
hadoop

- An open-source software framework
- Written in Java for
  - distributed storage
  - distributed processing of very large data sets on computer clusters built from commodity hardware.

Who uses Hadoop?

- Amazon/A9
- Facebook
- Google
- New York Times
- Veoh
- Yahoo!
- …. many more

Apache Hadoop framework

- ***Hadoop Common*** – contains libraries and utilities needed by other Hadoop modules.
- ***Hadoop Distributed File System (HDFS)*** – a distributed file-system that stores data on commodity machines, providing very high aggregate bandwidth across the cluster;
- ***Hadoop YARN*** – a resource-management platform responsible for managing computing resources in clusters and using them for scheduling of users' applications
- ***Hadoop MapReduce*** – a programming model for large scale data processing.

Ecosystem

- Collection of additional software packages that can be installed on top of or alongside Hadoop.
  - Apache Pig,
  - Apache Hive,
  - Apache HBase,
  - Apache Spark, and others

Terminology

Google calls it:	Hadoop equivalent:
MapReduce	Hadoop
GFS	HDFS
Bigtable	HBase
Chubby	Zookeeper

Hadoop File System

Basic Features: HDFS

- Highly fault-tolerant
- High throughput
- Suitable for applications with large data sets
- Streaming access to file system data
- Can be built out of commodity hardware

Fault tolerance

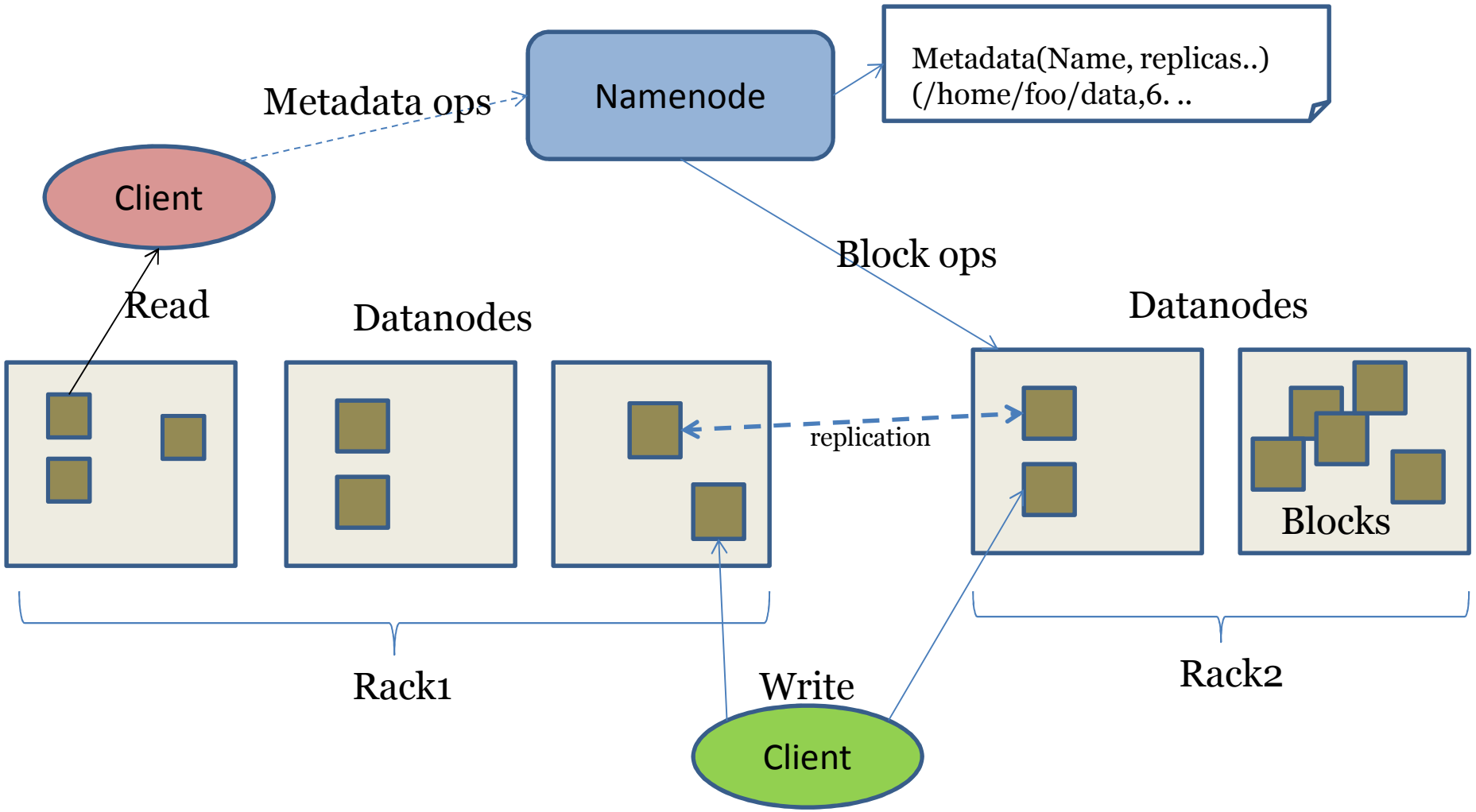
- Failure is the norm rather than exception
- Since we have huge number of components and that each component has non-trivial probability of failure means that there is always some component that is non-functional.
- Detection of faults and quick, automatic recovery from them is a core architectural goal of HDFS.

