Big Data Technologies

Chapter 06

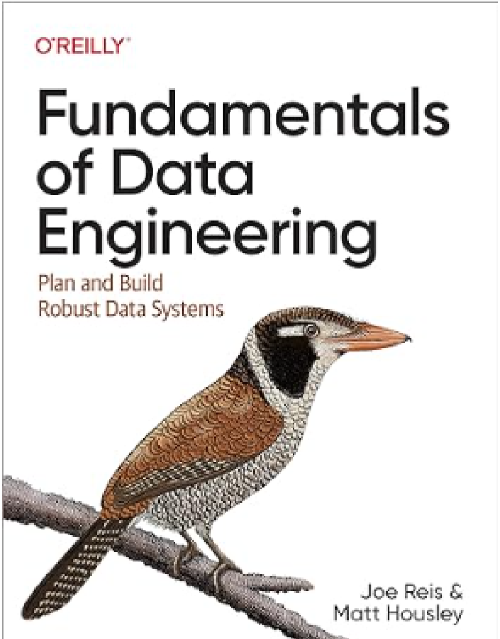
Fundamentals of Data Engineering

Storage

The Data Engineering Lifecycle in Depth

- Part II
  - Includes Chapters 5-9
  - Data Generation in Source Systems
  - **Storage**
  - Ingestion
  - Queries, Modeling, and Transformation
  - Serving Data for Analytics, ML, and Reverse ETL

Text Book


O'REILLY
Fundamentals of Data Engineering
Plan and Build Robust Data Systems
Joe Reis & Matt Housley

Objectives

- Discuss how storage is the cornerstone of the data engineering lifecycle
- Explain data access patterns
- Discuss how the undercurrents of data engineering apply to this phase of the data engineering lifecycle
- Discuss the impact of caching on storage and the data engineering lifecycle
- Discuss the major concepts of storage systems
- Discuss the major components of storage abstractions

Outcomes

At the conclusion of this lecture and lab you will have examined storage and a fine grain level and have examined the tradeoffs of different storage technologies. Next we will look at storage systems and then storage abstractions.

Review Chapter 1

- List the 5 stages of the Data Engineering lifecycle from Chapter 1?
- List the 4 technologies every data engineer should be familiar with?
- List the 5 business responsibilities of a data engineer
- List the 6 undercurrents to the Data Engineering lifecycle
- Which came first, Relational Database Model or SQL?

Review Chapter 2

- Define data life cycle management
- Discuss a Data Engineers relationship to business objectives

Review Chapter 3

- Defined data architecture
- Explain how data architecture sits fundamentally at the core of a business
- Explain 3 of the current data architectures

Review Chapter 4

- Discuss some of the trade-offs of using Opensource Software
- Explain the ideal time frame for how far to look into the future when making tech decisions
- Explain the concept of TCO
- Explain the concept of TOCO
- Explain the concept of Interoperability

Review Chapter 5

- Briefly explain the difference between Messages and Streams
- Briefly list 4 types of ways that data is created
- Briefly explain UTC and where it is used
- Briefly explain the difference between OLTP and OLAP

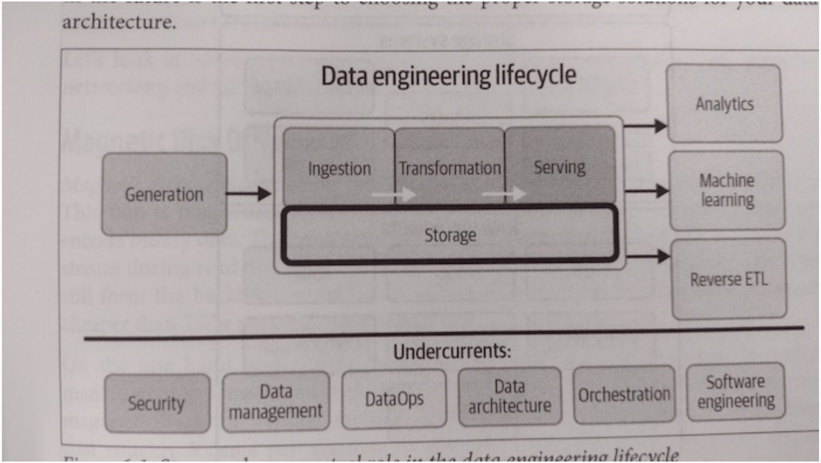
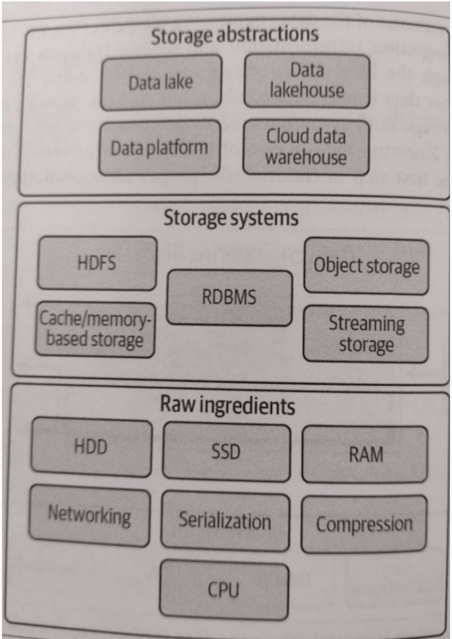


