Big Data Hadoop Ecosystem

from SQL to (Hadoop Parquet) Files HiveMetaStore, IO Optims

course Esilv 2024
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this document:
https://github.com/Arnaud-Nauwynck/presentations/tree/main/pres-bigdata
7-Sql-to-Hadoop-files-parquet-metastore

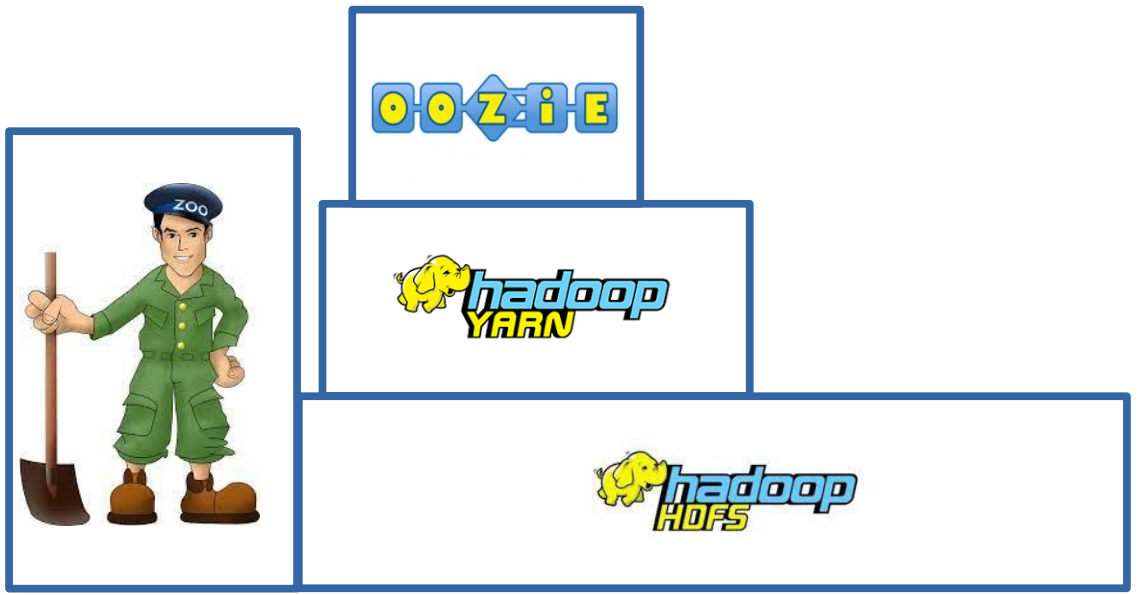
Outline

- Prev Part: Low-Level Hadoop components
  - ZooKeeper, Hdfs, Yarn, Oozie
- Sql Table Definition, Hive MetaStore
- Parquet
- IO Optims

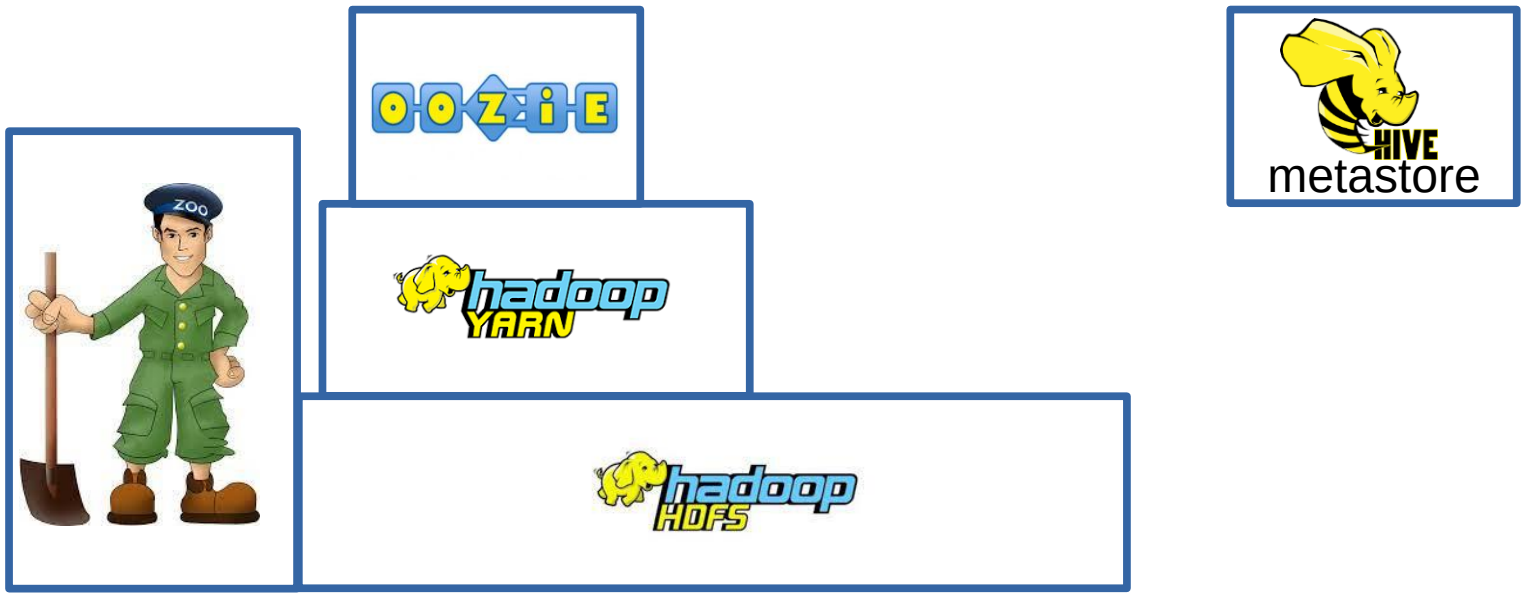
  Schema, Splittable blocks format, Partitions Pruning, Columns Pruning, PPD

