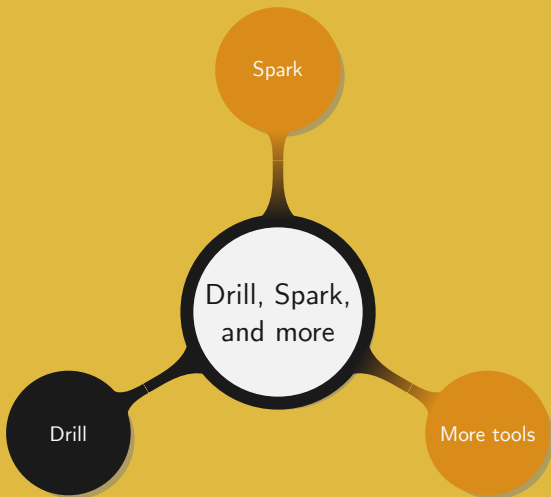


Methods and tools for big data

3. Drill, Spark, and more

Manuel – Summer 2023



Parties always involved in a Drill job:

- A client which initiates the job
- Zookeeper

Parties optionally involved in a Drill job:

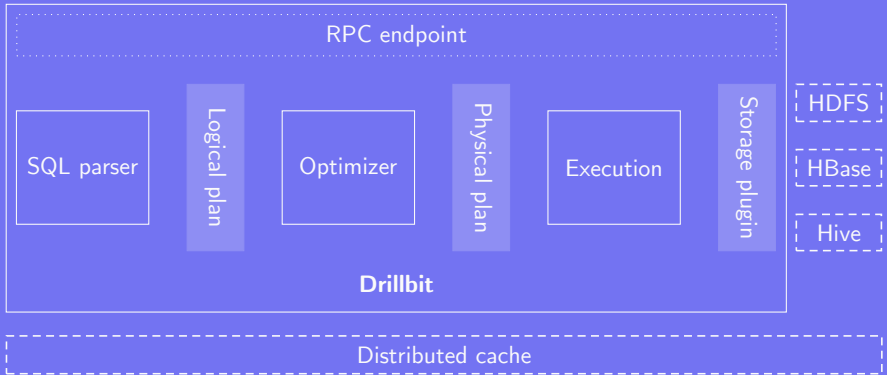
- YARN
- HDFS
- Hive
- HBase

Running Drill as a YARN application:

- ① Start Drill on the client machine
- ② Upload resources to the FS and request resources for the application master
- ③ Ask a node manager to prepare and start a container for the application master
- ④ The application master contacts the resource manager to obtain more containers

Running Drill as a YARN application:

- ⑤ Request the start of Drill software on each assigned node
- ⑥ Start a “Drill process” called a *drillbit*
- ⑦ Each drillbit starts and registers with Zookeeper
- ⑧ The application master checks the health of each drillbit through Zookeeper
- ⑨ Use Zookeeper to retrieve information on the drillbits, run queries, etc.



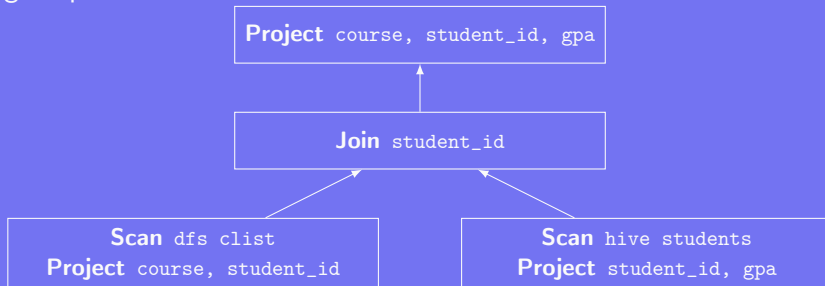
Foreman drillbit:

- Drillbit that receives the query
- It drives the entire query

Initial SQL query:

```
1 SELECT course, student_id, gpa
2 FROM clist.json l, hive.students s
3 WHERE l.student_id = s.student_id
```

Logical plan:

