Introduction to Distributed File Systems in Hadoop

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Agenda

- Introduction
  - Lecture Info
  - Lecture Goals
  - References
  - Hadoop
- File Systems
  - How does File System Work?
  - Distributed File Systems
- Hadoop Distributed File Systems (HDFS)
  - Different Nodes
  - How Data is Stored in HDFS
  - HDFS Architecture
  - HDFS in Practice
  - Further Research Directions
- Summary

Lecture Info: Who am I?

- Instructor: Dr. Javad Ghofrani
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  - Office : Z902, Faculty of Informatics / Mathematics, Dresden University of Applied Sciences
  - PhD From TU Clausthal, Postdoc University of Hanover and HTW Dresden
  - Research Interests:
    - Distributed Systems and Architectures
    - Industrial Internet of Things
    - Software Product Lines
    - Artificial Intelligence

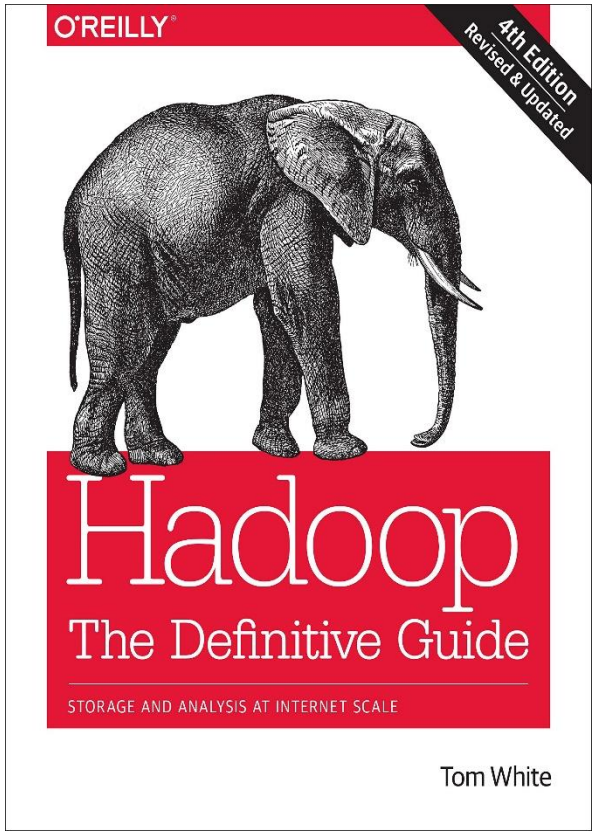
What this Lecture is About?

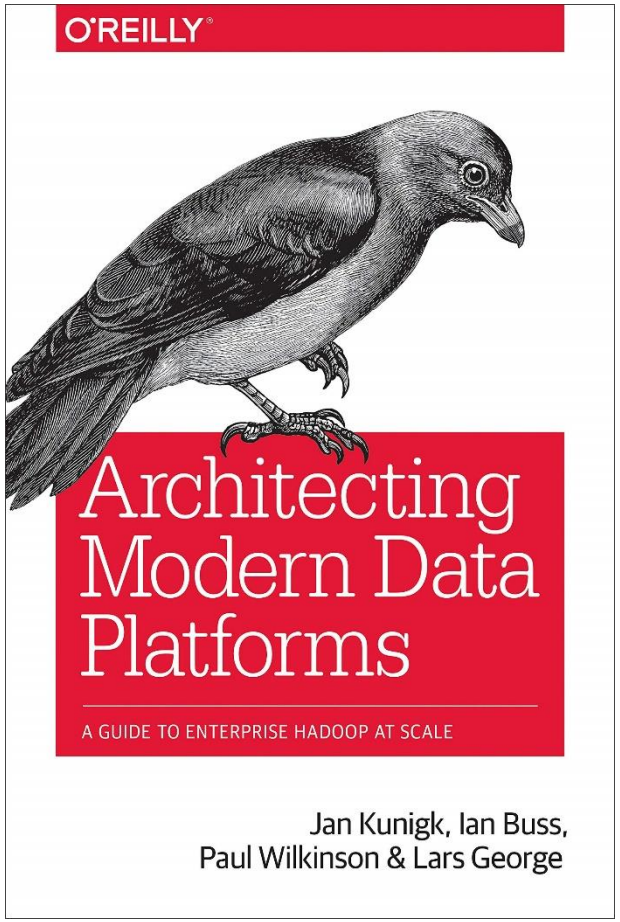
- 1: Concept of HDFS
  - Build a strong understanding of concepts of Hadoop Distributed File System in great details
- 2: Practical Aspects of HDFS
  - Get familiar with practical aspects of Hadoop Distributed File System
  - Do some practices in designing some real systems and architectures for storing data for parallel processing
- 3: Research Trends Around HDFS
  - Get familiar with the state-of-the-art in research around HDFS and related challenges

Introduction

References

Bit.ly/HDFS20





Introduction

Introduction

- The Hadoop Project is a Free reimplementation of Google's in-house MapReduce and distributed file system(GFS)[1]
- Originally written by Doug Cutting & Mike Cafarella, who also created Lucene and Nutch
- Now hosted and managed by the Apache Software Foundation

[1] Ghemawat, Sanjay, Howard Gobioff, and Shun-Tak Leung. "The Google file system." *Proceedings of the nineteenth ACM symposium on Operating systems principles*. 2003.

Introduction

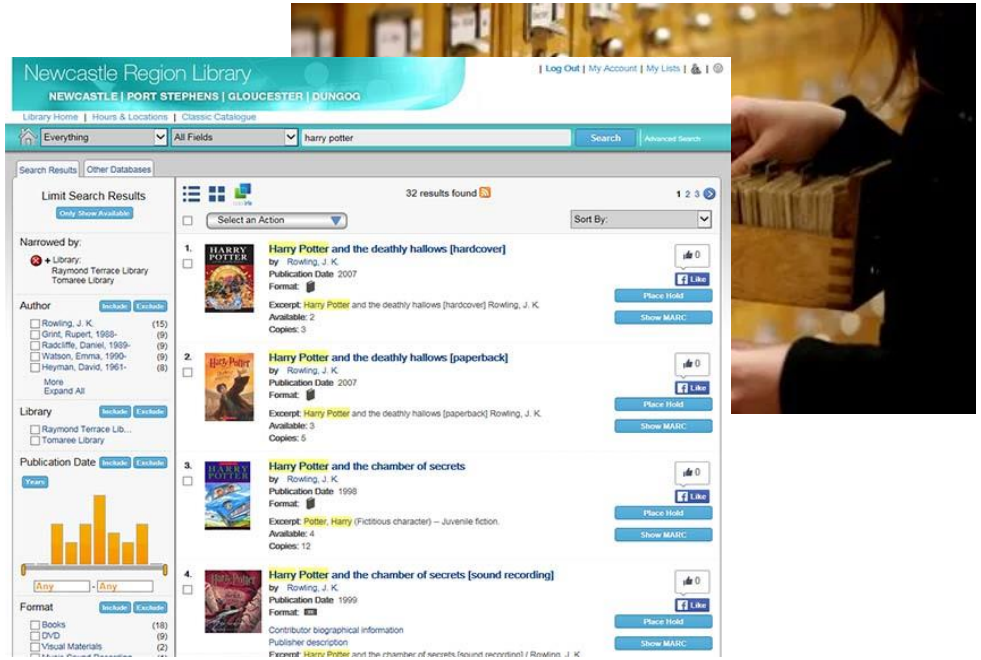
What does a File System mean?

