ISIT312 Big Data Management

Hadoop Architecture

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Hadoop Architecture

Outline

- Hadoop Distributed File System (HDFS)
- NameNode metadata
- DataNode and Secondary node
- Yet Another Resource Negotiator (YARN)
- ResourceManger
- NodeManager
- ApplicationMaster
- Summary

HDFS: Hadoop Distributed File System

HDFS is designed for:

- Very large files
- Stream data access
- Commodity hardware

But not for:

- Low-latency data access
- Lots of small files
- Multiple writers, arbitrary file modifications

HDFS: Hadoop Distributed File System

HDFS contains the following key components:

NameNode:

- HDFS master node process
- manages the filesystem metadata
- does not store a file itself

SecondaryNameNode and Standby NameNode

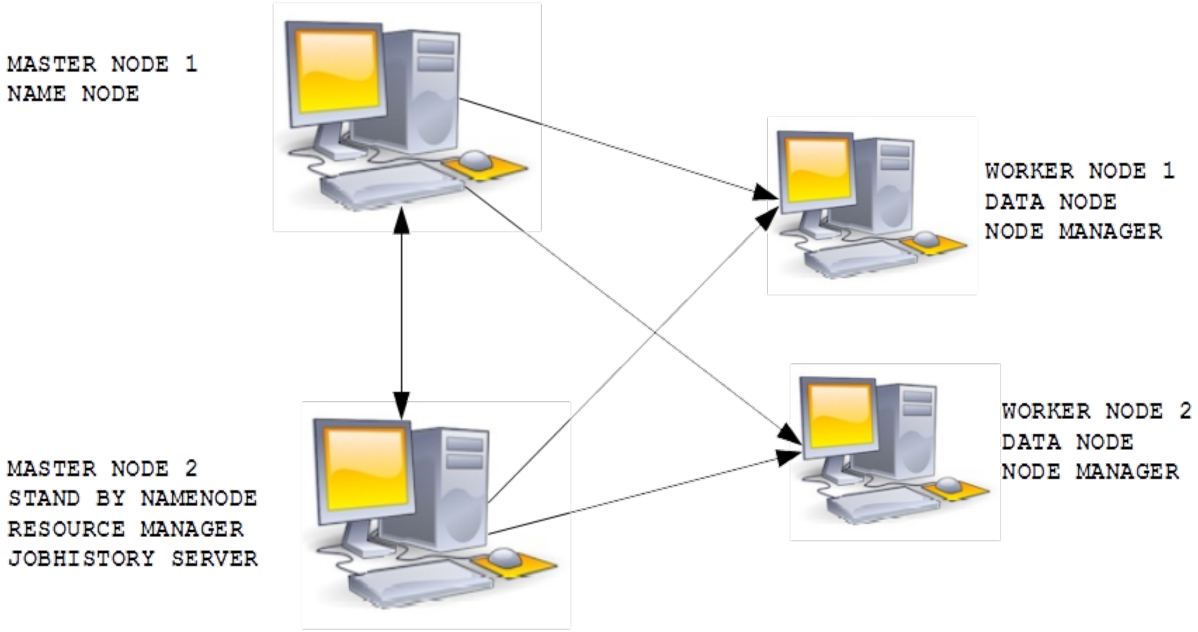
- SecondaryNameNode expedites the filesystem metadata recovery
- Standby NameNode (optional) provides high availability

DataNode

- runs HDFS slave node process
- manages block storage and access for reading or writing of data, block replication

