Introduction to Distributed File Systems in Hadoop

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Agenda

- Introduction
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    - 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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  - Website: ghofrani85.github.io
  - 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

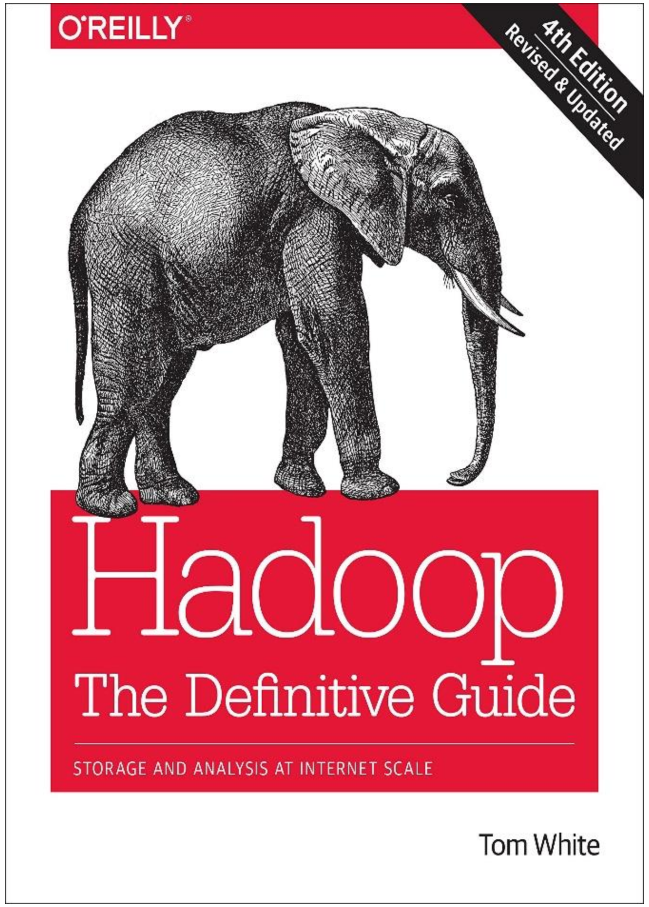
- 2: Practical Aspects of HDFS
  - Get familiar with practical aspects of Hadoop Distributed File System and fundamental knowledge in in design that store the data for parallel processing

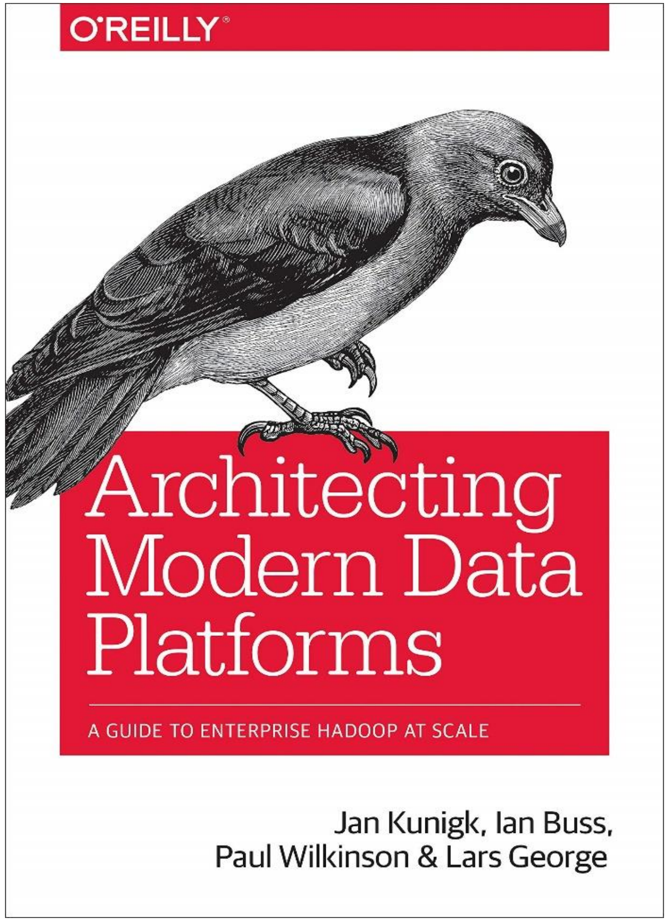
- 3: Research Trends Around HDFS
  - Get familiar with the state-of-the-art in research around HDFS and related challenges

Introduction

References

https://tinyurl.com/HDFS20




O'REILLY
Architecting Modern Data Platforms
A GUIDE TO ENTERPRISE HADOOP AT SCALE
Jan Kunigk, Ian Buss,
Paul Wilkinson & Lars George

Introduction

- The Hadoop Project is a Free reimplementation of Google's in-house MapReduce and distributed file system(GFS)[1]

- C created L Nut

- 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

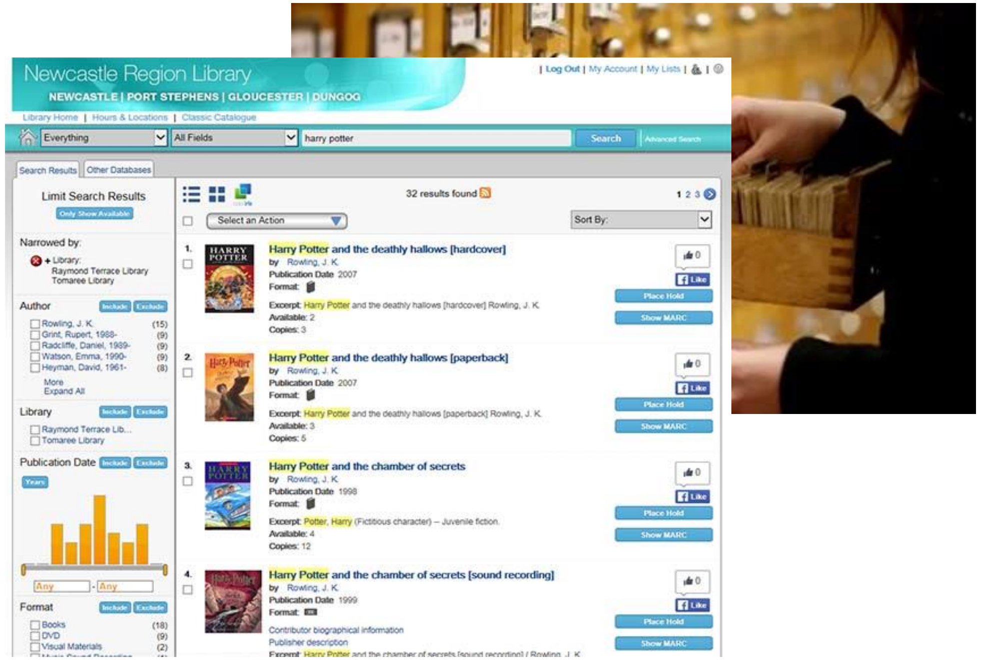
What does a File System mean?