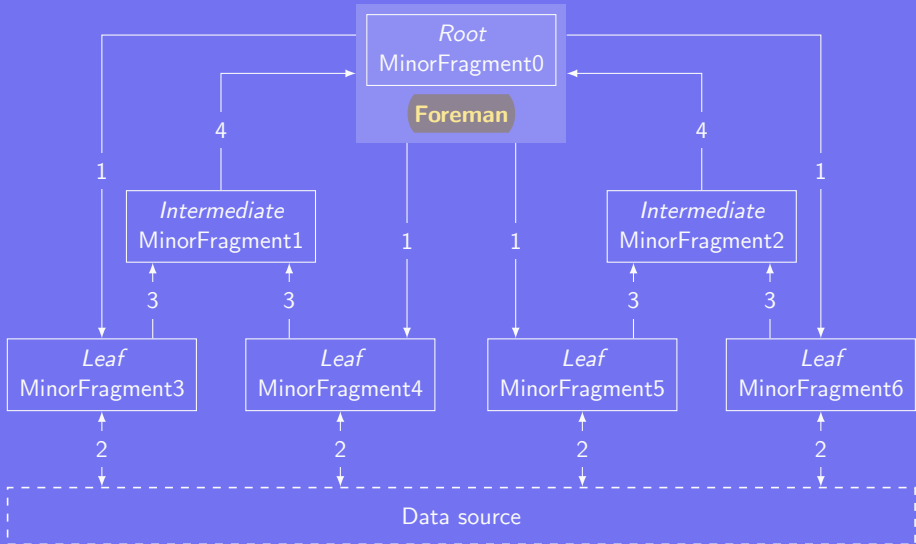


Major fragment:

- Concept representing a phase of the query execution
- Composed of minor fragments

Minor fragment:

- Logical unit of work running in a thread
- Contain one or more relational operators
- Usually as numerous as the number of available drillbits
- Scheduled based on data locality when possible and round-robin otherwise



Architecture:

- No central server, no master-slave concept
- Each drillbit contains all the services and capabilities of Drill
- Nodes can be added or removed at no cost

Columnar execution:

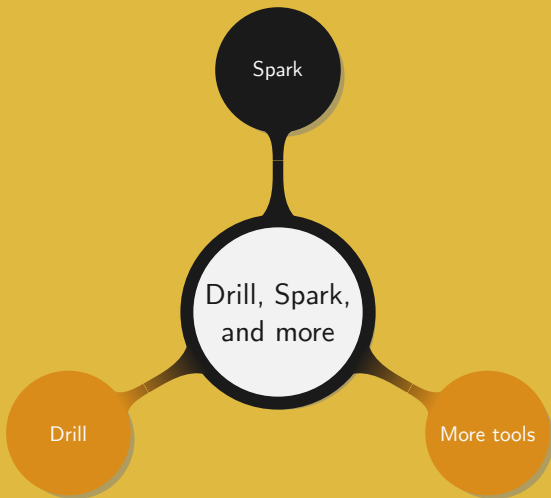
- Avoid access for columns not involved in the query
- Directly performs SQL processing on columns

Optimistic query execution:

- Assume no failure will occur during query execution
- Rerun the query in case of failure
- Only write on disk when memory overflows

Vectorization: allow the CPU to operate on vectors

Runtime compilation: generate efficient code for each query



Spark organisation:

- Application: user program built on Spark and composed of:
 - A driver program: process running the main function
 - Executors: processes launched for an application on worker nodes
- The driver program connects to a cluster manager
 - Standalone: cluster manager provided with Spark
 - YARN
 - Mesos
 - Kubernetes

Two modes available:

- Client mode:
 - Driver runs in the client
 - Required in the case of interactive programs
 - Useful when building a Spark program
- Cluster mode:
 - The entire application runs in the cluster
 - Appropriate from production jobs
 - YARN application master failure strategy (slide 2.31) is applied

Spark job workflow:

- ① Start the driver program on a client node
- ② The driver requests a container to the resource manager
- ③ A container starts and runs an Executor Launcher application master
- ④ The Executor Launcher requests more resources to start Executor backends processes in new containers
- ⑤ Each Executor Backend registers with the driver

Workflow similar to client mode but:

- The driver program runs in a YARN application master process
- The client submit a job but does not run any user code
- The application master starts the driver program
- The driver program “replaces” the Executor Launcher

Remark. Data locality:

- Executors are launched before data locality information is available
- The driver can optionally specify preferred locations

Resilient Distributed Dataset (RDD):

- Core abstraction in Spark
- Collection of objects distributed across a cluster:
 - Read-only: do not alter a dataset, transform it into a new one
 - Resilient: no disk write, reconstruct the RDD in case of partition loss
- Loaded as input:
 - Created from an external dataset
 - From an existing RDD
 - Parallelising an existing collection

Two types of operations on an RDD:

- Transformation:
 - Create a new dataset from an existing one
 - Only compute the result when an action is run
 - Do not return any result to the driver program
- Action:
 - Run a computation on a dataset
 - Return the value to the driver program

Benefits of this approach:

- Transformed RDD is in memory when performing an action
- No large dataset to send back to the driver program

Datasets are cached in memory across operations:

- An RDD is stored on the node where it was computed
- An old RDD is dropped following the LRU algorithm
- A lost RDD is automatically recomputed if needed

Caching levels:

- Memory only: no compression, lost partitions are recomputed
- Memory and disk: partitions that do not fit in the memory are spilled on disk
- Memory only serialized: compression enabled
- Replication: all the above but also replicate on another node

Serialization of data and functions:

- Used to share information among the executors
- Transparent to the user

Task closure:

- Cannot share variables among executors
- Determine what variables and methods an executor needs
- Serialize this closure and send it to the executor
- Each executor receives a copy of the original variable
- Variables are not updated on the driver