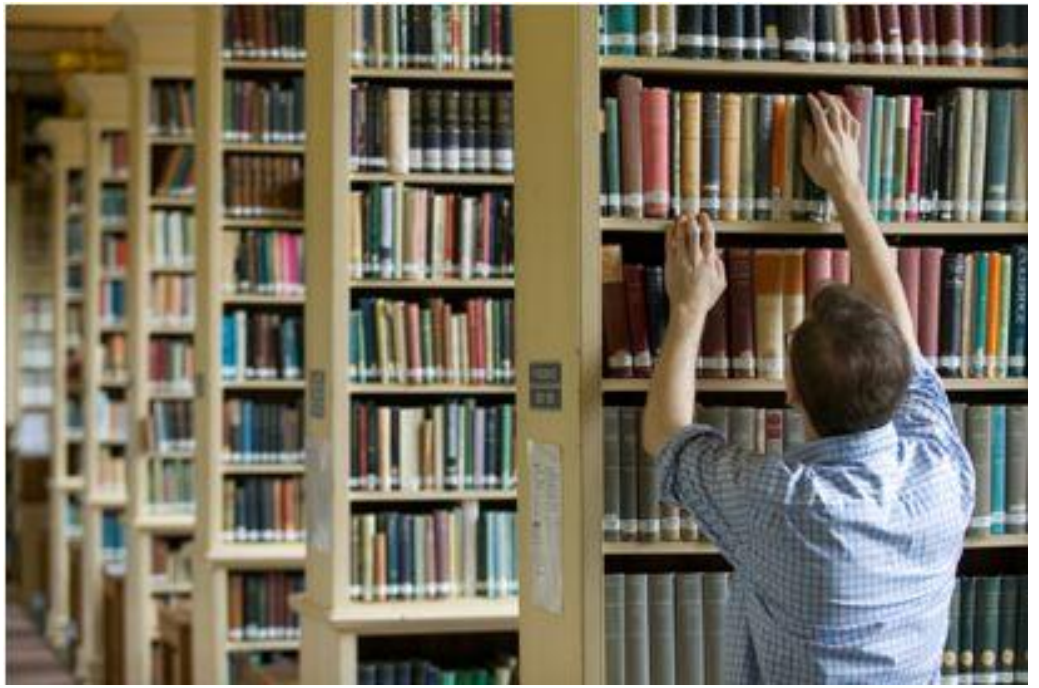
How does it work?

Introduction

- An example from daily life: Locate a book in the library
  - How to Find Books in a Library?

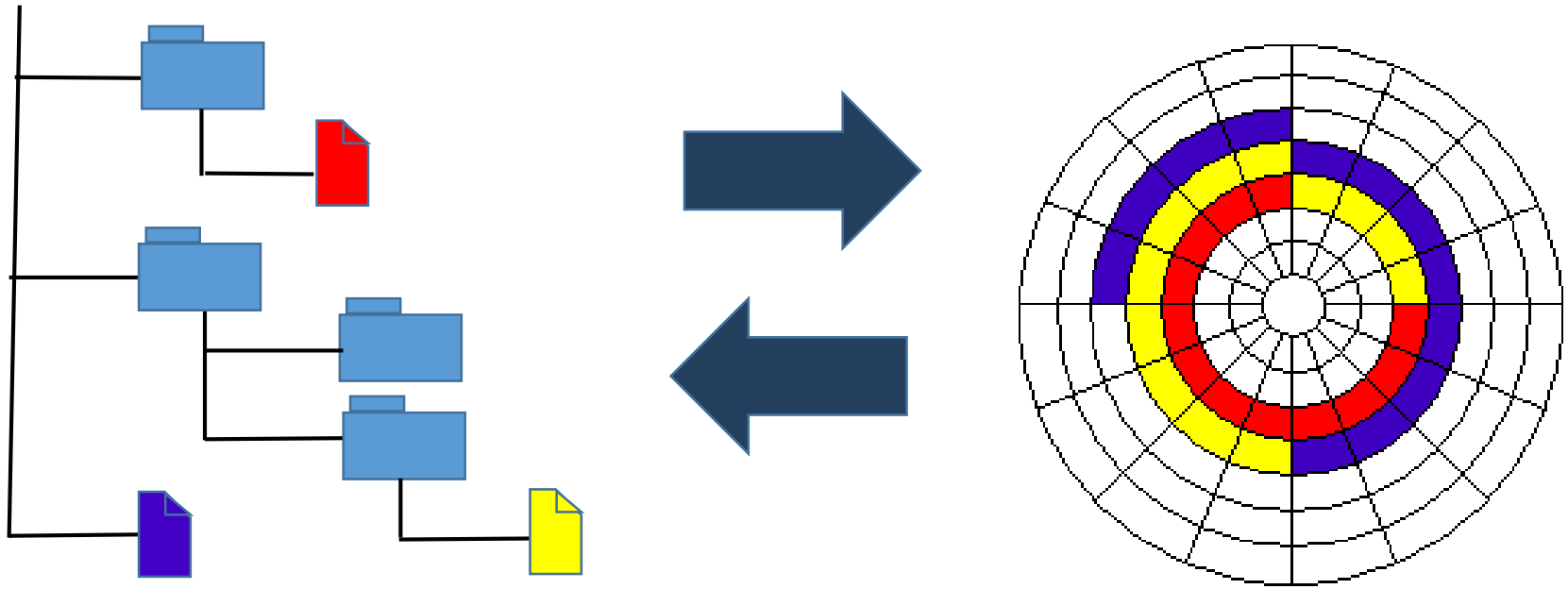
Searching the Catalogue!