Prev Part: Low-Level Focus

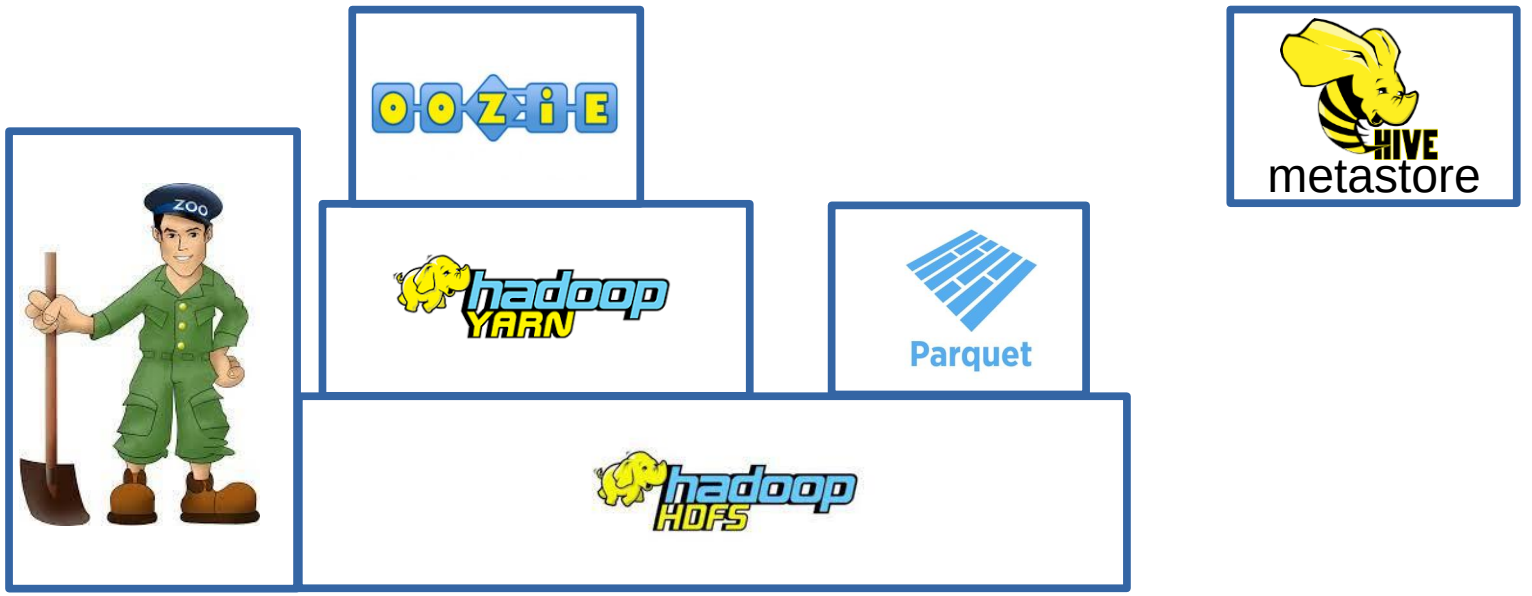
ZooKeeper, HDFS, Yarn, Oozie