How does it work?

Introduction

- An example from daily life: locating a book in the library
  - How to find books in a library?

Searching the Catalogue!



Narrowed by:

Library: Raymond Terrace Library, Tomaree Library

Author

- □ Rowling, J. K. (15)
- □ Grint, Rupert, 1988- (9)
- □ Radcliffe, Daniel, 1989- (9)
- □ Watson, Emma, 1990- (9)
- □ Heyman, David, 1961- (8)

More
Expand All

Library

- □ Raymond Terrace Lib...
- □ Tomaree Library

Publication Date

Any - Any

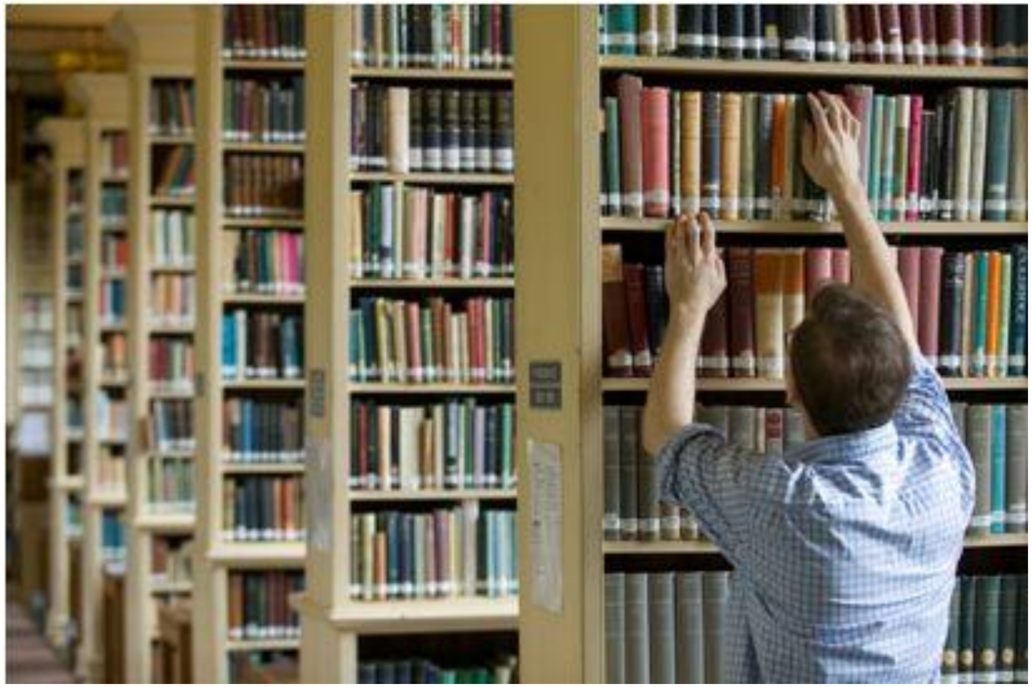
Format

- □ Books (18)
- □ DVD (9)
- □ Visual Materials (2)

