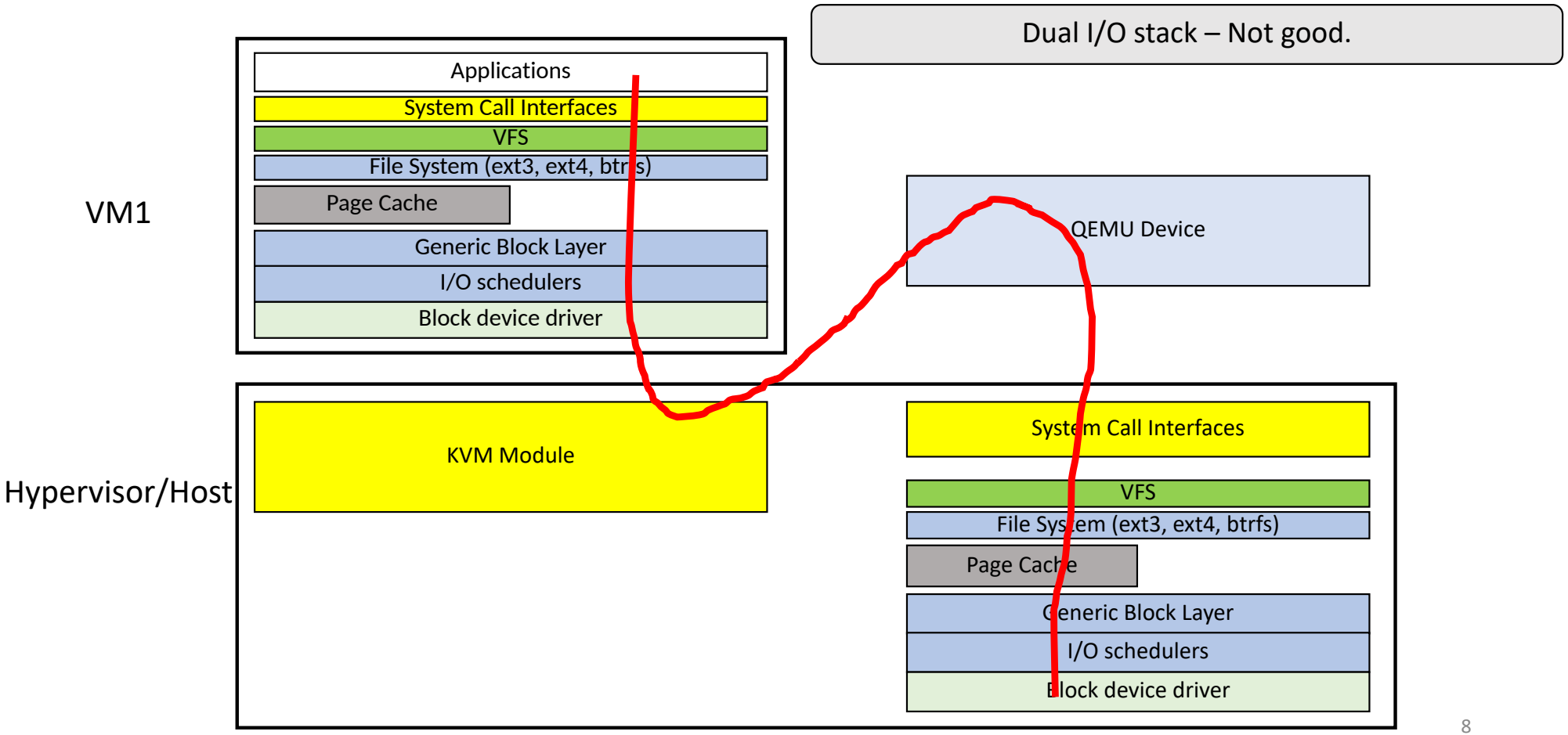
Response queue - Descriptors returned by Xen in response to serviced requests