Architecture

Namenode and Datanodes

- Master/slave architecture
- HDFS cluster consists of a single **Namenode**, a master server that manages the file system namespace and regulates access to files by clients.
- There are a number of **DataNodes** usually one per node in a cluster.
- The DataNodes manage storage attached to the nodes that they run on.
- HDFS exposes a **file system namespace** and allows user data to be stored in files.
- A file is split into one or more blocks and set of blocks are stored in DataNodes.
- DataNodes: serves read, write requests, performs block creation, deletion, and replication upon instruction from Namenode.

HDFS Architecture



File system Namespace

- Hierarchical file system with directories and files
- Create, remove, move, rename etc.
- Namenode maintains the file system
- Any meta information changes to the file system recorded by the Namenode.
- An application can specify the number of replicas of the file needed: replication factor of the file. This information is stored in the Namenode.
- Blocks are replicated for fault tolerance

Replica Placement

- The placement of the replicas is critical to HDFS reliability and performance.
- Rack-aware replica placement:
  - Goal: improve reliability, availability and network bandwidth utilization
- Many racks, communication between racks are through switches.
- Replicas are typically placed on unique racks
  - Simple but non-optimal
  - Writes are expensive
  - Replication factor is 3
- **Replicas are placed: one on a node in a local rack, one on a different node in the local rack and one on a node in a different rack.**

Replica Selection

- Replica selection for READ operation: HDFS tries to minimize the bandwidth consumption and latency.
- If there is a replica on the Reader node then that is preferred.
- HDFS cluster may span multiple data centers: replica in the local data center is preferred over the remote one.

Safemode Startup

- On startup Namenode enters Safemode.
- **Replication of data blocks do not occur** in Safemode.
- Each DataNode checks in with Heartbeat and BlockReport.
- Namenode verifies that each block has acceptable number of replicas
- After a configurable percentage of safely replicated blocks check in with the Namenode, Namenode exits Safemode.
- It then makes the list of blocks that need to be replicated.
- Namenode then proceeds to replicate these blocks to other Datanodes.

Namenode

- Keeps image of entire file system namespace and file Blockmap in memory.
- 4GB of local RAM is sufficient to support the above data structures that represent the huge number of files and directories.
- When the Namenode starts up it gets the FsImage and Editlog from its local file system, update FsImage with EditLog information and then stores a copy of the FsImage on the filesytstem as a checkpoint.
- Periodic checkpointing is done. So that the system can recover back to the last checkpointed state in case of a crash.