32 results found

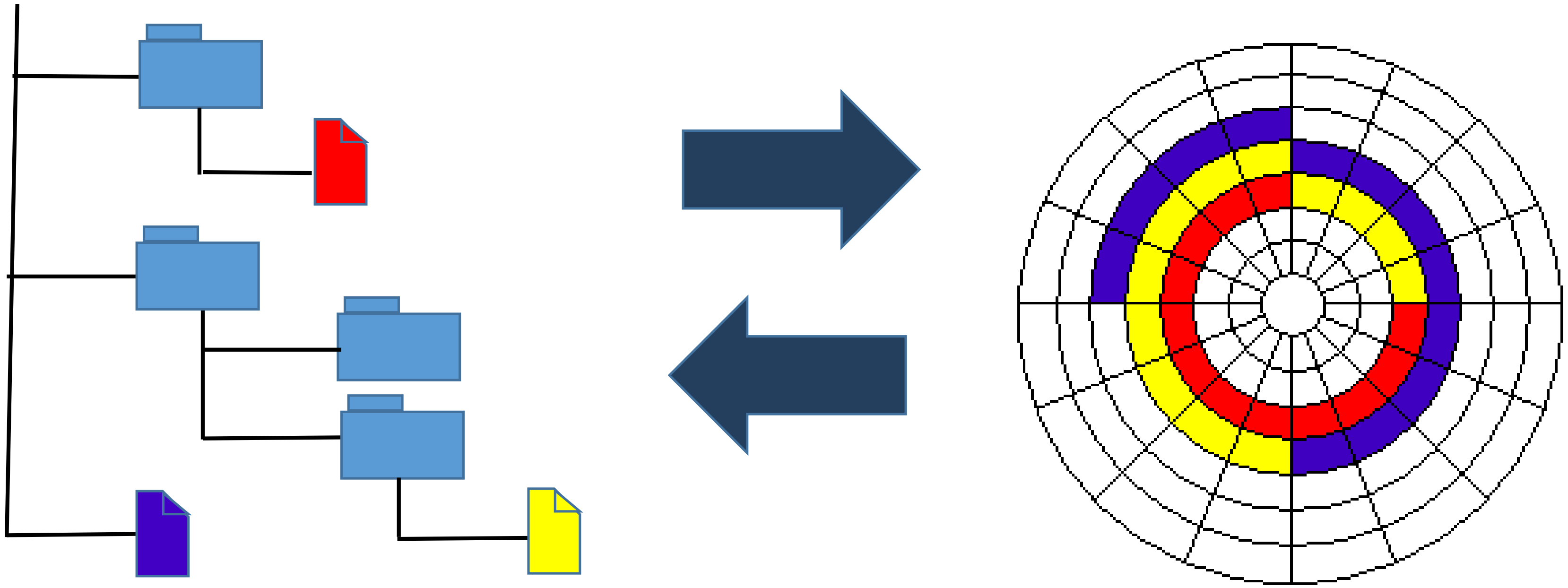
1 2 3

1. Harry Potter and the deathly hallows [hardcover]
   by Rowling, J. K.
   Publication Date 2007
   Format:
   Excerpt: Harry Potter and the deathly hallows [hardcover] Rowling, J. K.
   Available: 2
   Copies: 3
2. Harry Potter and the deathly hallows [paperback]
   by Rowling, J. K.
   Publication Date 2007
   Format:
   Excerpt: Harry Potter and the deathly hallows [paperback] Rowling, J. K.
   Available: 3
   Copies: 5
3. Harry Potter and the chamber of secrets
   by Rowling, J. K.
   Publication Date 1998
   Format:
   Excerpt: Potter, Harry (Fictitious character) -- Juvenile fiction.
   Available: 4
   Copies: 12
4. Harry Potter and the chamber of secrets [sound recording]
   by Rowling, J. K.
   Publication Date 1999
   Format:
   Contributor biographical information
   Publisher description
   Excerpt: Harry Potter and the chamber of secrets [sound recording] / Rowling, J. K.



File System

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

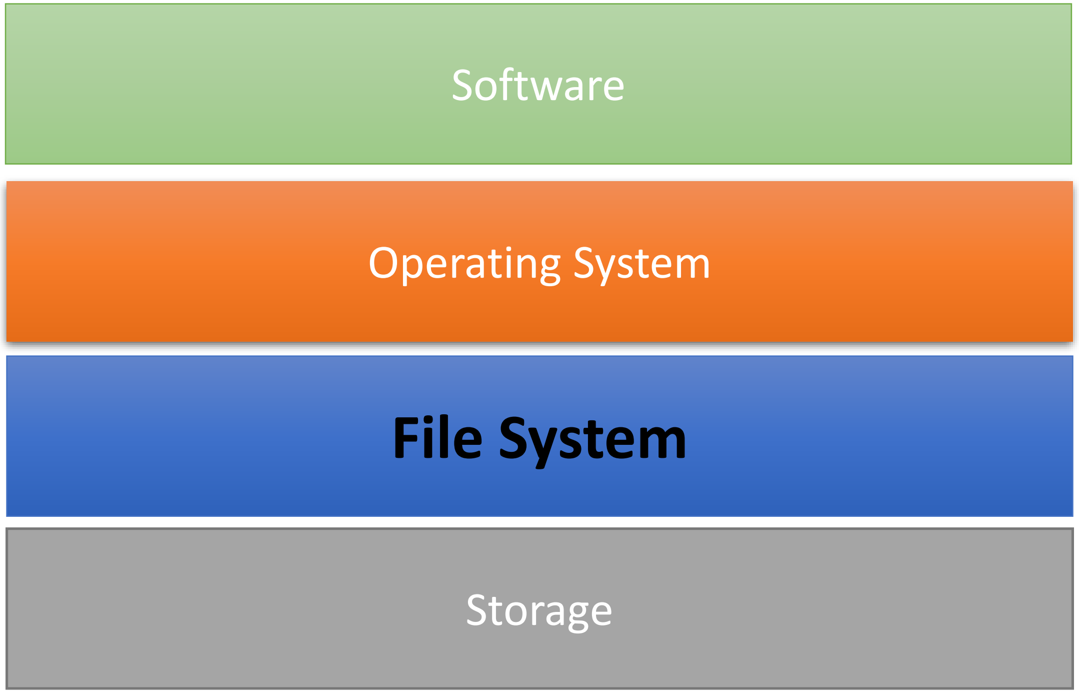


Logical Structure

Physical Structure

File System

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



Software

Operating System

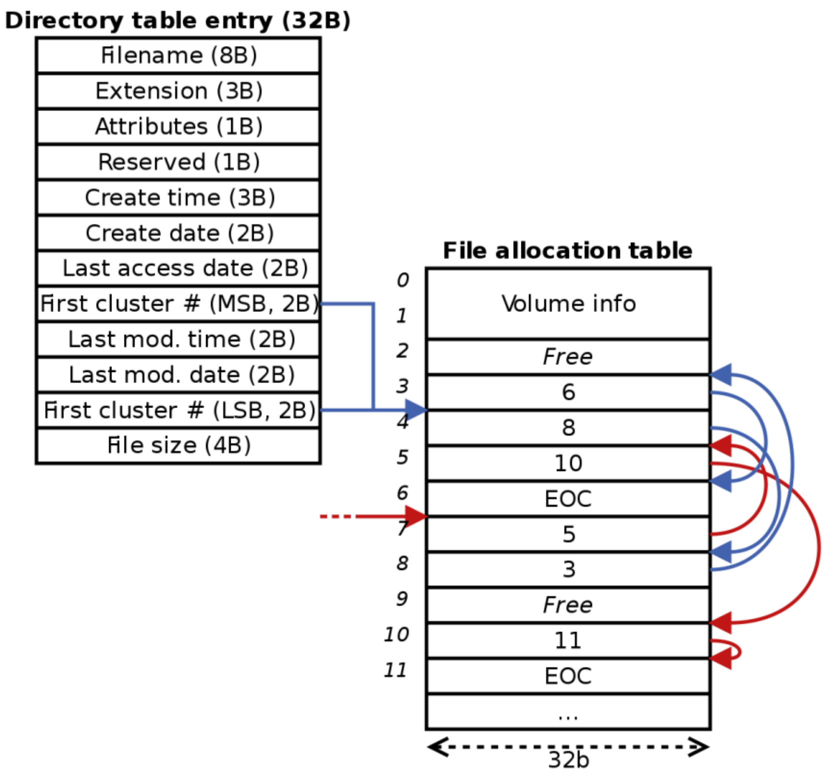
File System

Storage

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



Directory table entry (32B)