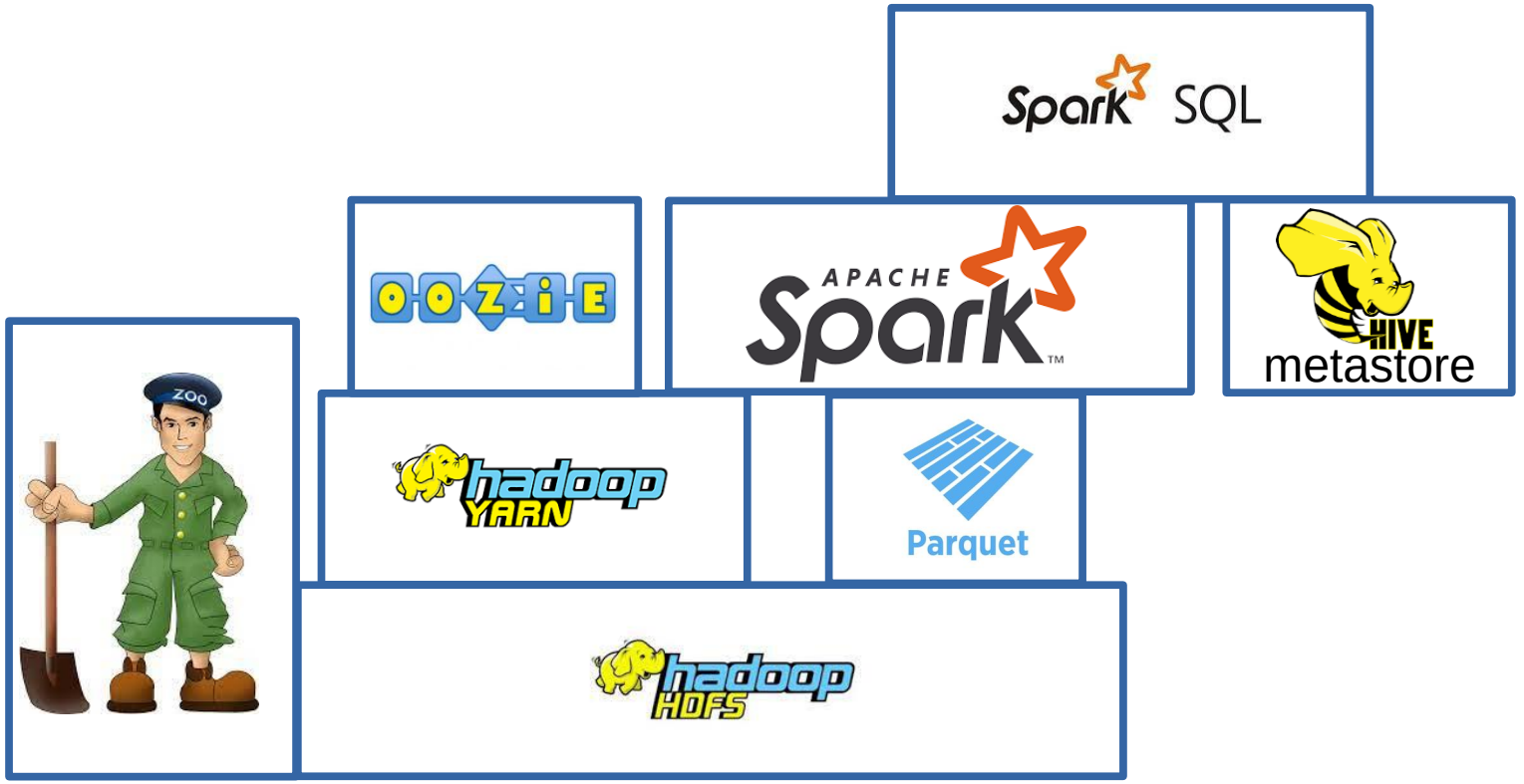
This Part: … Technical Focus
MetaStore, Directory-Files Partitions



