1. Identify Performance Bottlenecks in a Data Pipeline
Scenario:
You are building a data ingestion pipeline that continuously collects log data from edge devices and writes it to a central storage system. The system needs to process millions of small log entries per second.
Objective:
Determine whether Latency, Throughput, or IOPS is the most critical factor in selecting the right storage backend.
Guidelines:
• Estimate average log size (e.g., 1KB).
• Calculate expected write operations per second.
• Research SSDs/HDDs with high IOPS performance.
• Justify your choice of storage.
Expected Outcome:
• Which of the factor is primary concern & why?

Primary Concern: IOPS (Input/Output Operations Per Second):

workload issues (1-2) **million** writes/sec. Even if throughput is met, we need enough discrete I/O operations per second to avoid queuing.

If average log size is 4KB , we will need IOPS of (4 x 1 million) writes/second minimum. i.e.(almost 3.8Gbs/second).

HDDs cannot sustain this much high IOPS
SATA SSDs also cannot sustain
Only NVMe SSDs can sustain this

• Which factors is of the secondary concern & why?
Secondary Concern:
Throughput:

- PCIe 4.0 SSDs: 6-7GB/s sequential writes
- PCIe 5.0 SSDs: Up to 14GB/s

We see that PCIe NVMe SSDs can easily handle this much throughput.
SATA SSDs and HDDs fall short in throughput.

Latency:

Lower latency improves responsiveness and queuing, but if IOPS and throughput suffice, sub-ms vs. ms differences are less critical.

RECOMMENDED SSDs:

Enterprise NVMe SSD (PCIe Gen4/5)-Expensive

Enterprise SATA SSDs- cheaper than NVMes slightly lower performance but many brands with newer technologies offer much higher performance and little bit more affordable than NVMe's.

2. Designing Storage for a Machine Learning Model Training Pipeline
Scenario:
You are training a deep learning model on large datasets (e.g., image or video data). Training
jobs run on GPUs and frequently read large data batches from disk.
Objective:
Determine whether Latency, Throughput, or IOPS is most important.

Guidelines:
• Estimate dataset size (e.g., 100GB of images).
• Identify access patterns (sequential batch loading).
Different Types of Access patterns:
Sequential Access:Reading/writing data in contiguous blocks
Random Access:Non-contiguous data access
Strided Access:Regular, fixed-interval access
Shuffled Access:Randomized access within batches or across epochs.
Batched Access:Grouping data samples into batches for parallel processing

• Compare NVMe SSDs vs traditional SSDs or network storage.

Storage Type	Latency	IOPS (Random)	Throughput (Seq. Read)
SATA SSD	~100 µs	~30K–100K IOPS	~500–550 MB/s
NVMe SSD (PCIe Gen4)	<50 µs	700K – 1M IOPS	**3,000–7,000 MB/s**
Network storage (NFS/SMB)	1–10 ms	Variable (100s–1000s IOPS)	100–1000 MB/s (limited by network bandwidth)

• Choose a suitable storage architecture.
Expected Outcome:

• Which of the factor is primary concern & why?

Primary Concern:
Throughput:
Why?
Training pipelines load large batches of data from disk to feed into the GPU.
If throughput is low, the GPU will idle while waiting for data.
If the model takes 200 MB/sec of image data and disk only delivers 100 MB/s, GPU is underutilized.

• Which factors is of the secondary concern & why?

Secondary Concern: **Latency**
Why?
If batches are large (e.g., 64–256 images), a single read loads 10–50 MB, so access latency becomes a bottleneck over a large transfer.

IOPS
Since the access is largely sequential, (not random), IOPS (which measures small, random operations) is not the bottleneck.

Recommended Storage Architecture:
1st choice would be NVMe SSD (PCIe Gen4) - Expensive but best performance.
2nd choice would be SATA SSDs - budget option but could cause GPU underutilization.
3rd choice would be Network Storage(NFS)- requires very high internet speeds(10GBps networks).
4th choice could be HDDs also for budget constraints it can cause GPU underutilization.

3. Supporting Interactive Data Exploration in a Dashboard
Scenario:
A real-time analytics dashboard allows users to filter and visualize large datasets dynamically. Each query accesses small data chunks from storage with low latency requirements.
Objective:
Identify which storage performance metric is most important.
Guidelines:
- **Estimate number of dashboard users and queries per second.**
- **Understand read patterns (random, small queries).**
- **Consider memory caching and backend storage.**

Expected Outcome:
- **Which of the factor is primary concern & why?**

Primary Concern: Latency
Each user action issues a random read of a small data chunk. If read latency is high it can impact User interaction.