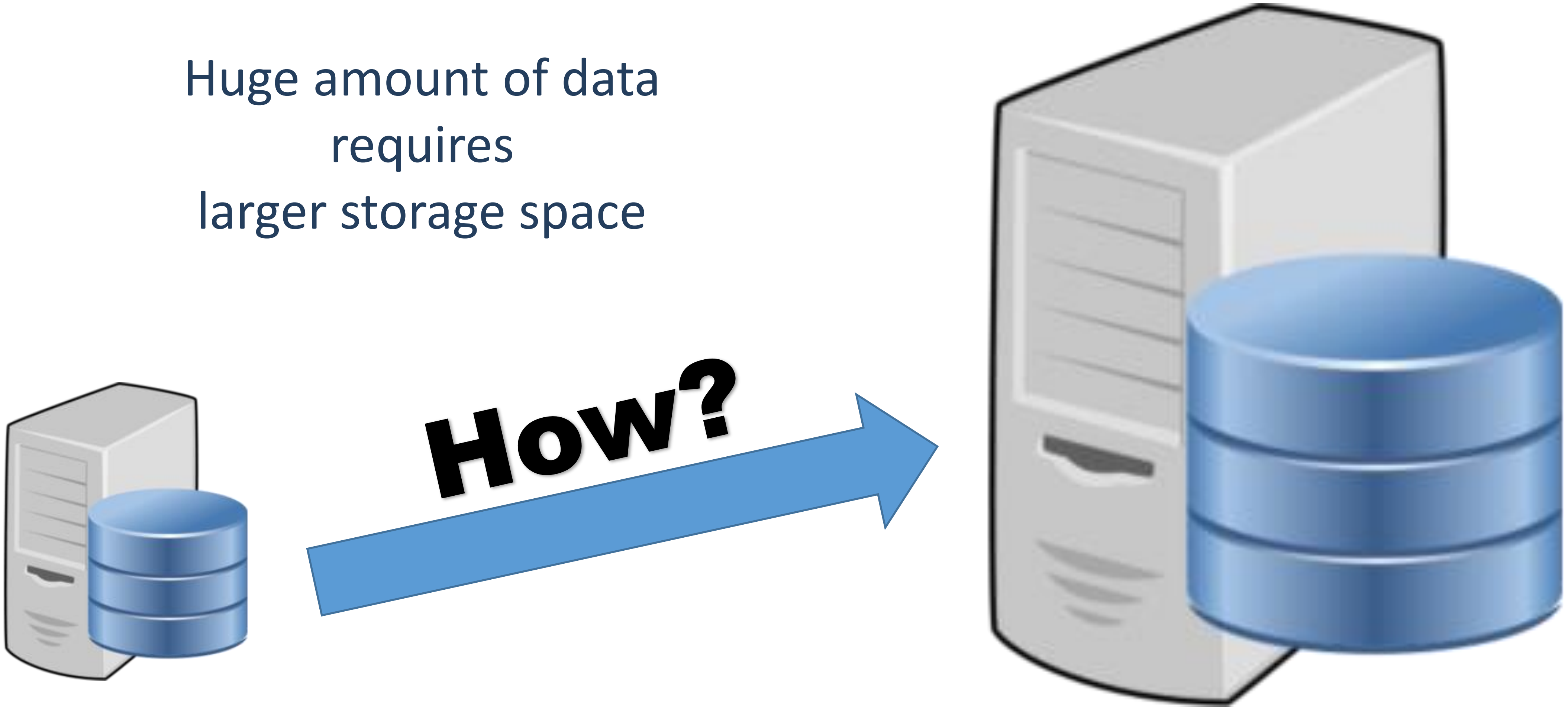
Filename (8B)
Extension (3B)
Attributes (1B)
Reserved (1B)
Create time (3B)
Create date (2B)
Last access date (2B)
First cluster # (MSB, 2B)
Last mod. time (2B)
Last mod. date (2B)
First cluster # (LSB, 2B)
File size (4B)