File System

File System (often abbreviated to fs) provides an abstraction layer between logical and physical structure of the storage

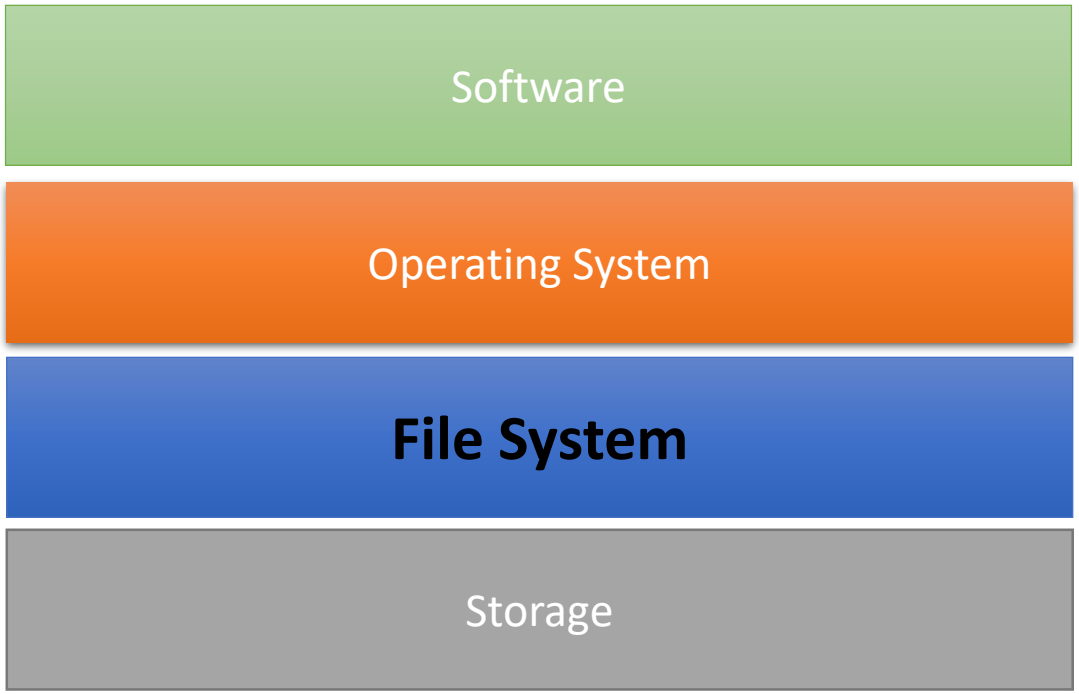


Logical Structure

Physical Structure

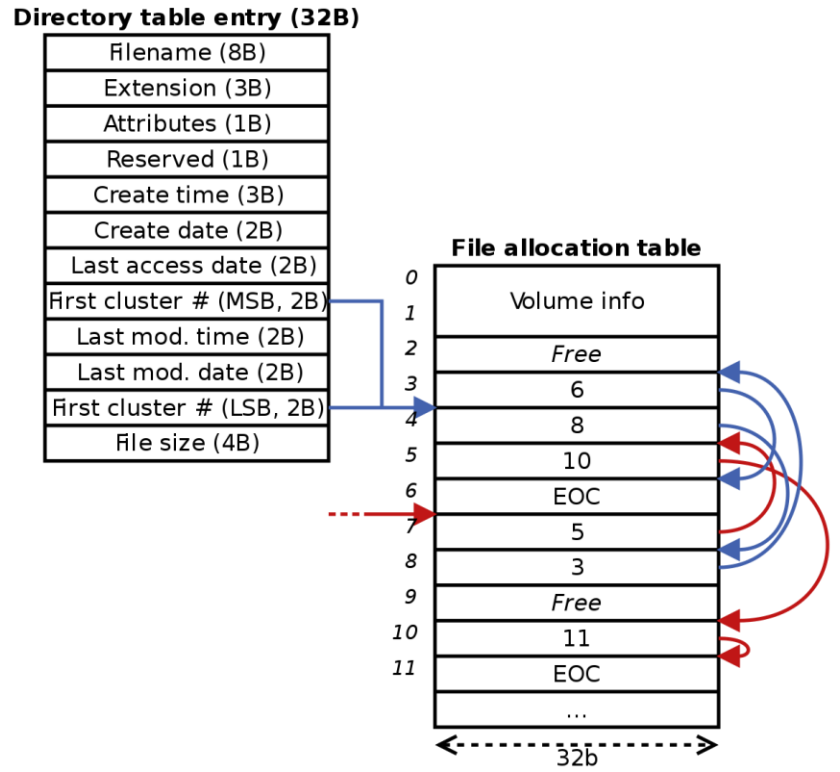
File System

- File System Describes how the data is stored on the storage
- Provides efficient and convenient access to disk
  - Create
  - Open
  - Read/write
  - Close
  - Delete



File System

- Metadata: information about files in file system
  - Information about files (e.g., path, name, type of file, dates of creation and modification, permission to access or change, etc.)
- Different features and properties
  - e.g., FAT 32, NTFS, ext* (ext2, ext3, ext4…), HFS+, XFS, JFS
  - different structure and logic



Discussion

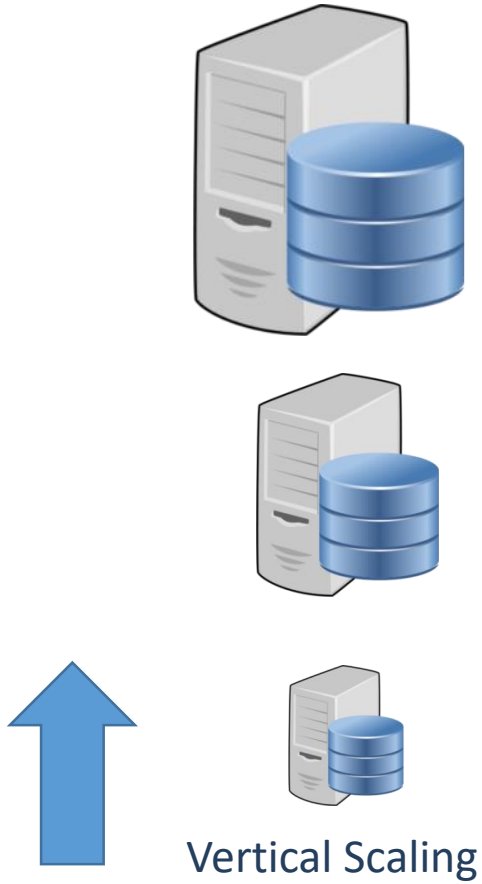
- Why we store the data?
- How we analyze the data?
- What if the size of the data is bigger than the capacity of our storage?
  - E.g., reviews on social networks, transaction of credit card holders

Solution

Huge Amount of Data
Requires
Larger Storage Space

Distributed File System

- How to provide more storage for big size of data?