Unused descriptors

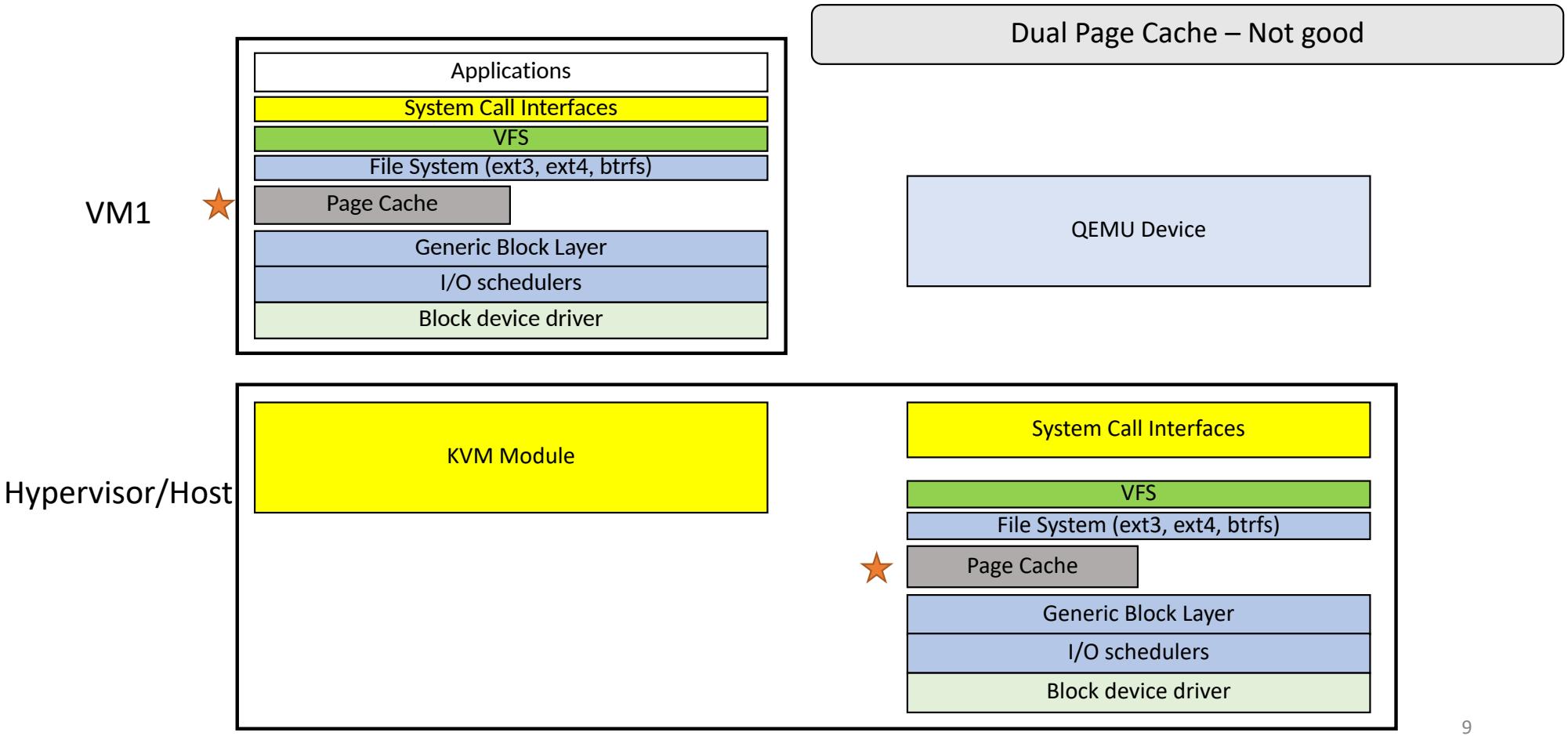
I/O layers in Virtualization



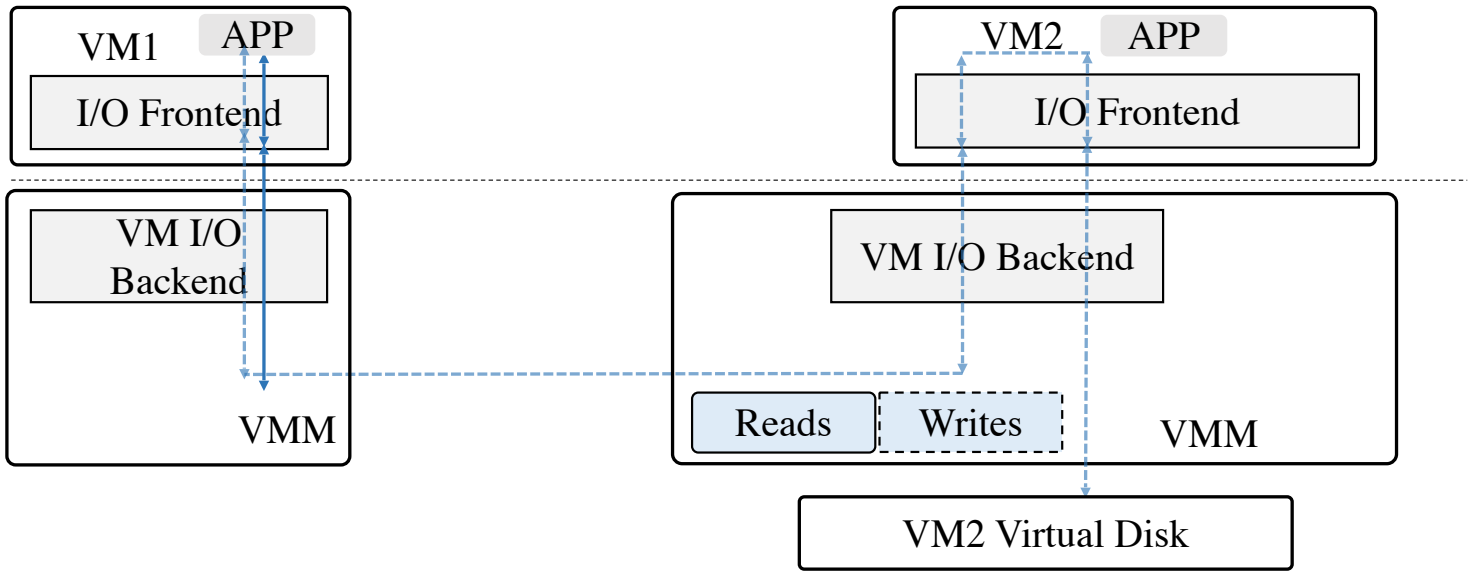
I/O layers in Virtualization