File allocation table

0	Volume info
1	
2	*Free*
3	6
4	8
5	10
6	EOC
7	5
8	3
9	*Free*
10	11
11	EOC
	…

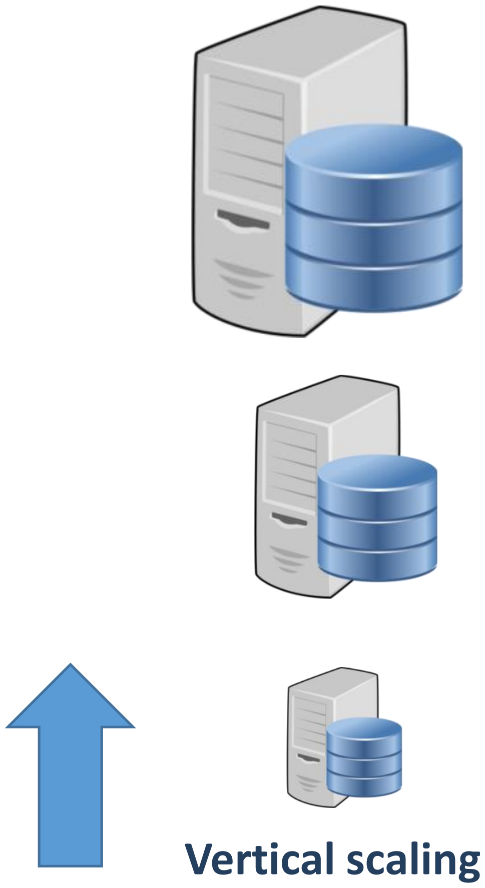
Challenge

Huge amount of data
requires
larger storage space



Distributed File System

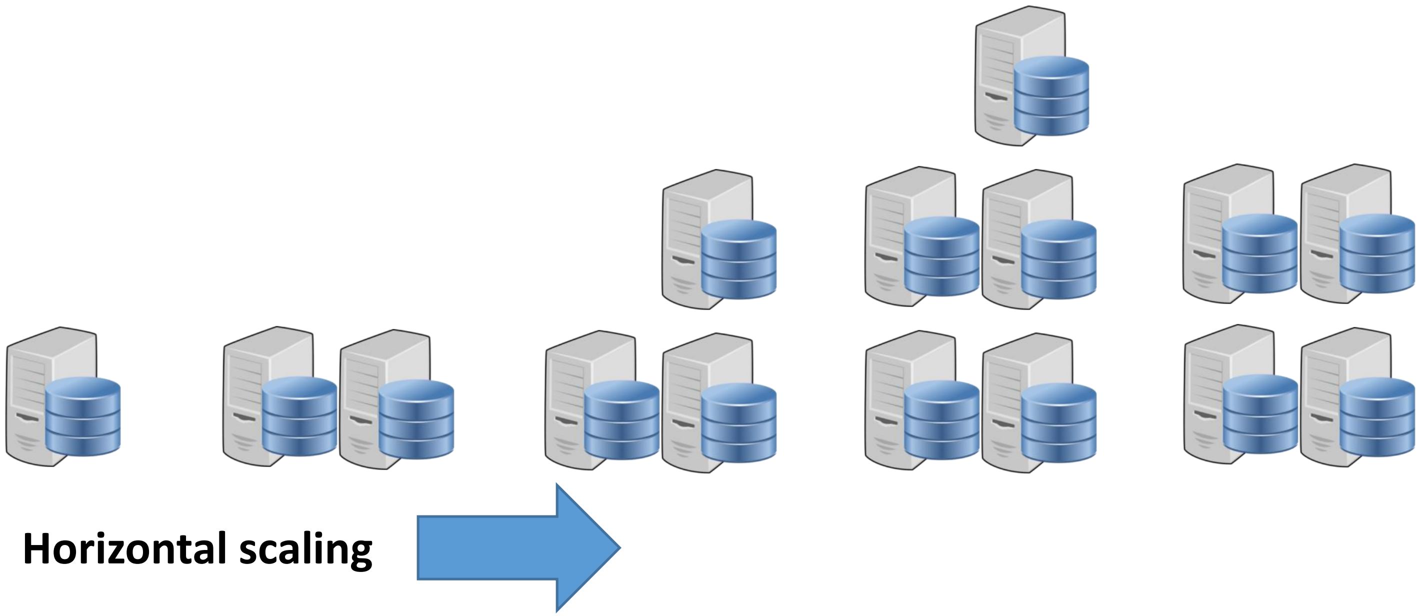
- How to provide more storage for big size of data?



- **Challenges:**
  - Limited computation power
  - Limited storage
  - Flexibility

Distributed File System

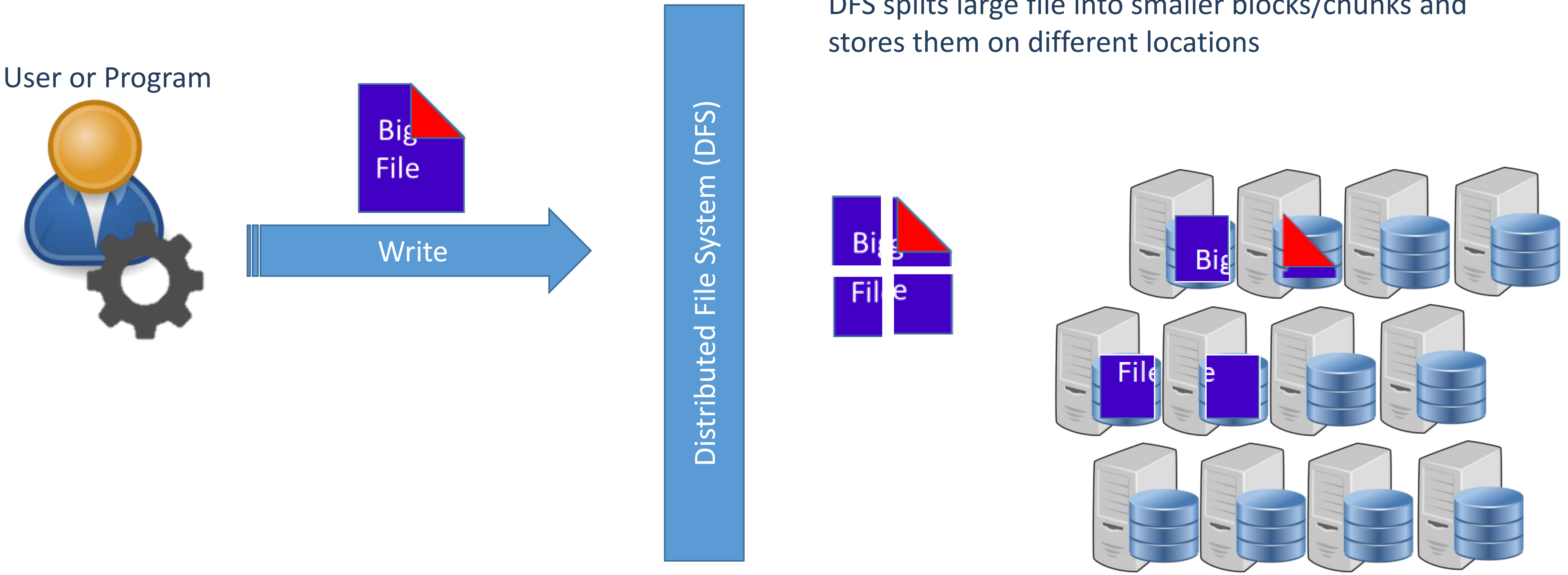
- How to provide more storage for big size of data?