- **Which factors is of the secondary concern & why?**

Secondary Concern: IOPS
500 users at 5 QPS(Queries Per Second) each, that's 2,500 random reads/sec.
A device with only 10 K IOPS could handle this, but heavy usage spikes demand enterprise NVMe delivering 100 K+ IOPS is a safe choice.

Secondary Concern: Throughput

Total data volume per second (~MB/s) is low compared to modern SSD bandwidth. Even a SATA SSD's ~550 MB/s easily covers typical dashboard throughput, so it rarely limits performance.

4. Comparing Storage Options for Batch ETL Workloads
Scenario:
Your team runs a nightly ETL pipeline that processes 1TB of data over several hours. The job has no strict time constraints but must finish before the next day's job.
Objective:
Evaluate storage needs and performance considerations.
Guidelines:
- **Estimate average ETL duration and required read/write rates.**

Data volume: 1 TB = 1,024 GB
Time window: 8 hours = 28,800 seconds
Sustained throughput required:36 MB/s
need ~36 MB/s continuous read+write

- **Compare costs of high-throughput SSDs vs economical HDDs.**

Cost & Performance of Storage options

	Sequential TP	**Cost per TB**	
7200 RPM HDD	**80–160 MB/s**	**≈ $14 / TB**	**Cheapest, easily meets 36 MB/s; high latency, low IOPS**
SATA SSD (2.5″/M.2)	**200–550 MB/s**	**≈ $79 / TB**	**5×–15× faster throughput; moderate cost**
NVMe SSD (PCIe 4.0)	**3,000–7,000 MB/s**	**$100–150 / TB (gen4)**	**Overkill throughput; highest cost per TB but lowest latency/IOPS**

- **Analyze trade-offs between cost and speed.**

The more the throughput the more the cost.
HDDs are cheaper and NVMe SSDs are more expensive.

Expected Outcome:

- **Which of the factor is primary concern & why?**

Throughput:
ETL bottleneck is moving 1 TB in a fixed window.need sustained MB/s more than tiny-IO performance.an HDD's 80–160 MB/s is >2× our 36 MB/s need, so throughput is the gating metric.

- **Which factors is of the secondary concern & why?**

IOPS:
ETL reads/writes are largely large, sequential transfers; random IOPS (small-IOPS) matter far less. HDDs' ~100 IOPS are enough for metadata operations.

Latency:
Per-operation latency (ms) doesn't impact a long, streaming job—batch jobs amortize latency over large transfers.

RECOMMENDATION:
A modern 7200 RPM HDD (≈$14/TB) easily meets throughput needs and keeps your nightly pipeline within budget.

If we ever shorten our window (e.g., to 4 h → needs ~72 MB/s), a SATA SSD ($79/TB) still covers with headroom.

5. Design a Storage System for a High-Frequency Trading Platform

Scenario:

You are designing a backend for a financial platform where microseconds matter. It must

write market data updates and process trades in near real-time.

Objective:

Decide which metric dominates: Latency, Throughput, or IOPS.

Guidelines:

• Research time constraints in trading systems.

HFT profits depend on reacting to market events faster than competitors-often in microseconds or low milliseconds. Even a 1-millisecond advantage can translate into significant financial gains or losses.

Modern HFT systems target end-to-end latencies well below 100 milliseconds, with many aiming for single-digit microseconds for network and storage operations.

Market data updates, order execution, and trade processing must occur with as little delay as possible; any bottleneck in storage latency can result in missed opportunities or losses.

• Assess read/write operations during trading bursts.

• Consider in-memory databases or high-end NVMe storage.

Expected Outcome:

• Which of the factor is primary concern & why?

Primary: **Latency**

Every micro-/nanosecond directly delays your trade execution. HFT systems invest heavily in sub-100 μs (and even sub-10 μs) I/O paths.

Microsecond response is critical for profitability and competitiveness

• Which factors is of the secondary concern & why?

Secondary:
IOPS

must sustain bursts of 100 K–1 M tiny random writes/reads per second. Enterprise NVMe and in-memory can easily deliver this headroom.

Throughput:
Total data volume (MB/s) is small—hundreds of KB per message—so even modest devices can meet the requirements.

RECOMMENDATION:

In-Memory DB (e.g. kdb+, Redis):
estimated cost**-**
$267,750 / year(kdb+ enterprise)
$2,400 / year(redis enterprise)

Enterprise NVMe SSD:
estimated cost**-$144–200 / TB**

Since, we do not need Bulk storage NVMe SSD(PCIeGen5) are the optimal choice.