HDFS: Hadoop Distributed File System

Architecture of HDFS



HDFS: Hadoop Distributed File System

HDFS is a virtual filesystem

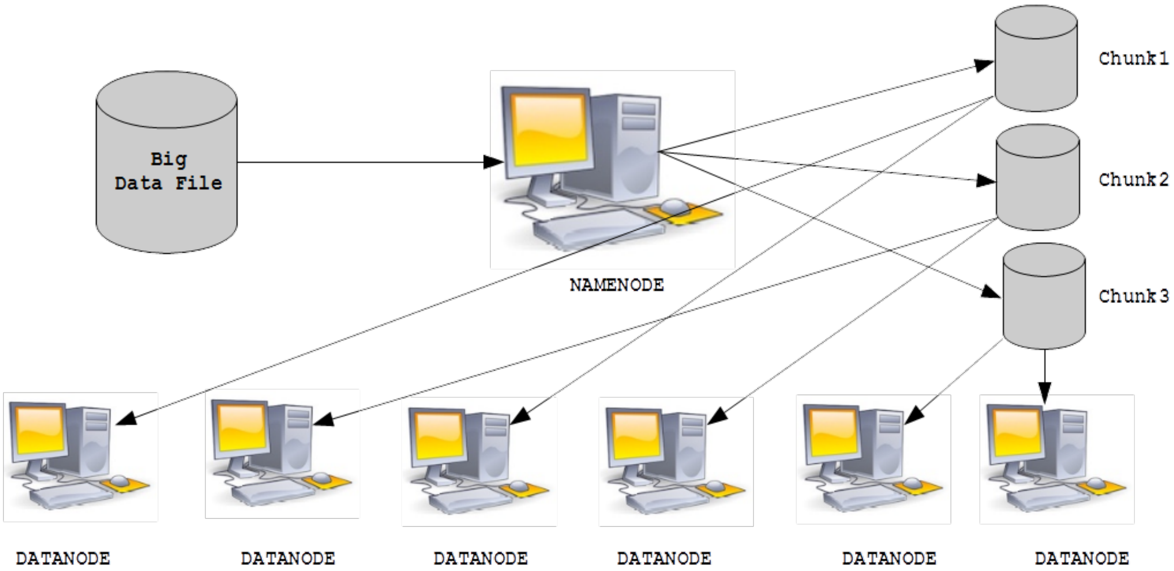
- appears to a client as one file system, but the data is stored in multiple different locations
- deployed on the top of the native filesystems (such as `ext3`, `ext4` and `xfs` in Linux)

Each file in HDFS consists of blocks

- The size of each block defaults to 128MB but is configurable
- The default number of replicates for blocks is 3, but it is also configurable