- 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



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

User or Program

Big File

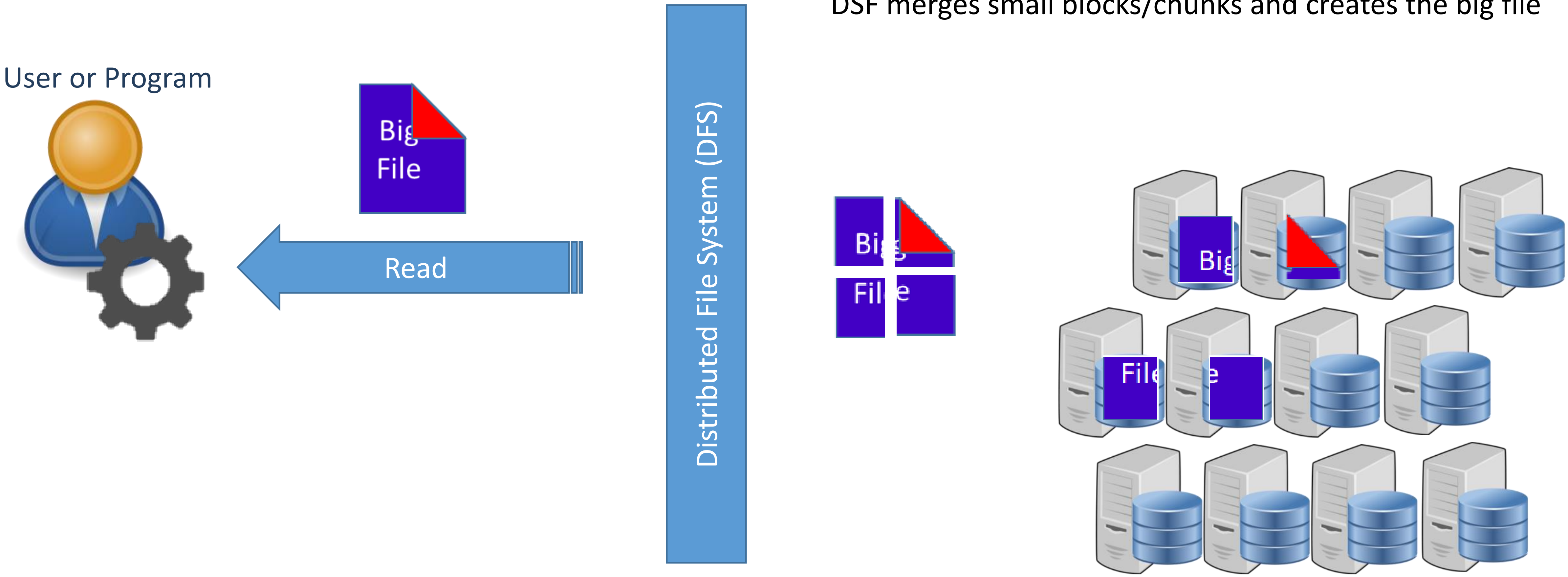
Write

Distributed File System (DFS)