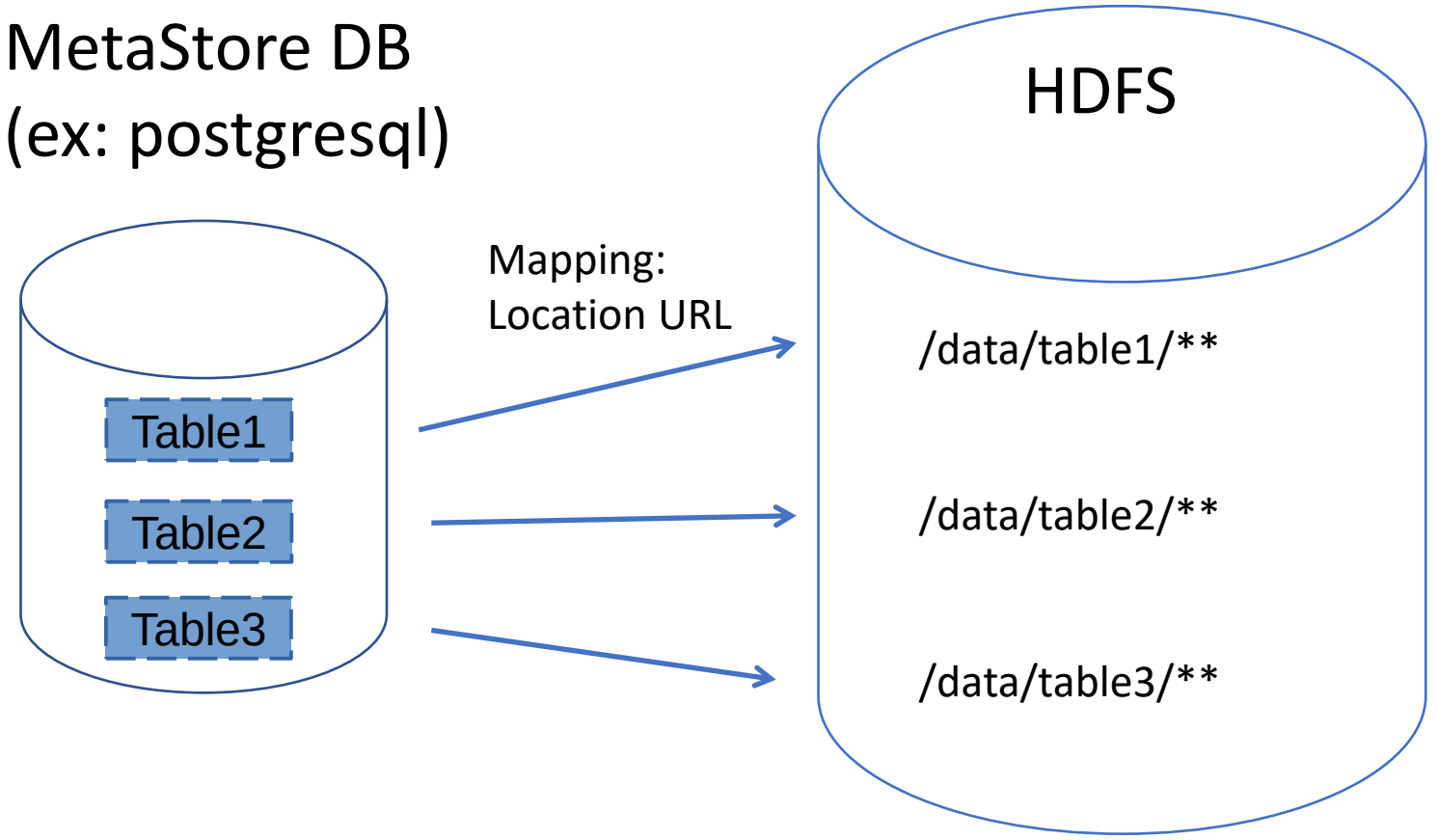
This Part : ... Parquet, IO Optims



Next Part … High-Level Focus Spark, Spark SQL



(Hive) MetaStore



MetaStore

Contains only **DDL** (Data Definition Langage)
metadata (no HDFS data)