I/O layers in Virtualization

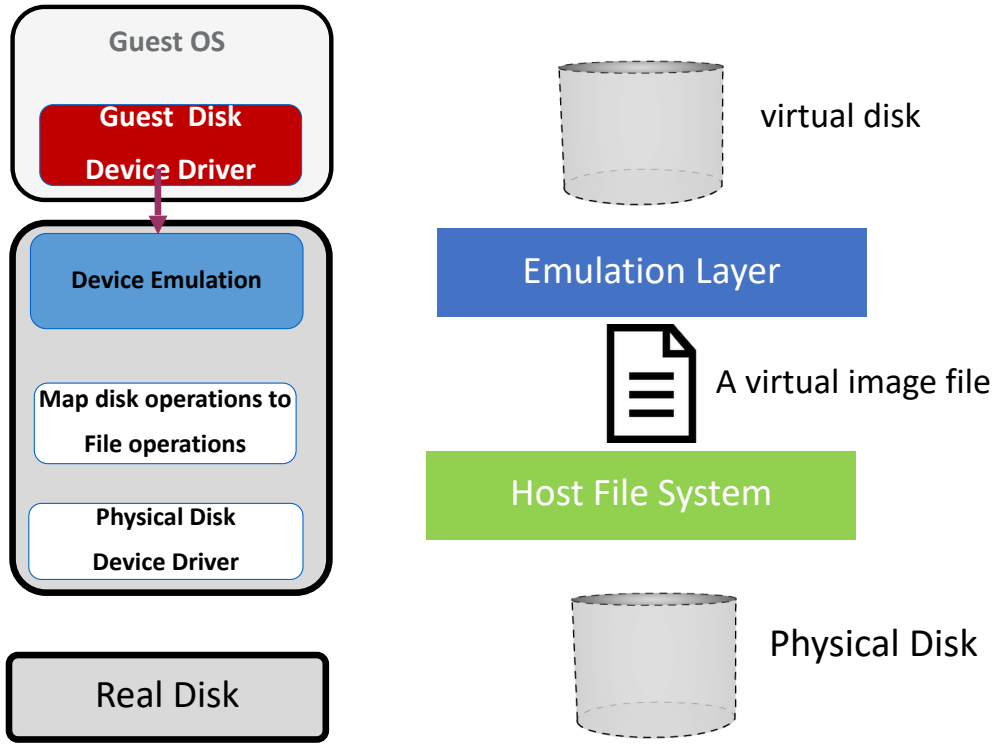


I/O Data Plane Redundancy



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

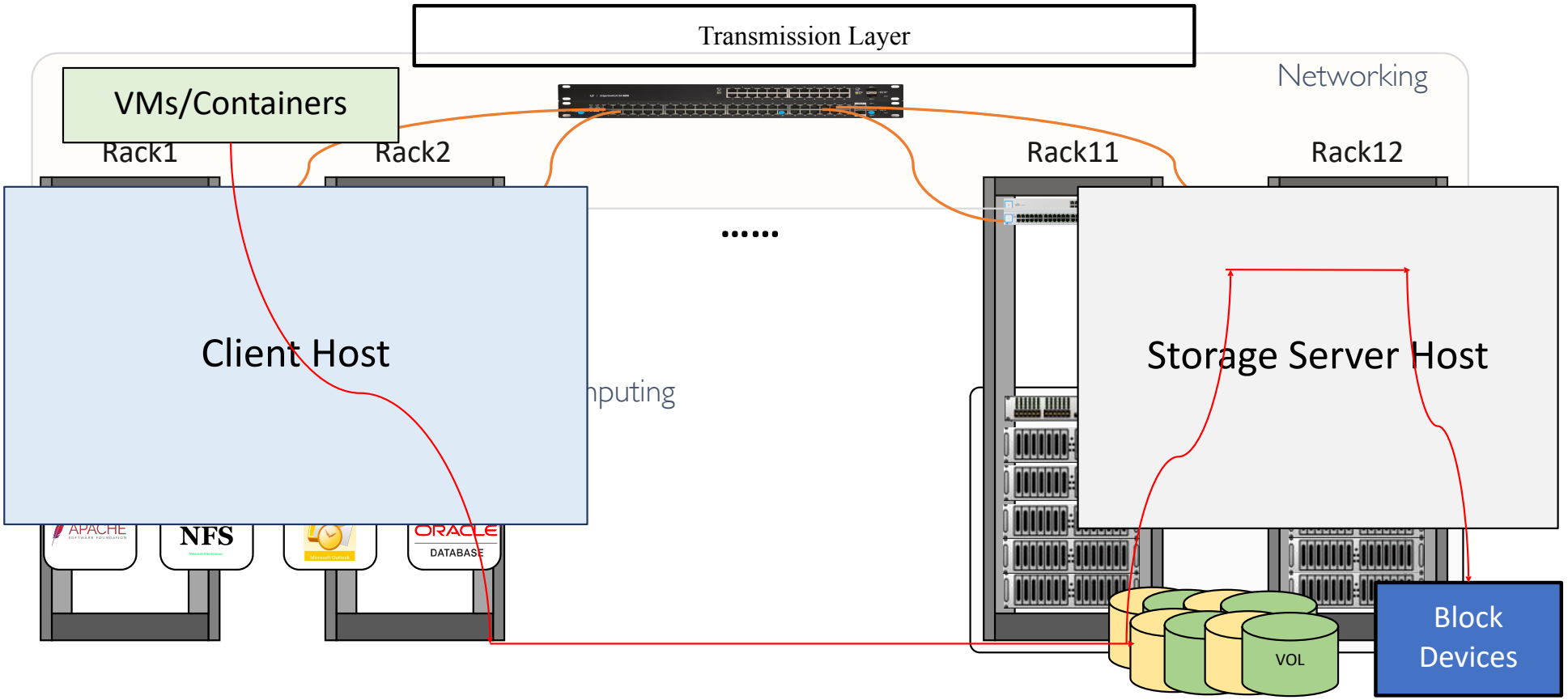
- QEMU-KVM’s “QCOW2” (Qemu Copy On Write, v.2) format (extensible)
  - Grow-on-demand
  - Compression support
  - Encryption support
  - Copy-on-write!