Distributed File System

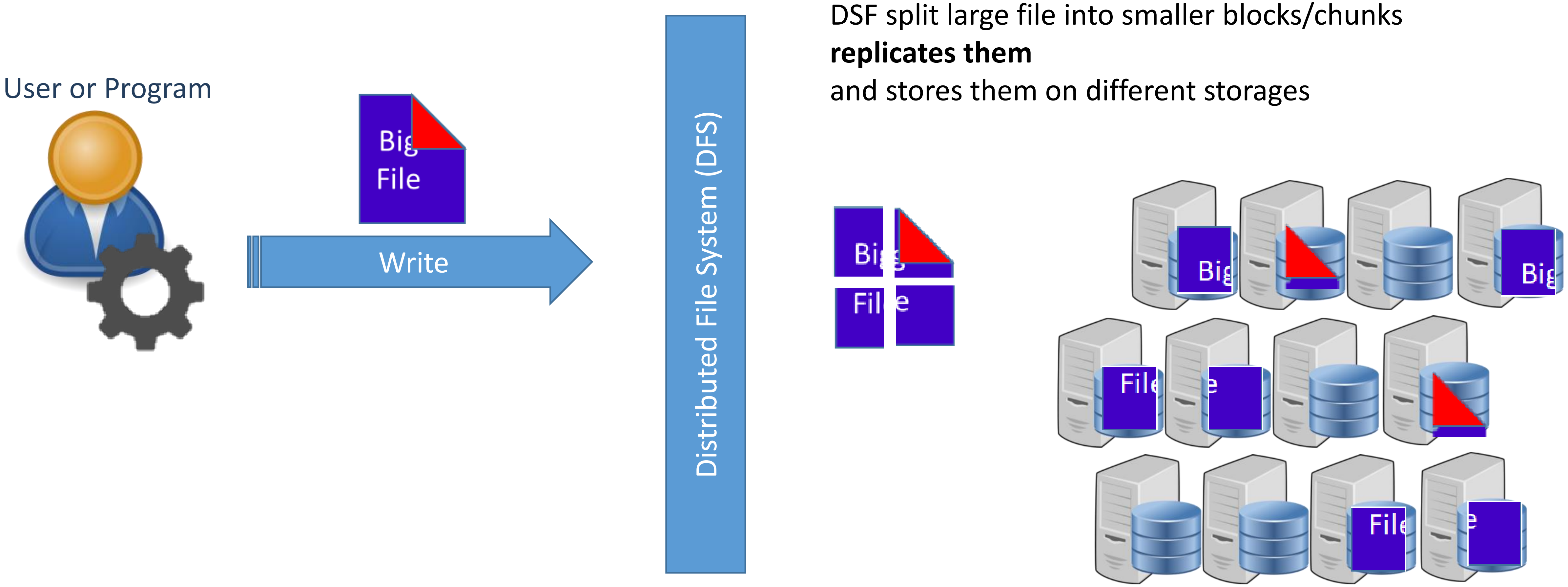
- Transparency — Abstraction

DSF merges small blocks/chunks and creates the big file



Distributed File System

- Reliability

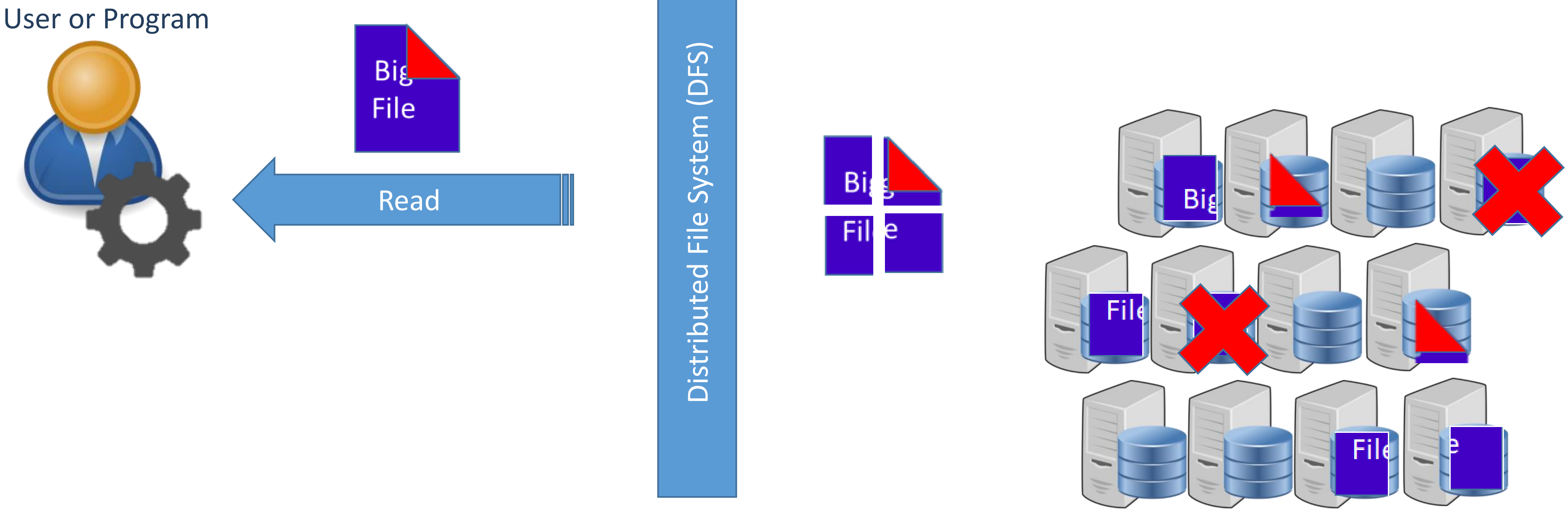


DSF split large file into smaller blocks/chunks
replicates them
and stores them on different storages

Distributed File System

- Reliability

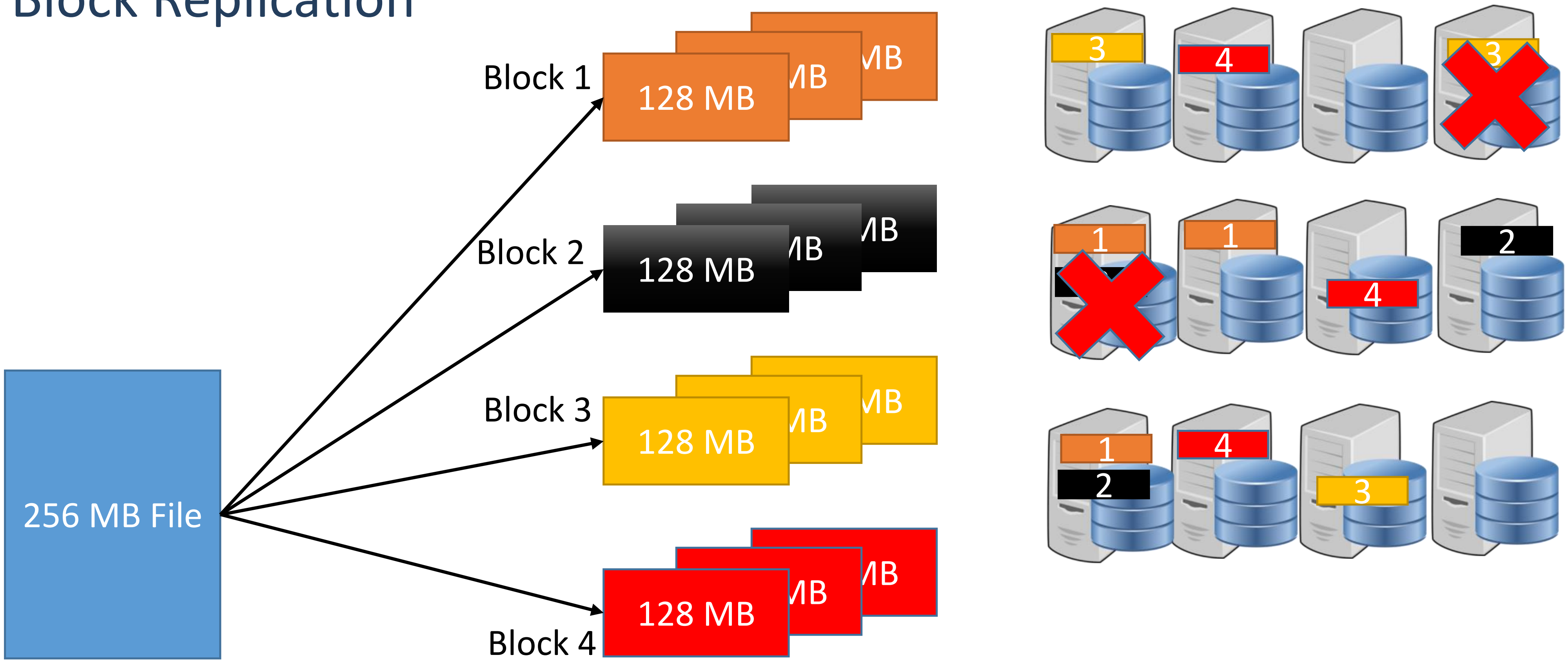
In case of a failure of one or more machines, data is still safe



