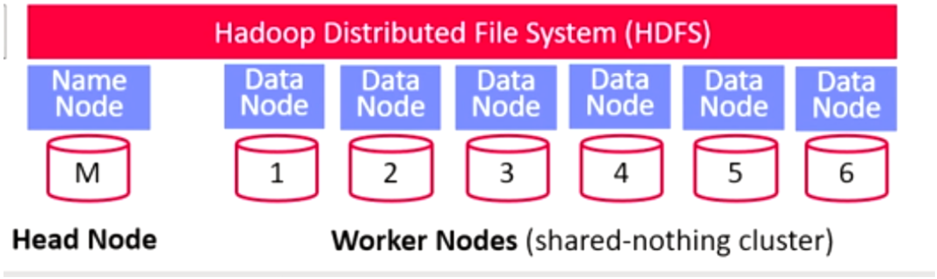
HDFS Overview

- distributed file system for large clusters and datasets
- splits files in 128 MB blocks, 3x replicated and distributed
- 

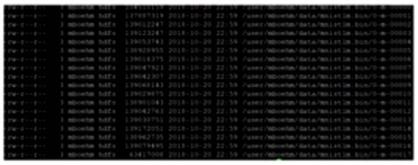
HDFS NameNode

Master daemon that manages file system namespace and access by clients

Metadata for all files (e.g., replication, permissions, sizes, block ids, etc)

FSImage: checkpoint of FS namespace

EditLog: write-ahead-log (WAL) of file write operations (merged on startup)



```
-rw-r--r--   3 mboehm hdfs [illegible] 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00000
-rw-r--r--   3 mboehm hdfs 1378987319 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00001
-rw-r--r--   3 mboehm hdfs 1390012247 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00002
-rw-r--r--   3 mboehm hdfs 1391233247 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00003
-rw-r--r--   3 mboehm hdfs 1390533743 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00004
-rw-r--r--   3 mboehm hdfs 1389289955 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00005
-rw-r--r--   3 mboehm hdfs 1390163375 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00006
-rw-r--r--   3 mboehm hdfs 1390047923 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00007
-rw-r--r--   3 mboehm hdfs 1390042307 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00008
-rw-r--r--   3 mboehm hdfs 1390068143 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00009
-rw-r--r--   3 mboehm hdfs 1390029875 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00010
-rw-r--r--   3 mboehm hdfs 1389001043 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00011
-rw-r--r--   3 mboehm hdfs 1390042763 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00012
-rw-r--r--   3 mboehm hdfs 1390030751 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00013
-rw-r--r--   3 mboehm hdfs 1391720051 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00014
-rw-r--r--   3 mboehm hdfs 1389962735 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00015
-rw-r--r--   3 mboehm hdfs 1390079495 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00016
-rw-r--r--   3 mboehm hdfs   63417008 2018-10-20 22:59 /user/mboehm/data/mnist1m.bin/0-m-00017
```

HDFS DataNode

Worker daemon per cluster node that manages block storage (list of disks)

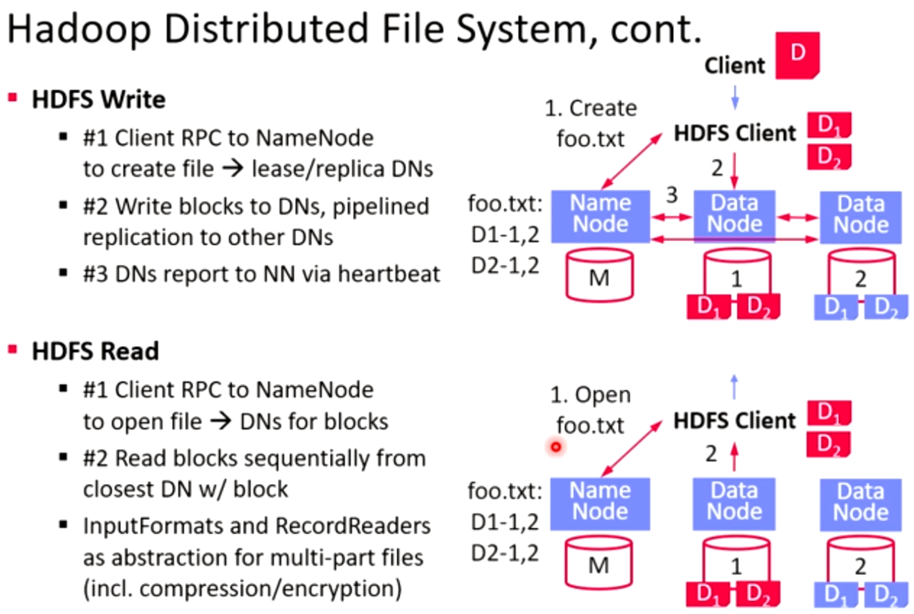
Block creation, deletion, replication as individual files in local FS

On startup: scan local blocks and send **block report** to name node

Serving block read and write requests

Send heartbeats to NameNode (capacity, current transfers) and receives replies (replication, removal of block replicas)

CRUD Operations



Hadoop Distributed File System, cont.