Logical view mapping : **name in SQL ⇔ location in HDFS**

File format encoding: parquet, orc, avro, csv, json, …

Schema : **column types**

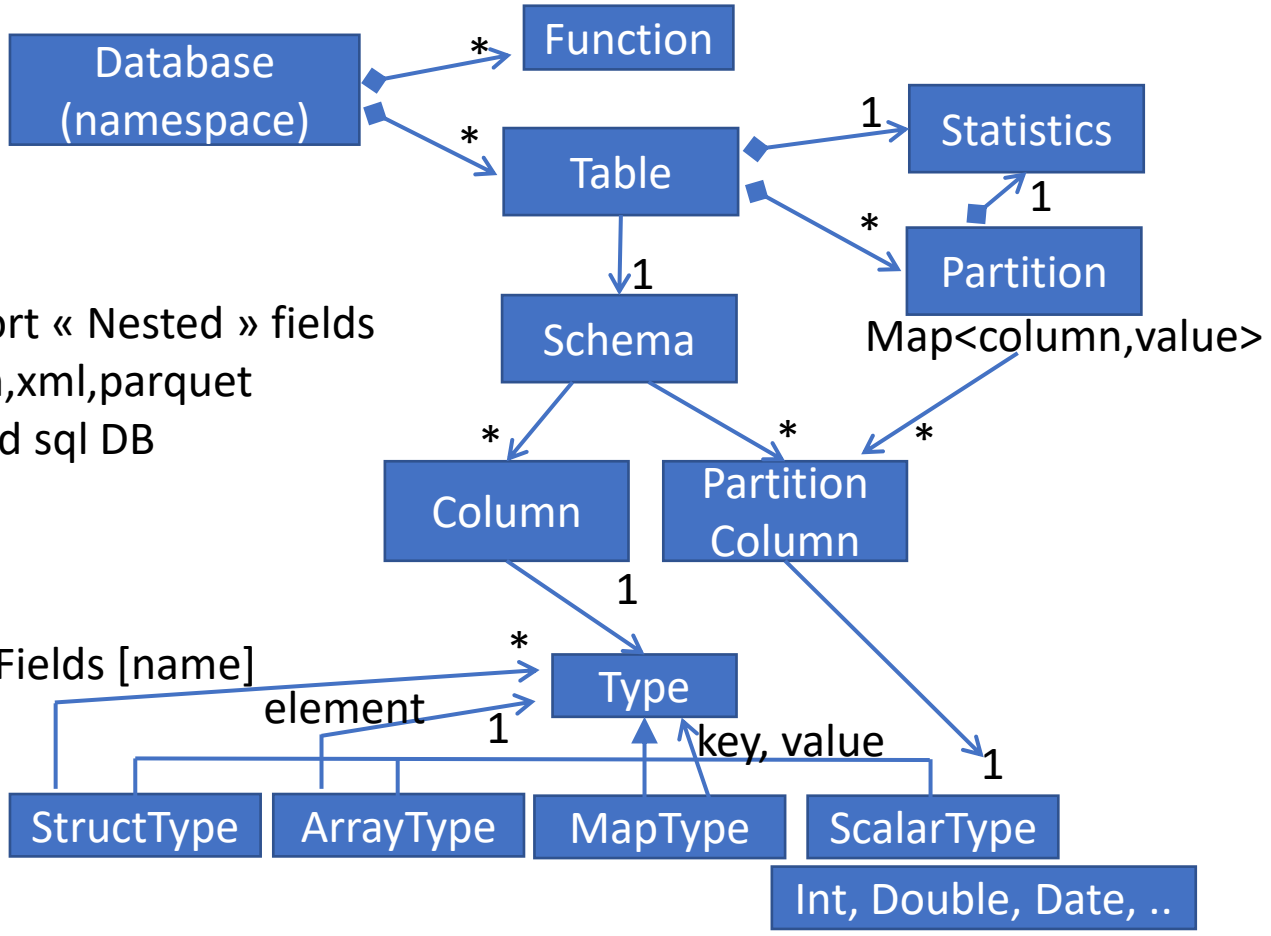
Sample CREATE EXTERNAL TABLE

```
CREATE EXTERNAL TABLE db.student (
   id int,
   firstName string,
   lastName string
)
PARTITIONED BY (
  promo int
)
STORED AS parquet
LOCATION ‘/data/student’
```