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.

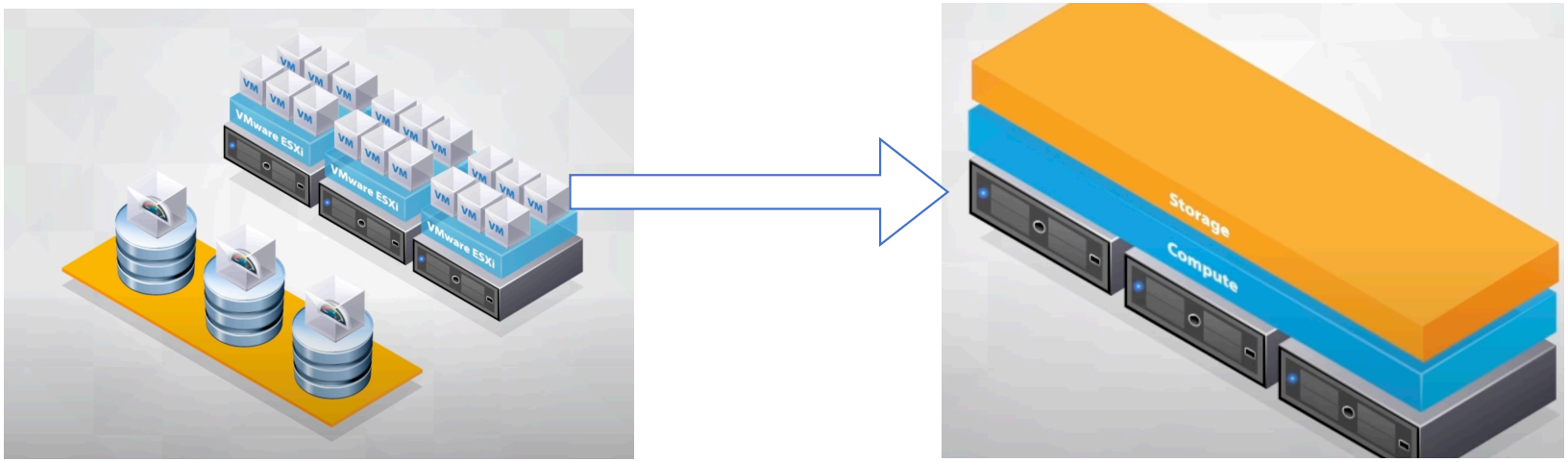
- Copy-on-write:
  - Write delta and store somewhere else (don’t modify the original copy)

Cloud Block Storage System

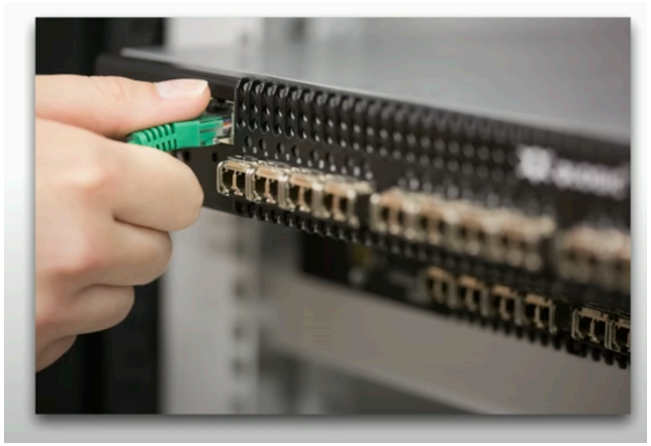


Storage Area Network (SAN)