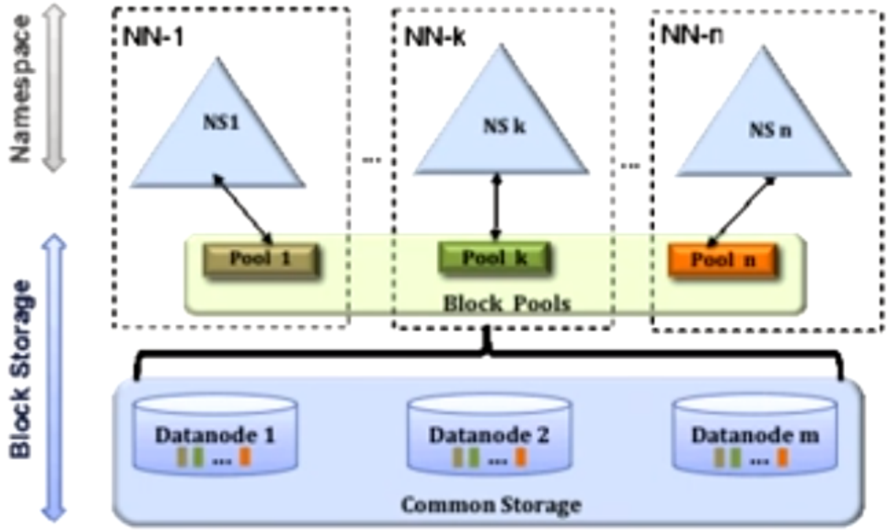
- **HDFS Write**
  - #1 Client RPC to NameNode to create file → lease/replica DNs
  - #2 Write blocks to DNs, pipelined replication to other DNs
  - #3 DNs report to NN via heartbeat
- **HDFS Read**
  - #1 Client RPC to NameNode to open file → DNs for blocks
  - #2 Read blocks sequentially from closest DN w/ block
  - InputFormats and RecordReaders as abstraction for multi-part files (incl. compression/encryption)

Data Locality

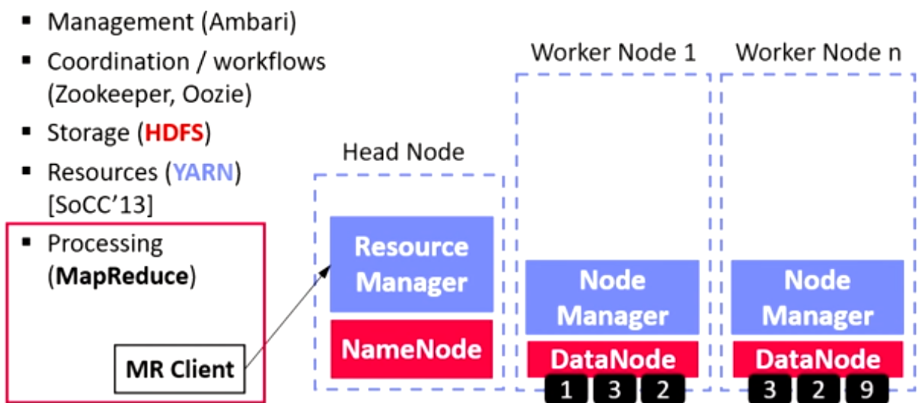
- HDFS is rack-aware
- schedule reads form closes DN
- replica placement 3x
  - local DN
  - other-rack DN
  - same-rack DN

HDFS Federation

- eliminates NN als namespace scalability bottleneck
- multiple independent NNs for name spaces
- each is responsible for subtrees of file system

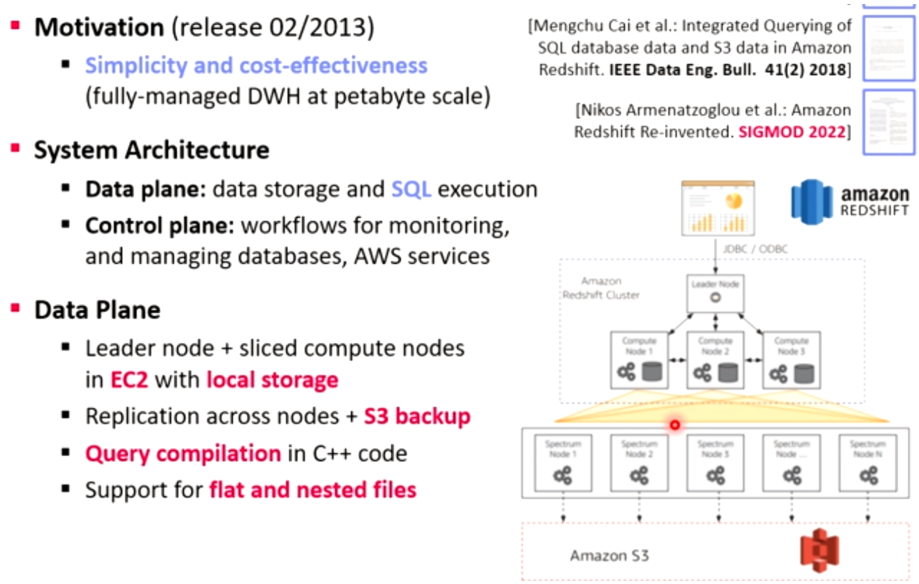
- 

Architecture



- Management (Ambari)
- Coordination / workflows (Zookeeper, Oozie)
- Storage (**HDFS**)
- Resources (**YARN**) [SoCC'13]
- Processing (**MapReduce**)

Excursus: Amazon Redshift



- **Motivation** (release 02/2013)
  - **Simplicity and cost-effectiveness** (fully-managed DWH at petabyte scale)
- **System Architecture**
  - **Data plane:** data storage and **SQL** execution
  - **Control plane:** workflows for monitoring, and managing databases, AWS services
- **Data Plane**
  - Leader node + sliced compute nodes in **EC2** with **local storage**
  - Replication across nodes + **S3 backup**
  - **Query compilation** in C++ code
  - Support for **flat and nested files**

[Mengchu Cai et al.: Integrated Querying of SQL database data and S3 data in Amazon Redshift. **IEEE Data Eng. Bull. 41(2) 2018**]

[Nikos Armenatzoglou et al.: Amazon Redshift Re-invented. **SIGMOD 2022**]

[[Distributed Data Storage]]