Datanode

- A Datanode stores data in files in its local file system.
- Datanode has no knowledge about HDFS filesystem
- It stores each block of HDFS data in a separate file.
- Datanode does not create all files in the same directory.
- It uses heuristics to determine optimal number of files per directory and creates directories appropriately:
- When the filesystem starts up it generates a list of all HDFS blocks and send this report to Namenode: Blockreport.

PROTOCOL

The Communication Protocol

- All HDFS communication protocols are layered on top of the TCP/IP protocol
- A client establishes a connection to a configurable TCP port on the Namenode machine.
- The Datanodes talk to the Namenode using Datanode protocol.
- RPC abstraction wraps both ClientProtocol and Datanode protocol.
- Namenode is simply a server and never initiates a request; it only responds to RPC requests issued by DataNodes or clients.

ROBUSTNESS

[COPE WITH ERRORS DURING EXECUTION, ABILITY OF AN ALGORITHM TO CONTINUE OPERATING DESPITE ABNORMALITIES IN INPUT, CALCULATIONS, ETC.]

- Primary objective of HDFS is to **store data reliably** in the presence of failures.
- Three common failures are: Namenode failure, Datanode failure and network partition (failure of a network device that causes a network to be split).

DataNode failure and heartbeat

- A network partition can cause a subset of Datanodes to lose connectivity with the Namenode.
- Namenode detects this condition by the absence of a Heartbeat message.
- Namenode marks Datanodes without Hearbeat and does not send any IO requests to them.
- Any data registered to the failed Datanode is not available to the HDFS.
- Also the death of a Datanode may cause replication factor of some of the blocks to fall below their specified value.

Re-replication

- The necessity for re-replication may arise due to:
  - A Datanode may become unavailable,
  - A replica may become corrupted,
  - A hard disk on a Datanode may fail, or
  - The replication factor on the block may be increased.

Cluster Rebalancing

- HDFS architecture is compatible with data rebalancing schemes.
- A scheme might move data from one Datanode to another if the free space on a Datanode falls below a certain threshold.
- In the event of a sudden high demand for a particular file, a scheme might dynamically create additional replicas and rebalance other data in the cluster.
- These types of data rebalancing are not yet implemented: research issue.

Data Integrity

- Consider a situation: a block of data fetched from Datanode arrives corrupted.
- This corruption may occur because of faults in a storage device, network faults, or buggy software.
- A HDFS client creates the checksum of every block of its file and stores it in hidden files in the HDFS namespace.
- When a clients retrieves the contents of file, it verifies that the corresponding checksums match.
- If does not match, the client can retrieve the block from a replica.

Metadata Disk Failure

- FsImage and EditLog are central data structures of HDFS.
- A corruption of these files can cause a HDFS instance to **be non-functional.**
- For this reason, a Namenode can be configured to maintain multiple copies of the FsImage and EditLog.
- Multiple copies of the FsImage and EditLog files are updated synchronously.
- Meta-data is not data-intensive.
- The Namenode could be single point failure.

DATA ORGANIZATION

Data Blocks

- HDFS support write-once-read-many with reads at streaming speeds.
- A typical block size is 64MB (or even 128 MB).
- A file is chopped into 64MB chunks and stored.

Staging

- A client request to create a file does not reach Namenode immediately.
- HDFS client caches the data into a temporary file. When the data reached a HDFS block size the client contacts the Namenode.
- Namenode inserts the filename into its hierarchy and allocates a data block for it.
- The Namenode responds to the client with the identity of the Datanode and the destination of the replicas (Datanodes) for the block.
- Then the client flushes it from its local memory.

Staging (contd.)

- The client sends a message that the file is closed.
- Namenode proceeds to commit the file for creation operation into the persistent store.
- If the Namenode dies before file is closed, the file is lost.
- This client side caching is required to avoid network congestion.

API (ACCESSIBILITY)

Application Programming Interface

- HDFS provides Java API for application to use.
- Python access is also used in many applications.
- A C language wrapper for Java API is also available.
- A HTTP browser can be used to browse the files of a HDFS instance.