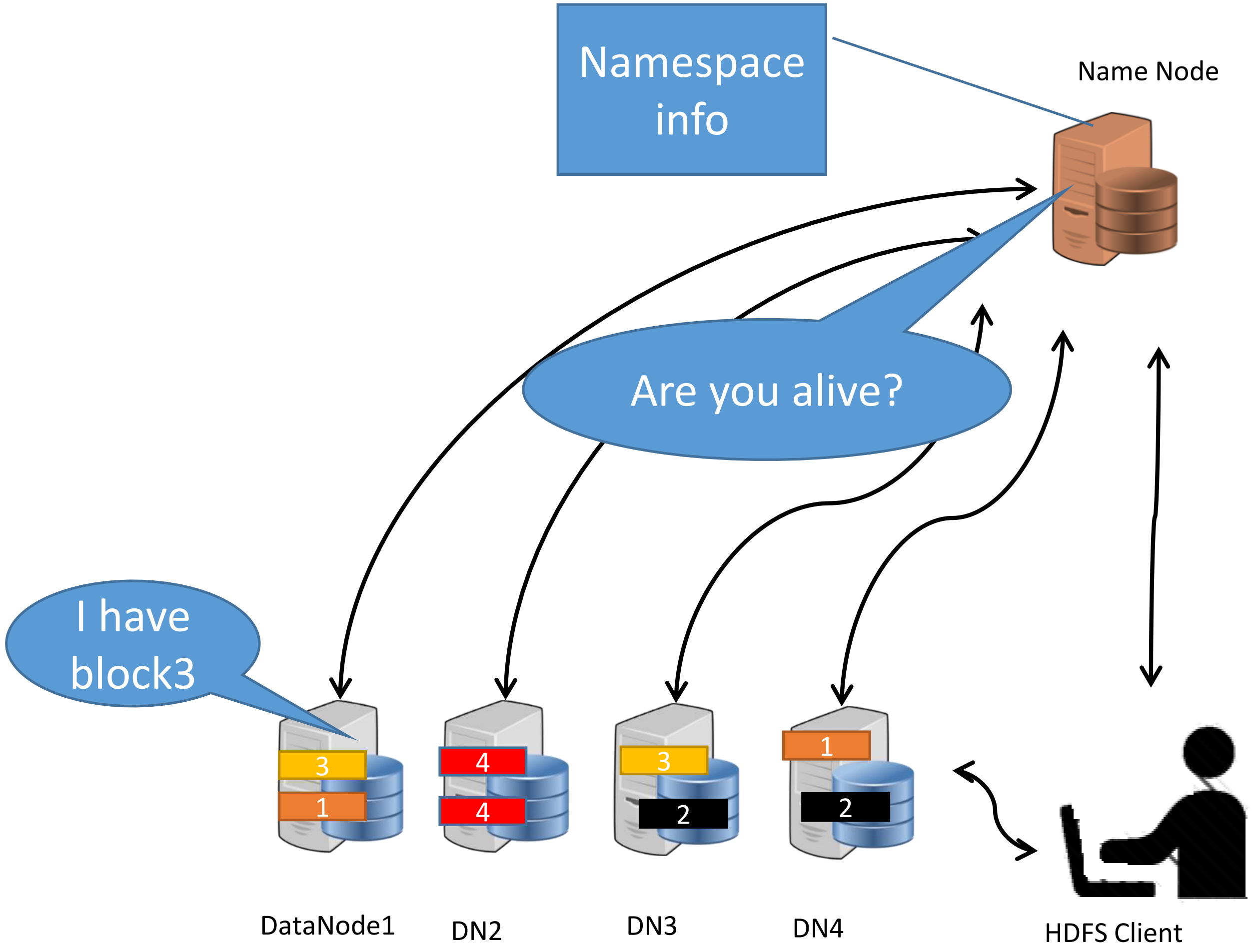
Hadoop Distributed File System (HDFS)

- HDFS Block
- Block Replication

3 Copies of Each Block → Default Replication Factor = 3



Hadoop Distributed File System (HDFS)



Hadoop Distributed File System (HDFS)

- Name Node (primary / master Node)
  - Very few nodes
  - Store Namespace (metadata) 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
- HDFS Client
  - Located on user side and fulfills user requests
  - Interacts with Name Node and Data Node

Hadoop Distributed File System (HDFS)

- HDFS Block: Files are broken-up into <u>blocks</u>
  - 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

- Advanced Topics: e.g., load balancing, rack awareness, replication placement, read and write, programming

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)

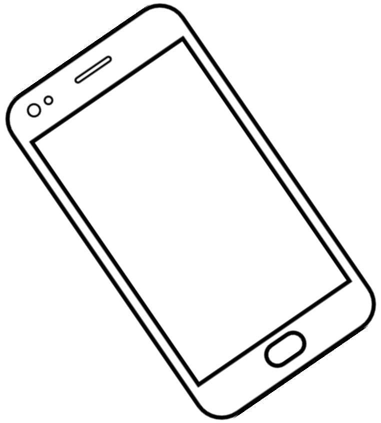
HDFS in Practice

```
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 in parallel fashion



  - Statistical analysis, ETL Processing, Business Intelligence
- Not recommended for Real Time use cases

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.