Advanced CREATE EXTERNAL TABLE

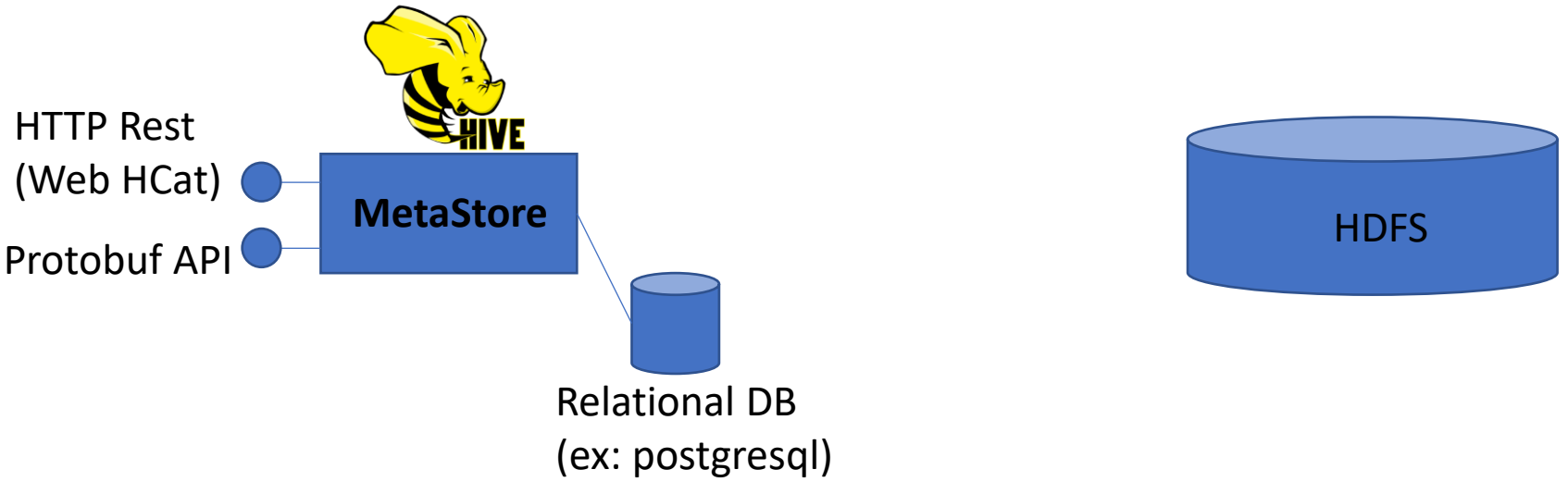
```
CREATE EXTERNAL TABLE db.student (
  id int, firstName string, lastName string,
  address struct< street string,number int,zipcode int >,
  graduations array< struct< name string, obtentionDate date > >,
  extraData map< string,string >
)
PARTITIONED BY ( promo int )
CLUSTERED BY ( id, ...)  SORTED BY (lastName, firstName )
STORED AS parquet
LOCATION '/data/student'
```

MetaStore Model

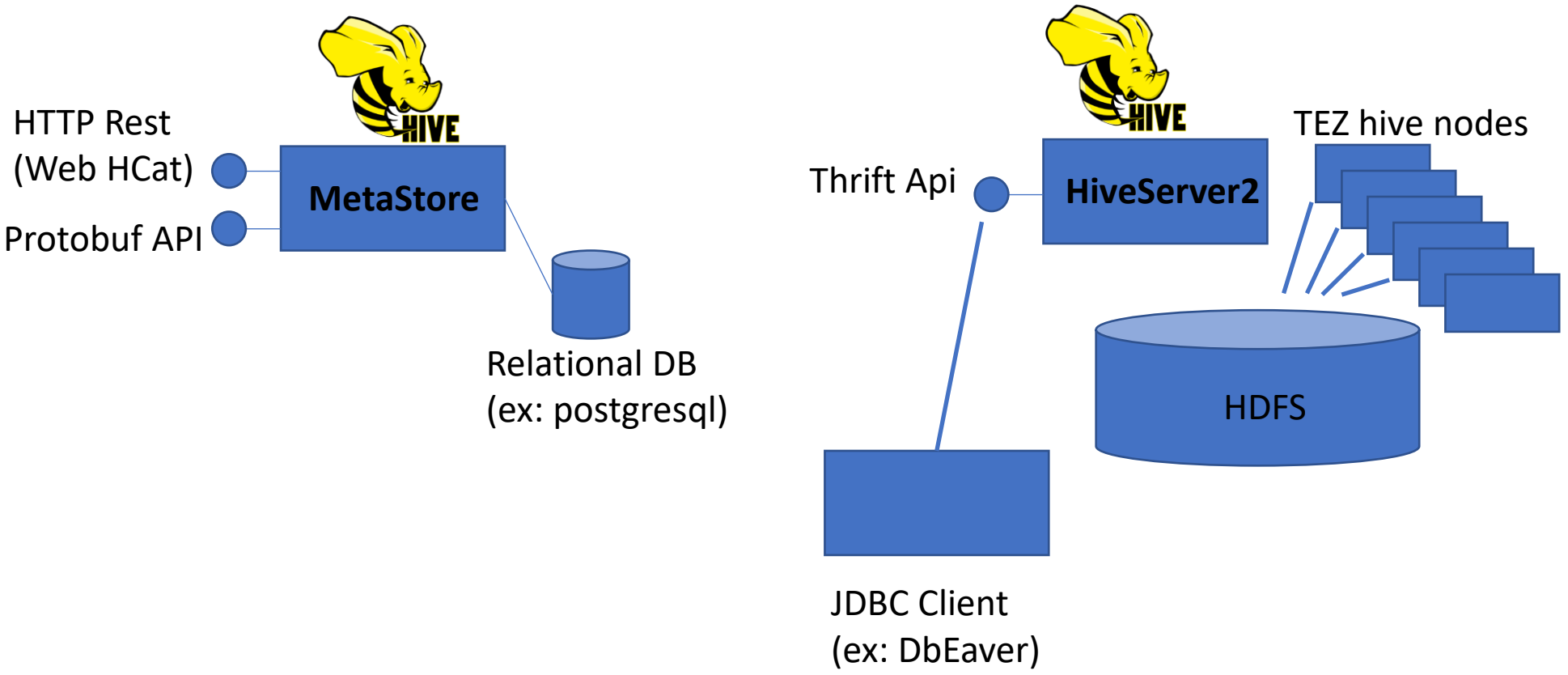


Schema support « Nested » fields
like typed json,xml,parquet
unlike standard sql DB