- A network which provides access to consolidated, block-level data storage.
- Looks and feels like a local block device
  - But unlike local hard drive or SSD, the “server” has to access storage over the network
- Access control (LUN masking)
  - needed to restrict which server can access which storage device
- Accessing storage over the network uses a lot of network bandwidth
  - Usually a dedicated/Isolated network for best performance and least interference.



Fiber Channel (FC)



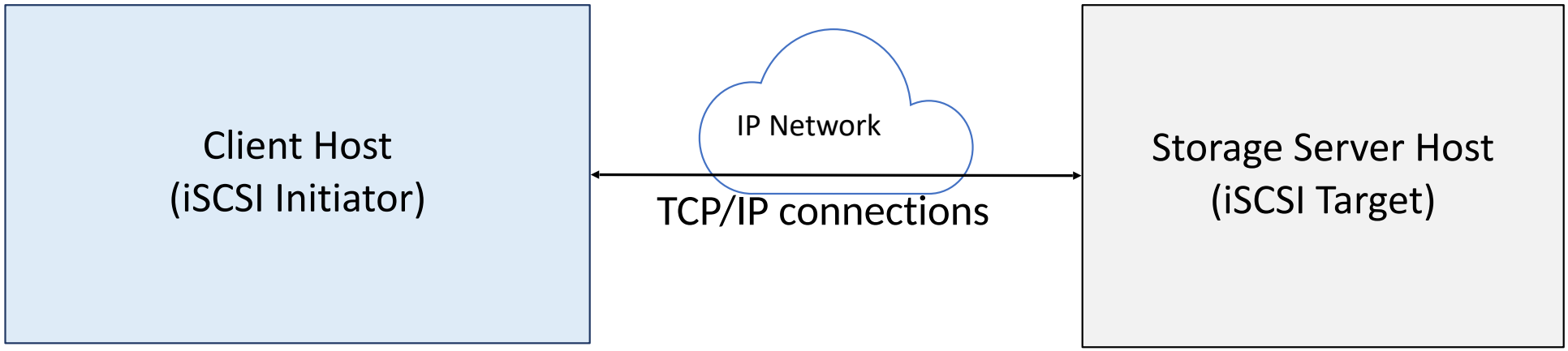
- Specialized high-speed SAN interconnect
  - 2/4/8/16 Gbps data rates (more now?)
- Can use both optical fiber and copper
- Storage devices and servers are connected to a FC switch
  - Server (initiator) needs a FC interface
  - Storage (target) is connected via traditional SCSI, SAS, or SATA interfaces.
- For the end user, these look like locally connected drives.

Fiber Channel over Ethernet (FCoE)

- Use FC over an Ethernet network.
  - No specialized network hardware required
  - Ethernet means a single broadcast domain with no routable information.

iSCSI (Internet Small Computer Systems Interface)

- iSCSI is a Storage Area Network (SAN) protocol that allows for SCSI command transmission over a TCP/IP network
- Similar to FC, iSCSI allows for the sharing of I/O devices over network using SCSI commands.
- Reuse Ethernet Network by encapsulating SCSI commands into IP packets that don't require an FC connection.
- iSCSI maintains the SCSI notion of an Initiator and Target device
- Just another protocol created by IBM and CISCO and now an RFC standard



Network-attached storage (NAS)

- File-level (vesus block-level storage) storage server accessed over a computer network.
- Networked appliances that contain one or more storage drives
- NAS provides both storage and a file system.
  - SAN provide only block-device access.
  - NAS = file server, SAN = disk over network
- Provide access to files using network file sharing protocols such as NFS, SMB, or AFP.

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?

References

- SAN: https://en.wikipedia.org/wiki/Storage_area_network
- NAS: https://en.wikipedia.org/wiki/Network-attached_storage
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