Figure 2: *Figure 6.1*

Storage, Storage Systems, and Storage Abstractions

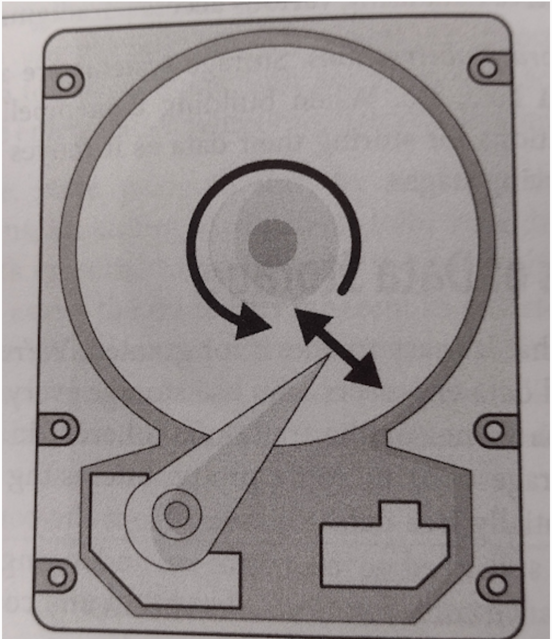


Raw Ingredient of Data Storage

- How and where is data stored?
  - Disk
  - What does it look like?
  - How is data accessed?
- Hard Drive - Hard Disk - Disk Drive
  - Magnetic Storage
  - SSD
  - NVMe SSD

Magnetic Disk

Magnetic Disk



Magnetic Disk

- Use spinning platters
  - Read/Write head writes +5 or -5 electrons to represent a 1 or 0
  - Bit per dollar cost very dense
  - WD Purple 10 TB
    - $227
  - WD Purple 22 TB
    - $599
  - So much storage that these HDDs have a little hard drive themselves on them for caching

Magnetic Disk

- Disk Transfer Speed
  - About 200-300 MB/s
  - How long to transfer a 22 TB disk?
- Seek Time
  - Time it takes for the rotating platters to rotate into the place to read the data
  - Disks spin 7200 RPMs
  - As much as 4 milliseconds per seek
- Other tricks such as Native Command Queuing (NCQ)
- Limited by the nature of the disk and the nature of the SATA transfer protocol

Solid State Drive

Figure 6: *SSD*

Solid State Drive

- Not spinning physical media
  - Uses Flash memory
  - No mechanical parts
  - Equal time to access each piece of data
  - Only .1 millisecond of latency
- Cost per byte not as good as spinning platters (HDD)
  - Densities not as highly available
  - Up to about 4 TB available
- Still limited by the transfer speeds of the SATA protocol

NVMe SSD

Figure 7: *NVMe SSD*

NVMe SSD

- Motherboard manufacturers realized that the disks could have faster I/O
    - Replaced the SATA connectors and protocol
    - Created an M.2 connector
    - Attached the SSD to this connecter
    - Connected the M.2 directly to the PCI Express bus
    - Which is running at near processor speed
    - PCIe has multiple lanes of data transfer (parallel)
- Your laptops have NVMe drives
    - Its how they get so thin

RAM

- RAM (Random Access Memory) or also known as Memory
  - Sits next to the CPU
  - Fastest thing on the system outside of the processor
  - The staging place for the CPU to consume data
  - Roughly $10 per GB
  - Computer has only so many slots for RAM
- Spark treats RAM as its working space
  - The more the better

Networking

- Sometimes network can be the bottleneck
  - Only so much data can flow over a single cable
  - Solutions such as faster network
    - 1 Gbps
    - 2.5 Gbps
    - 10 Gbps
    - 100 Gbps
  - Link trunking
- Change from Ethernet copper cable
  - Fiber optics

Data Compression

- We can overcome transfer rates when we compress our raw data
- Transfer the compressed data and let the client CPU decompress it
- Speeds up our overall Network Throughput

Caching

- Store frequently used or accessed data in a fast access layer
  - Slower the response time the cheaper the cost
  - Need to find a matrix of cost vs access time

Data Storage Systems

- Generally we are not building or running storage systems on a single laptop or PC
  - Usually we have a cluster of systems
  - There are ways to use the network to distribute the storage across many systems
  - This is a tradeoff to consider
  - Introduces Network latency
  - But allows for increasing amounts of storage

Object Storage

- We learned that Applications consume Object Storage
  - Over HTTP
  - This can be local or can be over the internet
  - Connecting to Amazon S3
- This leads to data being sent over the internet
  - But also leads to potentially everyone on the internet accessing at the same time
  - But the data hasn't had time to replicate over the internet
  - What to do?