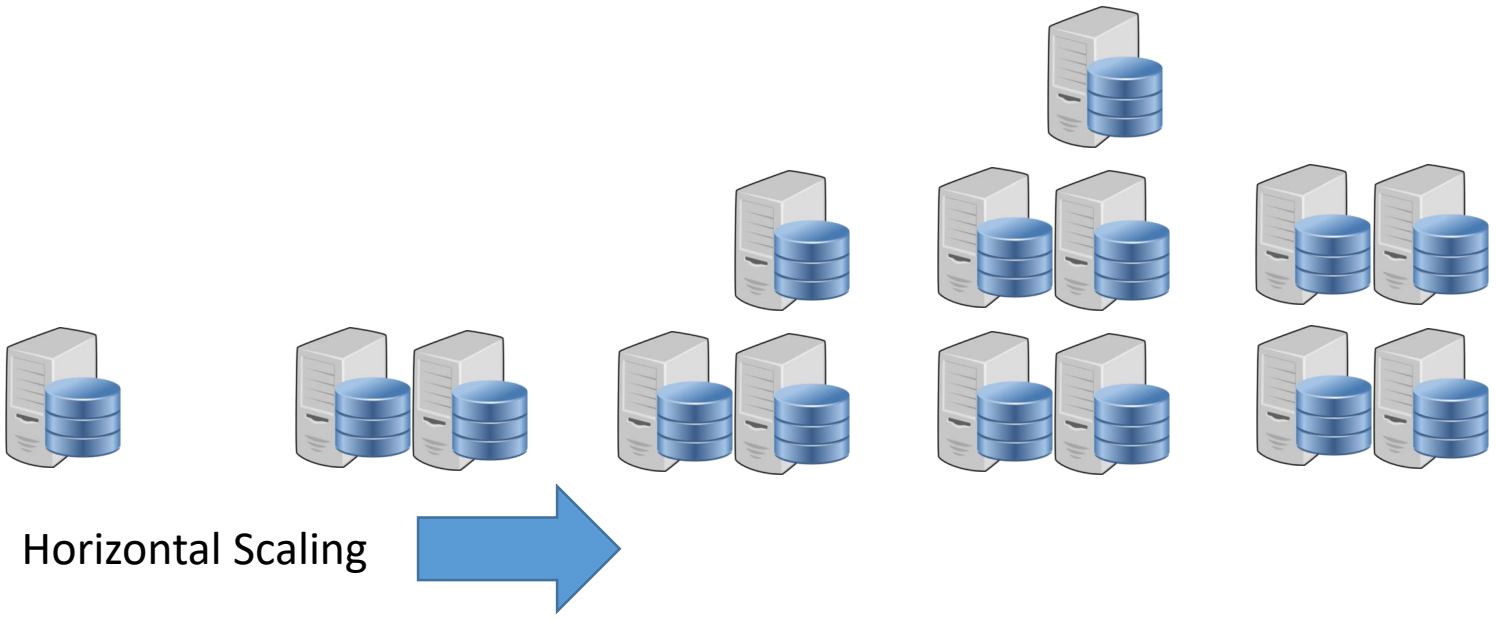
Vertical Scaling

Challenges:

- Reliability
- Maintenance
- Limited capacity
- Fast obsolete
- Optimal usage of resources
  - How to scale down?

Distributed File System

- How to provide more storage for big size of data?

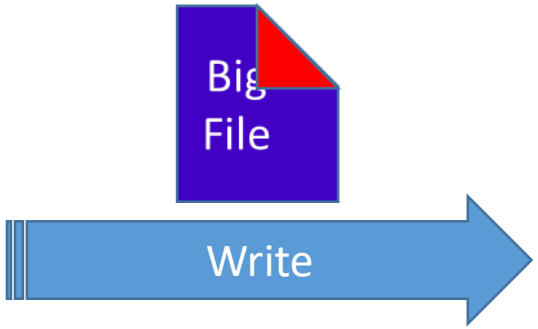


- Advantages
  - Flexibility and reliability
  - Resources optimization
    - Scale up/down
- Challenges
  - Transparency — Abstraction
  - Distribution of data and programs
  - Deal with network problems
    - Communication speed
    - Network failure

Distributed File System

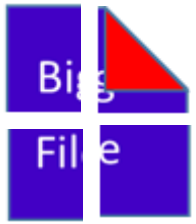
- Transparency — Abstraction

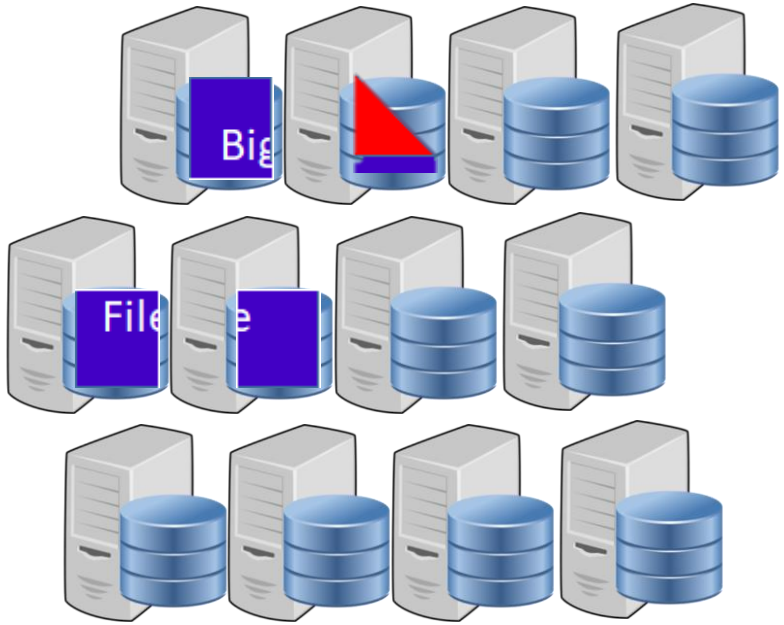
User or Program



Distributed File System (DFS)