Broadcast variables:

- Read-only variables broadcasted to each executor
- Data sent in an efficient way to minimize traffic
- Useful for data needed over several stages of the computation

Accumulators:

- Variables that can be added to, using associative and commutative operations
- The driver can retrieve their value
- They are only updated on action tasks
- Update only occurs once, even if an action is rerun

Job submission and execution:

- A job is submitted when an action is performed on an RDD
- The transformations on the RDD are organised into a logical execution plan
- Spark DAG scheduler transforms the logical plan into a execution physical plan
- The physical plan defines stages, split into tasks
- Spark task scheduler constructs a mapping of tasks to executors
- The executor runs the task
- Executors send status updates to the driver when a task is completed or has failed

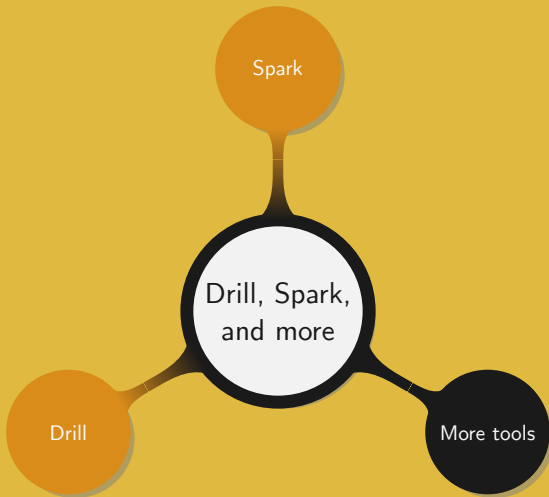
Newer and higher level abstractions relying on RDD:

- Datasets:
 - Foundational type of the structured APIs
 - Provide type-safety and allow much flexibility
 - Only available in Java and Scala and comes at a performance cost
- DataFrames:
 - Similar to a spreadsheet split into partitions
 - Internally defined as DataSets of type `Row`
 - Most common structured API, supported in all languages
- SQL Tables:
 - Data structure similar to DataFrames but defined within a database
 - Unmanaged table: defined from a file on the disk
 - Managed table: imported in and managed by Spark

Advantages of DAG:

- Any lost RDD can easily be recovered
- Offers more possibilities than a simple Map and Reduce approach
- Transformation on RDDs are not directly applied:
 - Allows better optimizations
 - Decreases disk writes and data transfer

Remark. Spark generalises the MapReduce approach, is much faster, and features many more high-level operators



Simple observations:

- Over 20 billions devices are connected to the internet
- The complexity of software keeps increasing
- New security challenges need to be addressed
- Package manager dependencies are complex to handle

Alternative package management systems:

- Flatpak, Snap, AppImage:
 - Distribution agnostic packages
 - Applications are sandboxed, i.e. isolated from each others and the host
- Nix: *all* packages are isolated from each others

LinuX Containers (LXC):

- Operating-system-level virtualization method
- Relies on the kernel's *cgroup* and *namespace* isolation functionalities
- Concurrently run multiple isolated Linux OS on a machine
- Each container must be individually maintained
- Containers can be either privileged or unprivileged
- Containers access the bare machine and rely on the host kernel

LXC requires the setup of a whole OS for each container

Docker uses a different approach than LXC:

- Initially based on LXC but *now* completely independent
- A daemon manages the docker containers
- A container is an encapsulated environment that runs applications
- An image containing an application and its dependencies is built based on a “configuration file”
- To update simply replace the old image with a new one

Docker needs to be “manually” deployed, managed, and scaled

Kubernetes is a container orchestration tool:

- Mostly used with, but not limited to Docker
- Initially developed as an internal Google project
- Kubernetes is a cluster application that handles a cluster:
 - *Master*: controls all other machines in the cluster
 - *Nodes*: the machines onto which applications are running
 - *Pods*: single instance of an application or running process

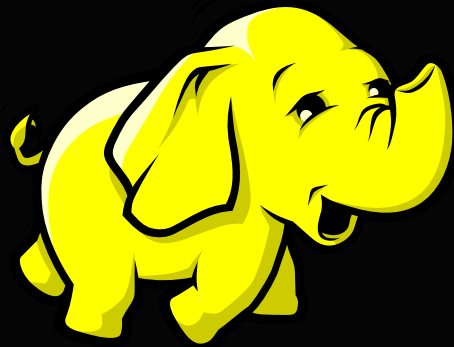
Main tasks of Kubernetes:

- Monitor the health of the running applications
- Balances the load
- Manages hardware resources allocation
- Eases the deployment of preconfigured applications
- Allows access to storage in the same way as any other resources

During the lifespan of an application:

- Containers can live, die, be resurrected
- Kubernetes handles everything without any human interaction

Kubernetes can be coupled to Hadoop or work independently



Thank you!