Object Storage Consistency

- Two choices
  - Eventual Consistency
    - Not all reads return the same data
    - Eventually all replicas will be consistent
  - Strong Consistency
    - All data is replicated and of the same state before an update is made available

File Storage

- Basic hard drive storage
- Network Attached Storage
- Cloud based File Systems
    - Amazon Elastic File System

Block Storage

- Computers consume storage in blocks
  - A block is the smallest unit of data the the storage will allow a read for
  - Generally 512 bytes but up to 4K bytes
- Storage Area Networks (SAN)
  - Provide virtualized block storage devices over a network
  - Our virtual machines provide virtualized block level devices
- Amazon EBS
  - Elastic BLock Store
  - Allows for attaching of block devices in the cloud to attach to VMs
  - Data can be snapshot, migrated, copied to a new block storage

Object Storage Part II

- Immutable Data Objects
  - Byte streams
  - Not files
  - Independent of OS
  - Removes dependence on a local system
- Makes *Big Data* available for smaller organizations
  - Pay per GB

Brands of Object Storage

- Cloud
  - Amazon S3
  - Azure Blob Storage
  - Google Cloud Storage
- On prem
  - Min.io
  - Ceph

Object Lookup

- `s3://oreilly-data-engineering-book/data-example.json`
  - Bucket name is: `s3://oreilly-data-engineering-book/`
  - Object name is: `data-example.json`
  - Looks like a filesystem but its not
  - Its a Key Value pair

Objects Versioning

- Objects are immutable
  - But can be versioned
  - Store versions of an object
  - Can roll back or forward
  - Test different datasets
- Costs extra to store two versions of a dataset

Cache and Memory-Based Storage Systems

- Ultra-fast query systems
- Memcached and lightweight object caching
  - Store Key Values in memory layer
  - Quick access via API
  - Wikipedia uses this
  - Caching algorithms for determining what to keep
- Redis, memory caching with optional persistence
  - Can store complex data types (sets and lists)
  - Caching algorithms for determining what to keep

Hadoop HDFS

- Hadoop Filesystem
  - Stored data in 256 mb chunks
  - Optimized for queries using MapReduce
  - Triplicated these blocks over a cluster
  - Allowed for parallel processing of parts of a job
- Legacy technology
  - Still in use

Indexing

- In an RDBMS tables create `indexes`
  - Optimizes `where` clauses
  - Prevents complete table scans
  - Usually for Primary Keys
- Rows to Columns
  - Columnar Serialization
  - Not the traditional rows of an RDBMS

Columns vs Rows

- Columns are bad for transactional operations
  - Perform well when large amounts of data need to be scanned
  - Aggregations and statistical calculations
- Move from large tables
  - Create smaller partitions
  - Reduce the `scan` time
  - Scan only what we need – not entire records/rows
- Snowflake micro-partitioning
  - Preclude micro partitions that don't contain a `WHERE` clause

Data Engineering Storage Abstractions

- The questions needed to ask to support Data Analytics
  - Purpose and use case
  - Update patterns
  - Cost
  - Separate storage and compute

The Data Warehouse

- Standard OLAP data architecture (chapter 3)
    - Google BigQuery
    - Teradata
- An organizational pattern inside of a company
- Used for centralized analytics
- Can be on-prem or cloud based
    - Roll your own and cloud based services

The Data Lake

- Data is retained in stored in raw form
- Have your storage be in Object storage
- Have your compute be a separate system
- Bring the data to the compute

The Data Lakehouse

- An architecture that combines aspects of the data warehouse and data lake
  - Easy to exchange data between systems
  - Various tools can be used to connect
  - Apache Hudi
  - Apache Iceberg

Big Ideas and Trends in Storage

- Data Sharing
  - AWS EBS snapshots
  - Census
  - NASA
- Separate Compute from Storage

Data Storage Lifecycle and Data Retention

- Hot, warm, and cold data
- Data retention
- Data Value
- Compliance
- Overall cost of storage

Conclusion

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Additional Resources

- https://oxide.computer/podcasts/oxide-and-friends/1734108
- https://www.backblaze.com/blog/backblaze-drive-stats-for-2023/
- See page 235 for additional readings

Homework

- Read FDOE chapter 7

Questions?

- Any questions?
  - Discord always open