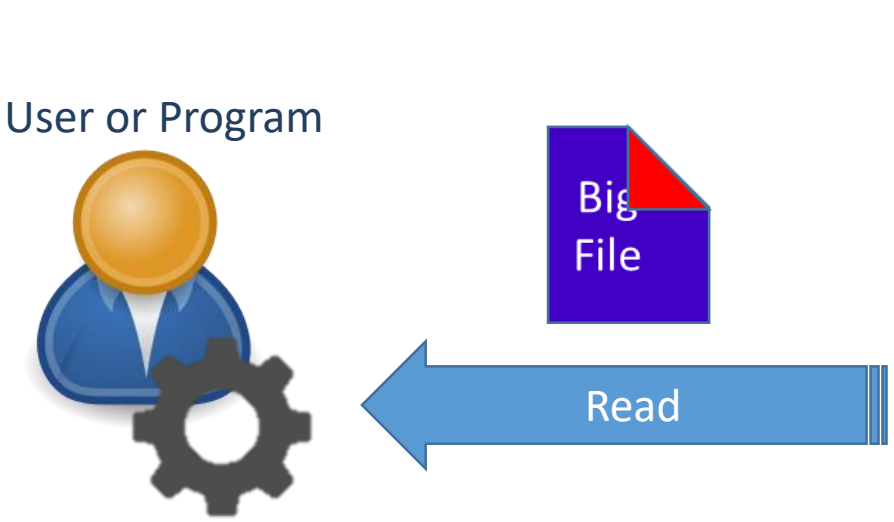
Splits large file into smaller blocks/ chunks and stores them on different locations

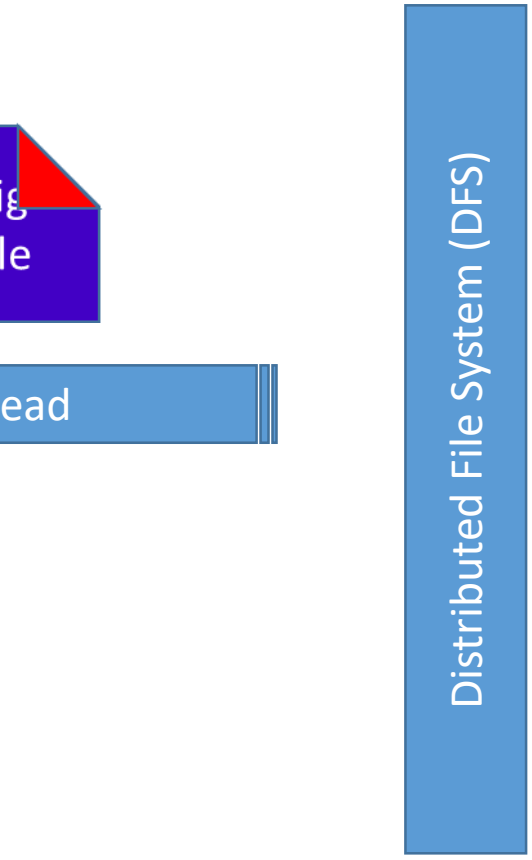




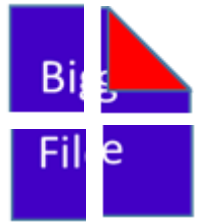
Distributed File System

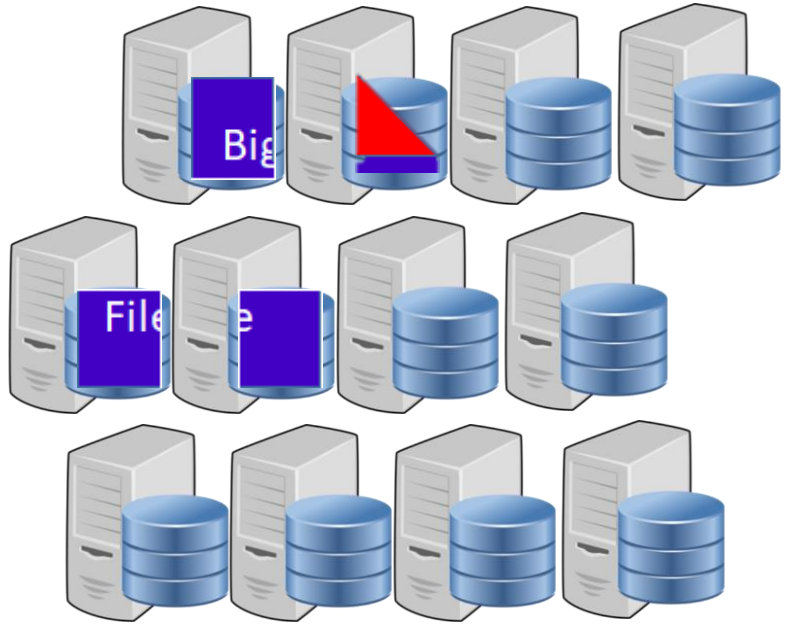
- Transparency — Abstraction





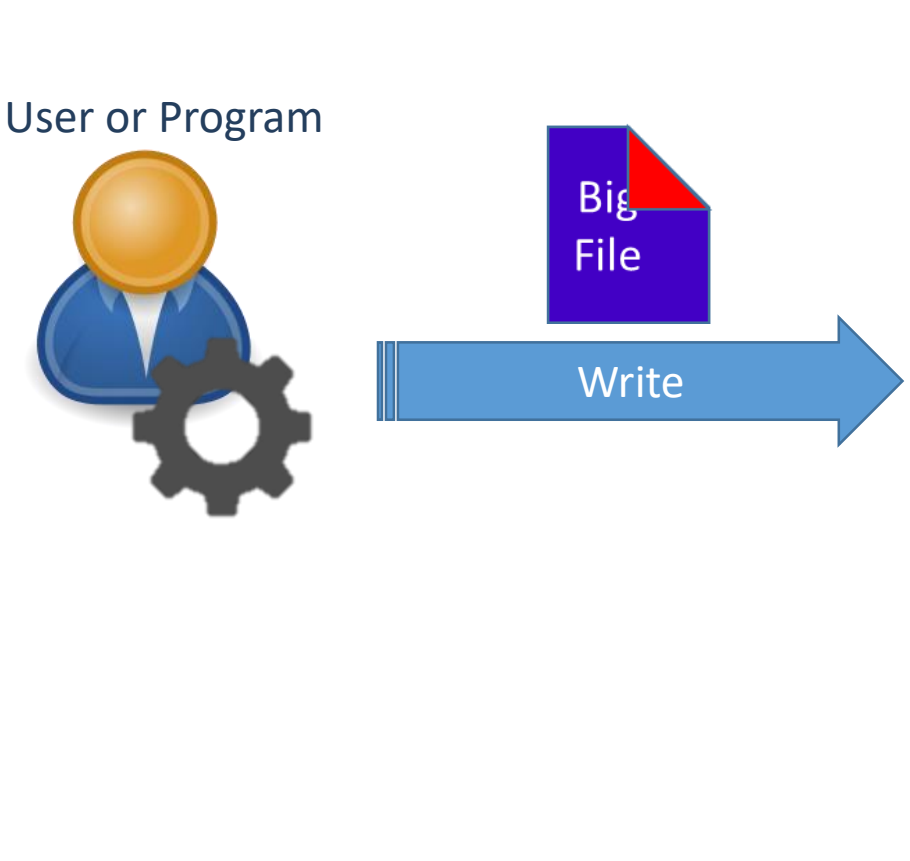
Merging smaller blocks/ chunks and create the big file