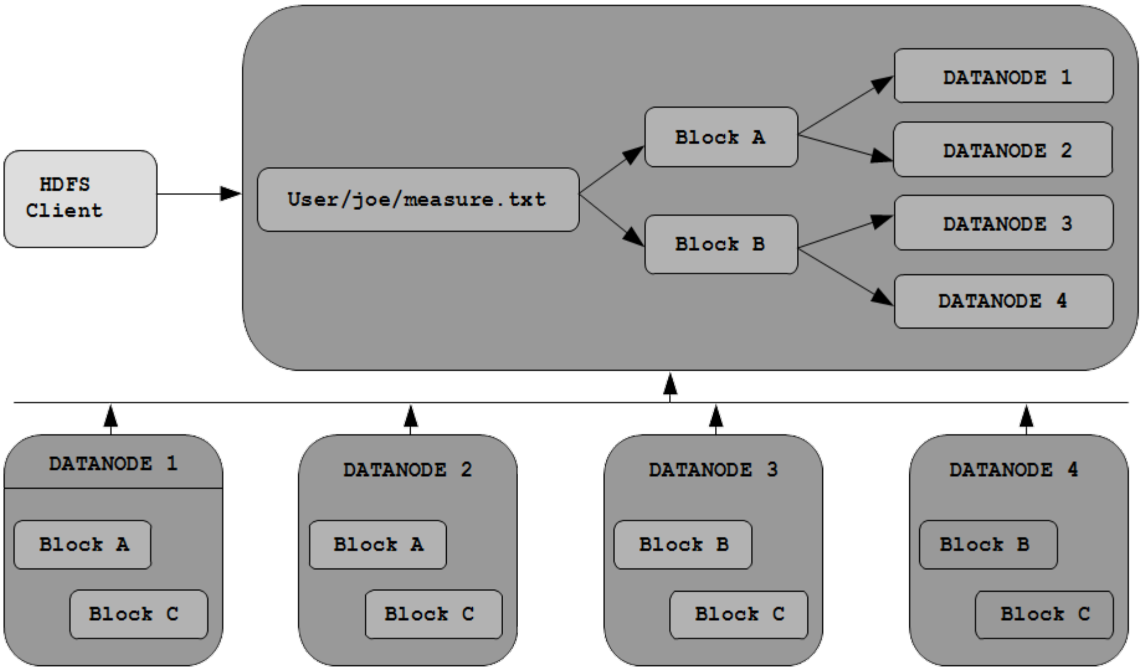
HDFS: Hadoop Distributed File System

Logical view of data storage



HDFS: Hadoop Distributed File Systeme

Physical implementation of data file storage



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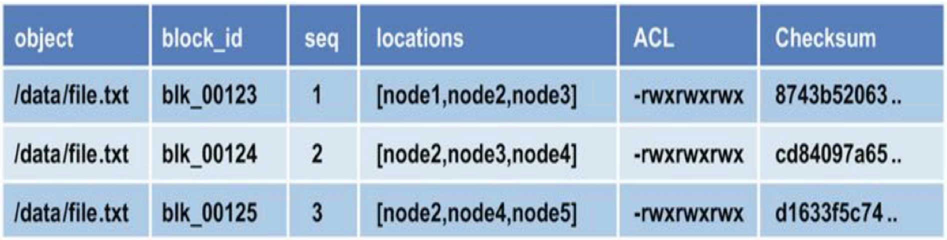
NameNode Metadata

NameNode stores the metadata of the files in HDFS



object	block_id	seq	locations	ACL	Checksum
/data/file.txt	blk_00123	1	[node1,node2,node3]	-rwxrwxrwx	8743b52063..
/data/file.txt	blk_00124	2	[node2,node3,node4]	-rwxrwxrwx	cd84097a65..
/data/file.txt	blk_00125	3	[node2,node4,node5]	-rwxrwxrwx	d1633f5c74..

NameNode functions:

- Maintain the metadata pertaining to the file system (e.g., the file hierarchy and the block locations for each file)
- Manage user access to the data files
- Map the data blocks to the DataNodes in the cluster
- Perform file system operations (e.g., opening and closing the files and directories)
- Provide registration services and periodic heartbeats for DataNodes

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DataNode and Secondary node

DataNode functions:

- Provide the block storage by storing blocks on the local file system
- Fulfil the read/write requests
- Replicating data across the cluster
- Keeping in touch with the NameNode by sending periodic block reports and heartbeats
- A heartbeat confirms the DataNode is alive and healthy, and a block report shows the blocks being managed by the DataNode

Secondary NameNode and Standby NameNode functions:

- Without a NameNode, there is no way to know to which files the blocks stored on the DataNodes correspond to
- In essence, all files in HDFS are lost
- Secondary NameNode periodically backups the metadata in the (primary) NameNode, which is usually for recovery
- Standby NameNode is a hot node that running together with the (primary) NameNode in the cluster, facilitating high-availability

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Yet Another Resource Negotiator (YARN)

YARN: the core subsystem in Hadoop responsible for governing, allocating, and managing the finite distributed processing resources available on a Hadoop cluster

- introduced in Hadoop 2 to improve the MapReduce implementation, but general enough to support other distributed computing paradigms

YARN provides its core services via two types of long-running daemons:

- A ResourceManager (one per cluster) to manage the use of resources across the cluster, and
- NodeManagers running on all the nodes in the cluster to launch and monitor containers

Yet Another Resource Negotiator (YARN)

Architecture of YARN

A client is the program that submits jobs to the cluster

- May also be the gateway machine that the client program runs on

A job, also called an application, contains one or more tasks

- A task in a MapReduce job can be either a mapper and a reducer task

Each mapper and reducer task runs within a container

- Containers are logical constructs that represent a specific amount of memory and other resources, such as processing cores (CPU)
- For example, a container can represent 2GB memory and 2 processing cores
- Containers may also refer to the running environment of an application