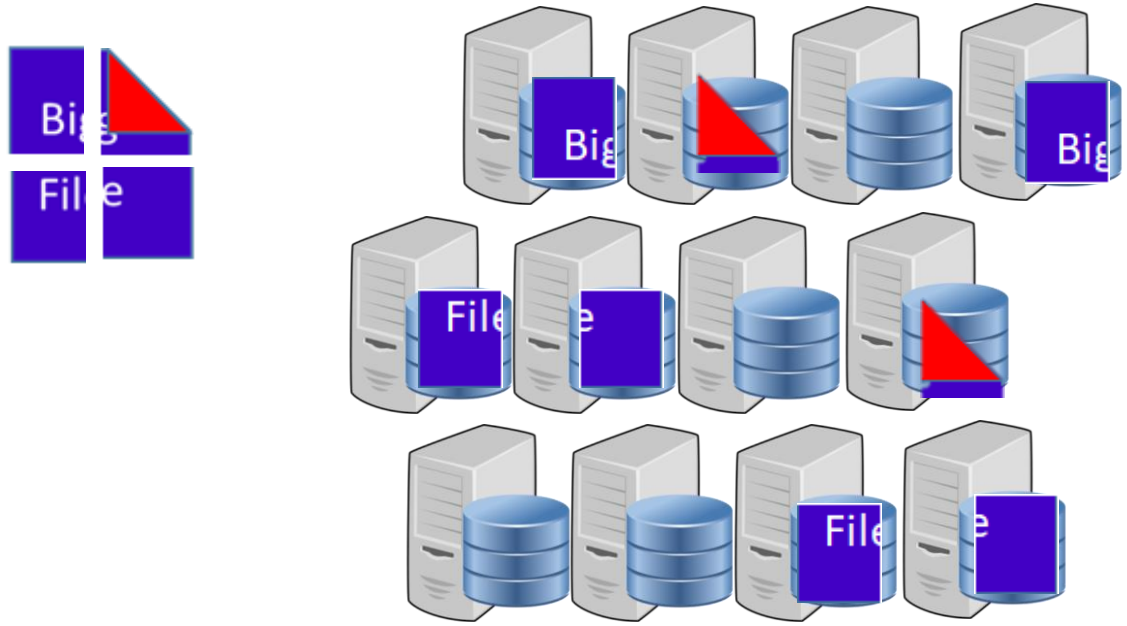


Distributed File System

- Reliability



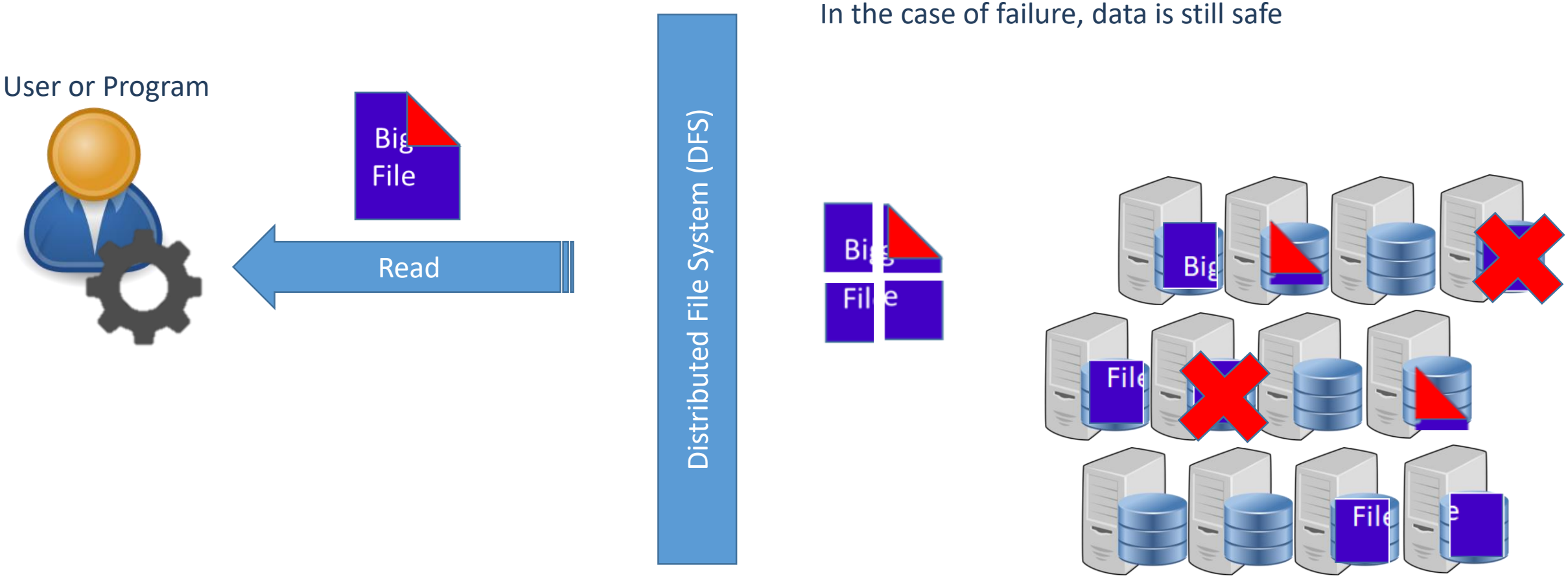
Split large file into smaller blocks/ chunks
Replicates them
and store them on different storages



Distributed File System

- Reliability

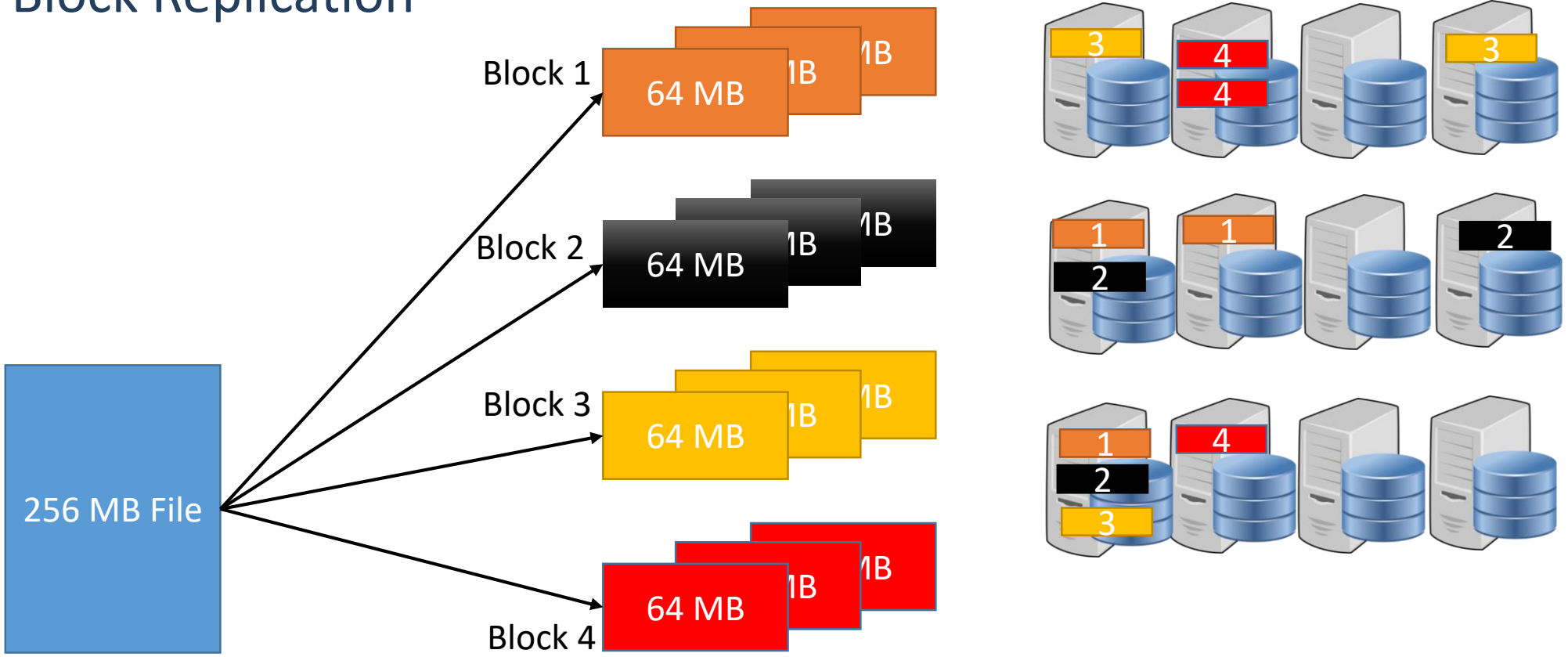
In the case of failure, data is still safe



Hadoop Distributed File System (HDFS)

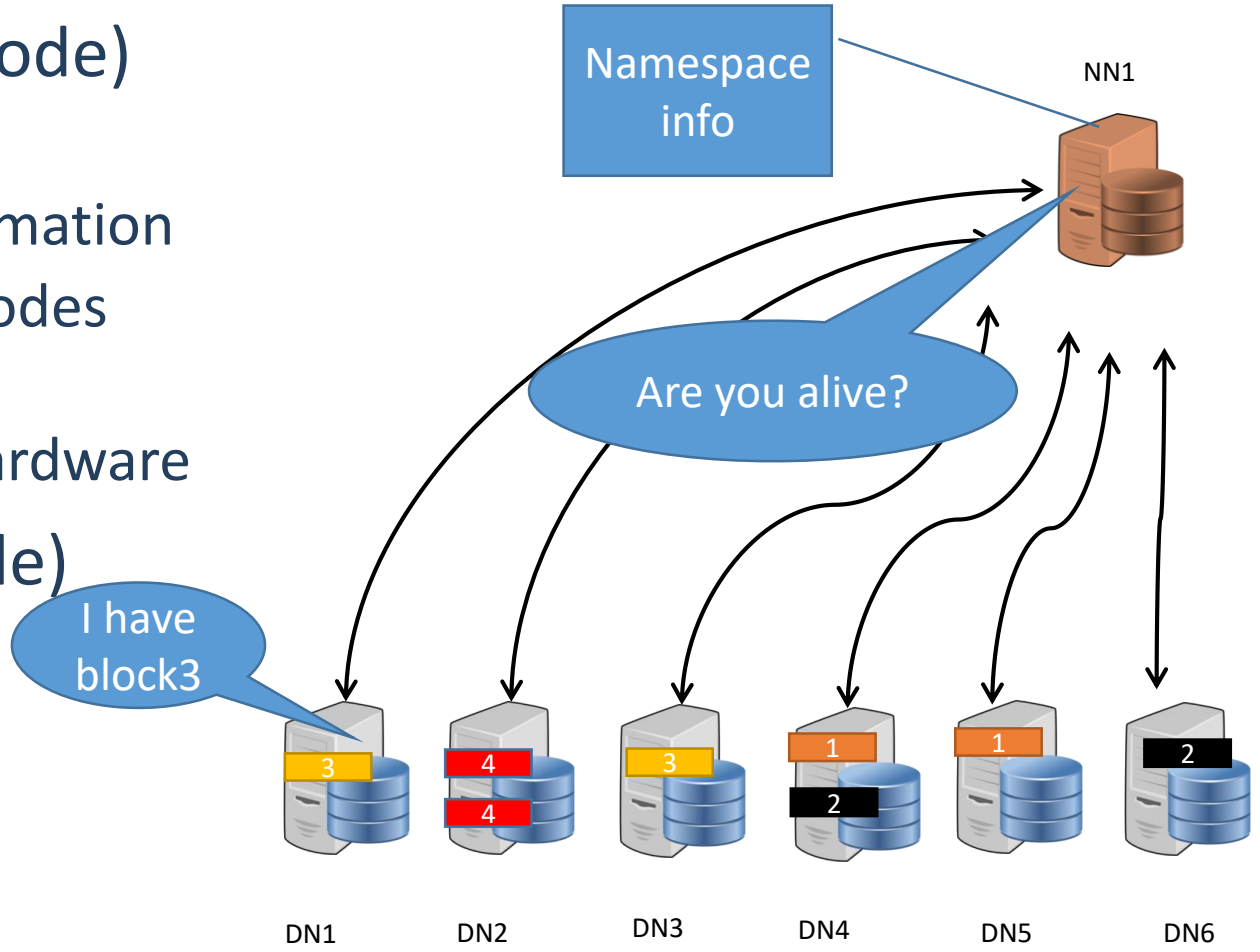
- HDFS Block
- Block Replication

3 Copies of Each Block → Default Replication Factor = 3



Hadoop Distributed File System (HDFS)