Yet Another Resource Negotiator (YARN)

Architecture of YARN

ResourceManager: YARN's daemon running on a master node

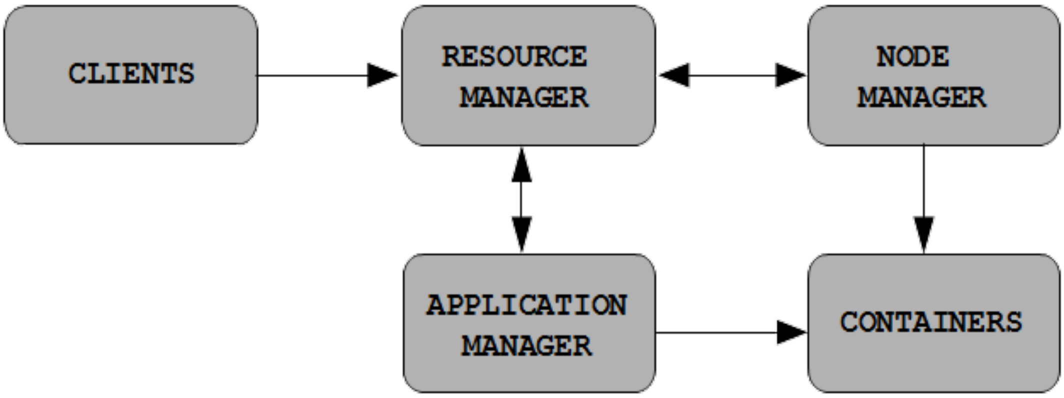
- ResourceManager is responsible for granting cluster computing resources to applications running on the cluster
- Resources are granted the items of containers

NodeManager: YARN's daemon running on a slave node.

- NodeManager manages containers on a slave node
- ApplicationMaster: the first container allocated by the ResourceManager to run on a NodeManager for each application

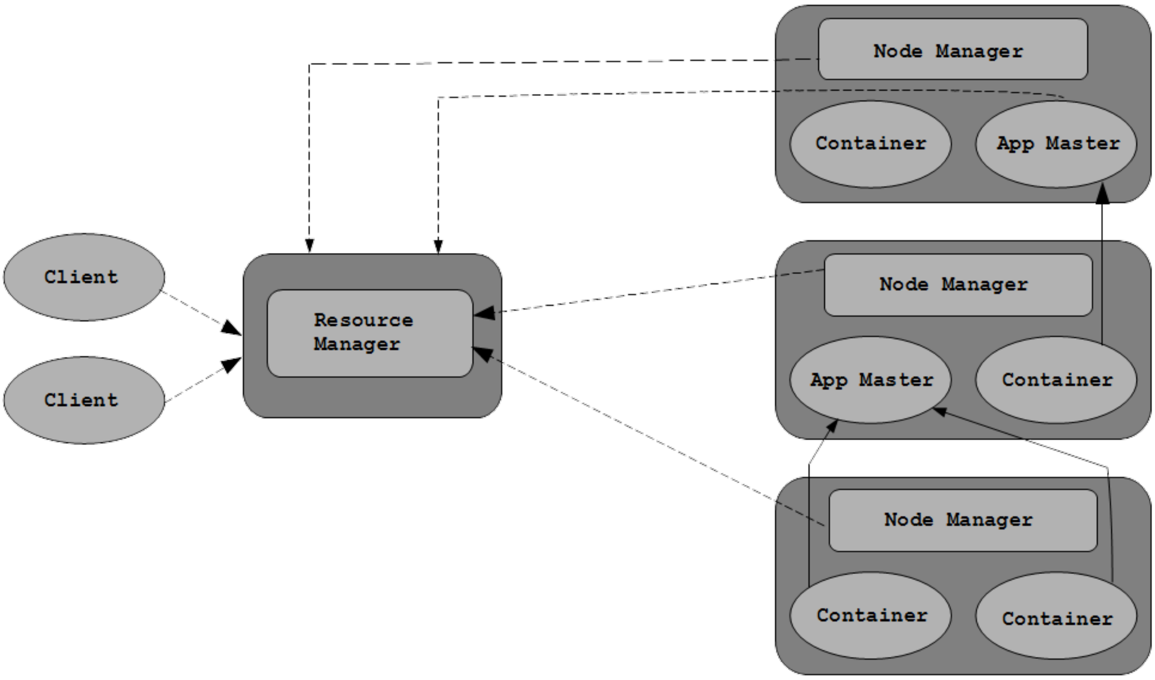
Yet Another Resource Negotiator (YARN)

Architecture of YARN



Yet Another Resource Negotiator (YARN)

Architecture of YARN



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ResourceManager

There is one ResourceManager per cluster, which consists of two key components: Scheduler and ApplicationManager

Key functions of ResourceManager:

- Creates the first container for an application to run ApplicationMaster for that application
- Tracks the heartbeats from NodeManagers to manage DataNodes
- Runs Scheduler to determine resource allocation among the clusters
- Manages cluster level security
- Manages the resource requests from ApplicationMasters
- Monitors the status of ApplicationMasters and restarts that container upon its failure
- Deallocates the containers when the application completes or after they expire

The role of ResourceManager is pure management and scheduler

It does not perform any actual data processing, for example the Map and Reduce functions in a MapReduce application

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NodeManager

Each DataNode runs a NodeManager daemon for performing YARN functions

Main functions of a NodeManager daemon:

- Communicates with ResourceManager through health heartbeats and container status notifications.
- Registers and starts the application processes
- Launches both ApplicationMaster and the rest of an application's resource containers (that is, the map and reduce tasks that run in the containers) on request from ApplicationMaster
- Oversees the lifecycle of the application containers
- Monitors, manages and provides information regarding the resource consumption (CPU/memory) by the containers
- Tracks the health of DataNode
- Provides auxiliary services to YARN applications, such as services used by the MapReduce framework for its shuffle and sort operations

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ApplicationMaster

For each YARN application, there is a dedicated ApplicationMaster

Functions of ApplicationMaster:

- Managing task scheduling and execution
- Allocating resources locally for the application's tasks

ApplicationMaster is running within a container

ApplicationMaster's existence is associated with the running application

When an application is completed, its ApplicationMaster no longer exists

Once created, ApplicationMaster is in charge of requesting resources with ResourceManager to run the application

The resource request are very specific, for example:

- the file blocks needed to process the job,
- the amount of the resource, in terms of the number of containers to create for the application,
- the size of the containers, etc.

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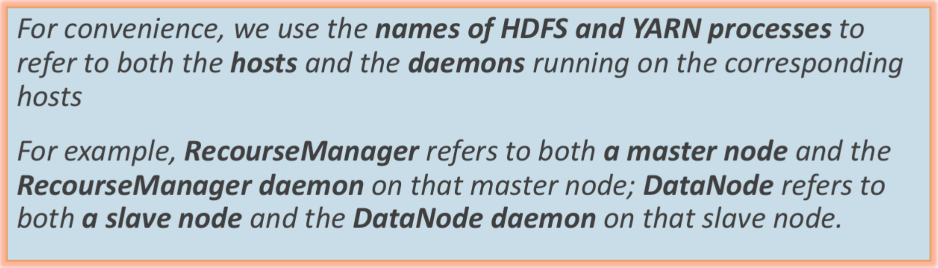
Terminologies



*For convenience, we use the **names of HDFS and YARN processes** to refer to both the **hosts** and the **daemons** running on the corresponding hosts*

*For example, **RecourseManager** refers to both **a master node** and the **RecourseManager daemon** on that master node; **DataNode** refers to both **a slave node** and the **DataNode daemon** on that slave node.*

Hadoop is a leading platform for big data

Hadoop consists of a storage layer (HDFS), a coordination and management layer (YARN) and a processing layer (e.g., MapReduce)

HDFS and YARN have key services (daemons)

MapReduce is a fundamental computing model (i.e., batch processing) for big data

Next: Interaction with Hadoop and "dive" into the MapReduce framework

References

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