- Name Node (primary / master Node)
  - very few nodes
  - Store Namespace (meta data) Information
  - maintains and manages the slave nodes
    - heartbeat
  - It should be deployed on reliable hardware
- Data Node (secondary /slave Node)
  - Majority of nodes
  - Runs with commodity hardware
    - Cheap, no special hardware needed



Hadoop Distributed File System (HDFS)

- HDFS Block: Files are broken-up into blocks
  - Size of each block = 128 MB (Hadoop 2. x) and 64 MB (Hadoop 1. x)

- Block Replication: Multiple copies of each block are stored across the cluster on different nodes
  - Default 3: two copies are in same rack and one outside the rack.
  - Storage capacity is reduced (to 1/4 by default)
    - 3 replications and 1 additional scratch space for temporary data
  - provides high availability, fault tolerance, and reliability

- HDFS Client
  - Located on user side and fulfills user requests
  - interacts with Name Node and Data Node

Discussion

- Why we store the data?
- How we analyze the data?
- What if the size of the data is bigger than the capacity of our storage?
  - E.g., reviews on social networks, transaction of credit card holders

HDFS in Practice

General format of hdfs commands

hdfs dfs –[normalUnixCommand] –[normalUnixArguments]

Making a directory in local file system

Unix: mkdir

Example: `mkdir /tmp/directory1`

Making a directory in hadoop distributed file system

HDFS: hdfs dfs -mkdir

Example: `hdfs dfs -mkdir /tmp/directory1`

Copy from local file system to HDFS

hdfs dfs -put <localsrc> ... <dst>

- **Example**: `hdfs dfs -copyFromLocal Sample1.txt /tmp/diretory1/`

Copy/Upload Sample1.txt available in current direcotory (local default) to /user/javad/directory1 (hdfs path)

HDFS in Practice

ls
hdfs dfs -ls
hdfs dfs -mkdir mydir
hdfs dfs -ls

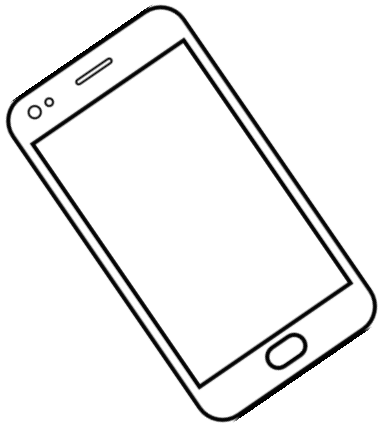
hdfs dfs -rm mydir
hdfs dfs -rm -r mydir
hdfs dfs -ls

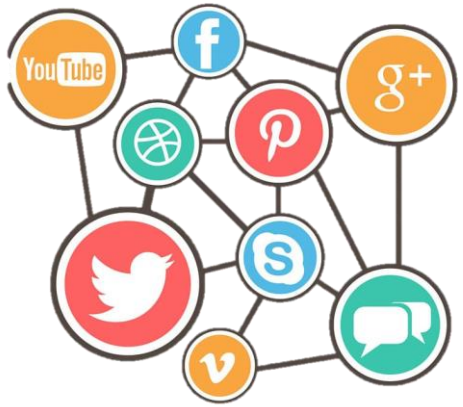
ls
hdfs dfs -put hadoop-3.1.3.tar.gz /tmp/
hdfs dfs -ls /tmp/
ls
du -h hadoop-3.1.3.tar.gz
hdfs dfs -du -h /tmp/hadoop-3.1.3.tar.gz
hdfs fsck /tmp/hadoop-3.1.3.tar.gz

Demo

HDFS in Practice

- BigData Analytics
  - Processing huge volume of data





- Statistical analysis, ETL Processing, Business Intelligence

Research Directions

- General:
  - Polato, Ivanilton, et al. "**A comprehensive view of Hadoop research—A systematic literature review.**" *Journal of Network and Computer Applications* 46 (2014): 1-25.
  - Adam, Khalid, et al. "**Bigdata: Issues, challenges, technologies and methods.**" *Proceedings of the International Conference on Data Engineering 2015 (DaEng-2015)*. Springer, Singapore, 2019.
- Performance:
  - Alange, Neeta, and Anjali Mathur. "**Small Sized File Storage Problems in Hadoop Distributed File System.**" *2019 International Conference on Smart Systems and Inventive Technology (ICSSIT)*. IEEE, 2019.
  - Bende, Sachin, and Rajashree Shedge. "**Dealing with small files problem in hadoop distributed file system**." *Procedia Computer Science* 79 (2016): 1001-1012.
  - Dai, Wei, Ibrahim Ibrahim, and Mostafa Bassiouni. "**An improved replica placement policy for Hadoop distributed file system running on cloud platforms.**" *2017 IEEE 4th International Conference on Cyber Security and Cloud Computing (CSCloud)*. IEEE, 2017.
  - Ciritoglu, Hilmi Egemen, et al. "**Towards a better replica management for hadoop distributed file system.**" *2018 IEEE International Congress on Big Data (BigData Congress)*. IEEE, 2018.
- Security:
  - Saraladevi, B., et al. "**Big Data and Hadoop-A study in security perspective.**" *Procedia computer science* 50 (2015): 596-601.
  - Wang, Fulin, et al. "**Complete Data Deletion Based on Hadoop Distributed File System.**" *Proceedings of the 3rd International Conference on Computer Science and Application Engineering*. 2019.

What we have Learned

- What is HDFS
  - How it works
  - Why, when, how to use HDFS
    - No silver bullet
    - Costs vs. Benefits
  - Examples of practice
- “When to use and when not to use Hadoop”
- Cutting edge research: e.g. , Security and Performance
- Advanced Topics: e.g., load balancing, rack awareness, replication strategies, read and write, programming