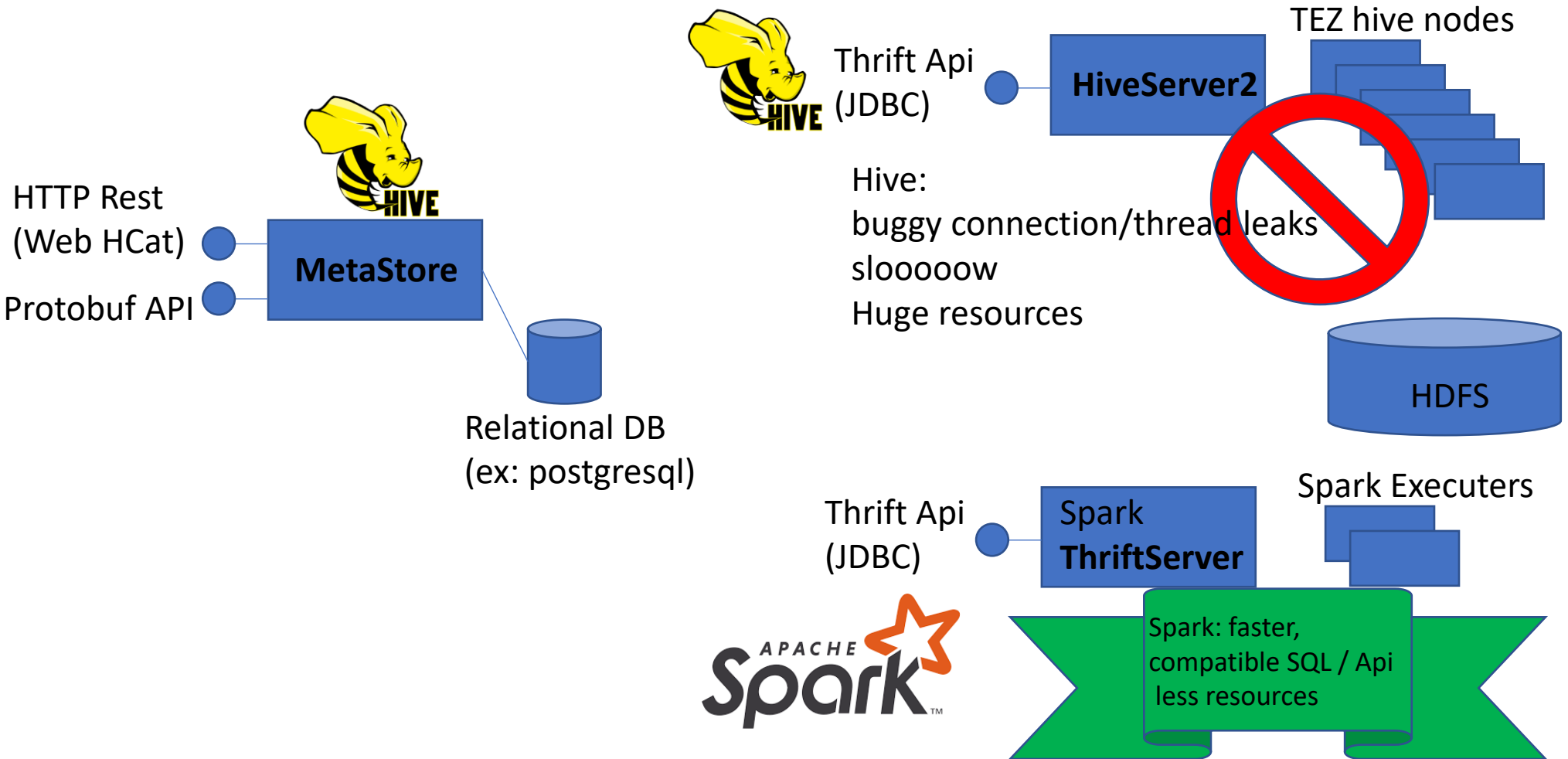
Hive MetaStore Architecture



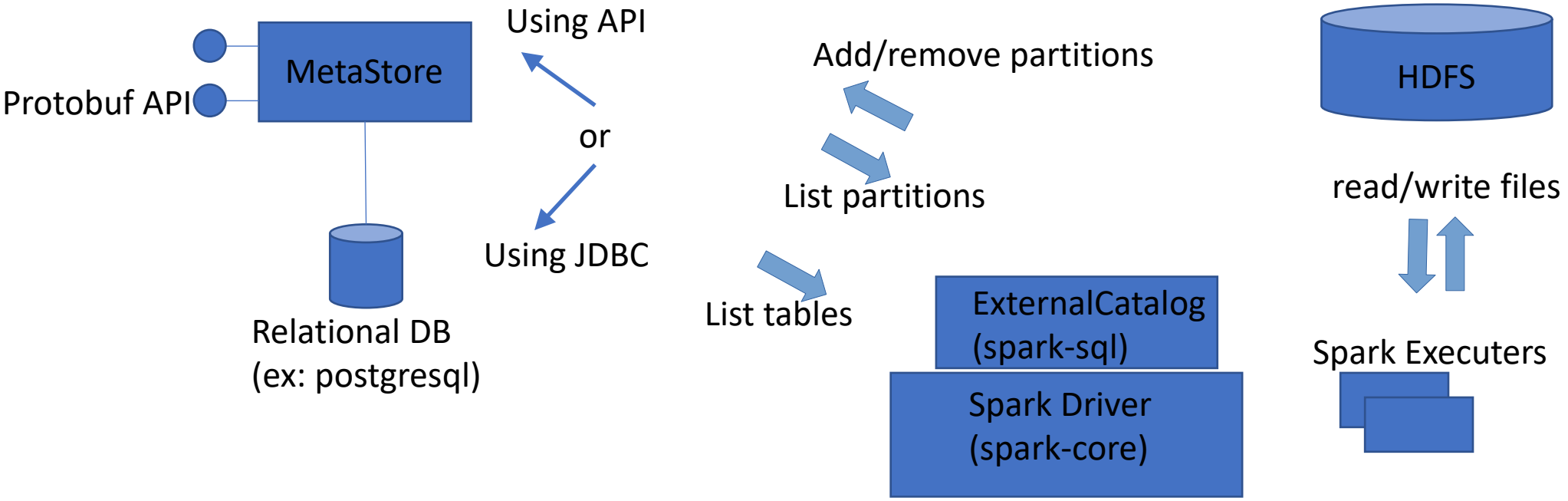
Hive MetaStore != Hive Server2



Hive Server2 ... Deprecated



Spark supports Hive MetaStore



Sql> DDL

```
Sql>
show databases;
use ‘db’;

show tables in ‘db’;
show tables in ‘db’ like ‘s*’;
describe table db.student;
show create table db.student;

alter table db.student set location ‘/data/student2’;
drop table db.student;
```

DDL.. EXTERNAL table

« EXTERNAL TABLE » : data exists independently of metastore

when creating table ... Schema must be compatible with existing files
Non-sense to « alter table » for column
When dropping … files are not deleted

Do not use opposite « MANAGED TABLE »
When creating => create empty dir, location= « {db.location}/{table} »
When dropping => delete all files !

Sql> DML

Sql>
INSERT INTO table values(..)
  => save to new file(s) !!
      preserve existing ones
      (also preserve partially uncommited ones..)

INSERT OVERWRITE / DELETE
  => reload all files
      + save all to new files
      + delete old files

Sql> Update? DML

by default Spark 3.x does NOT support UPDATE
(nor UPSERT, MERGE)

Only with extensions of « DeltaLake », « Iceberg », ..

Spark> Update?
read().map().write()

```
spark
    .read().format(« PARQUET »).load(« /data/table1 »)

    .map( x -> {   …transform row to ‘update’ values; return newRow } )

    .write().format(« PARQUET »).mode(SaveMode.Overwrite).save(« /data/table2 »)
```

Full Scan ALL files
Load ALL
in-memory

Process ALL
In-memory

Delete ALL files
+ save ALL
in-memory

Sql> … NO « ACID »

C onsistent

D urable

Granularity of insert (append / overwrite)

Write a single ROW → in 1 new **File**

HDFS hates Small Files (Too many files) !!

Write from shuffled RDD (several executors) → in 200 **Files** by default spark.sql.shuffle.partitions=200 !!

Overwrite some files, and no touch others → Possible only by **partition**

Make Long Story Short

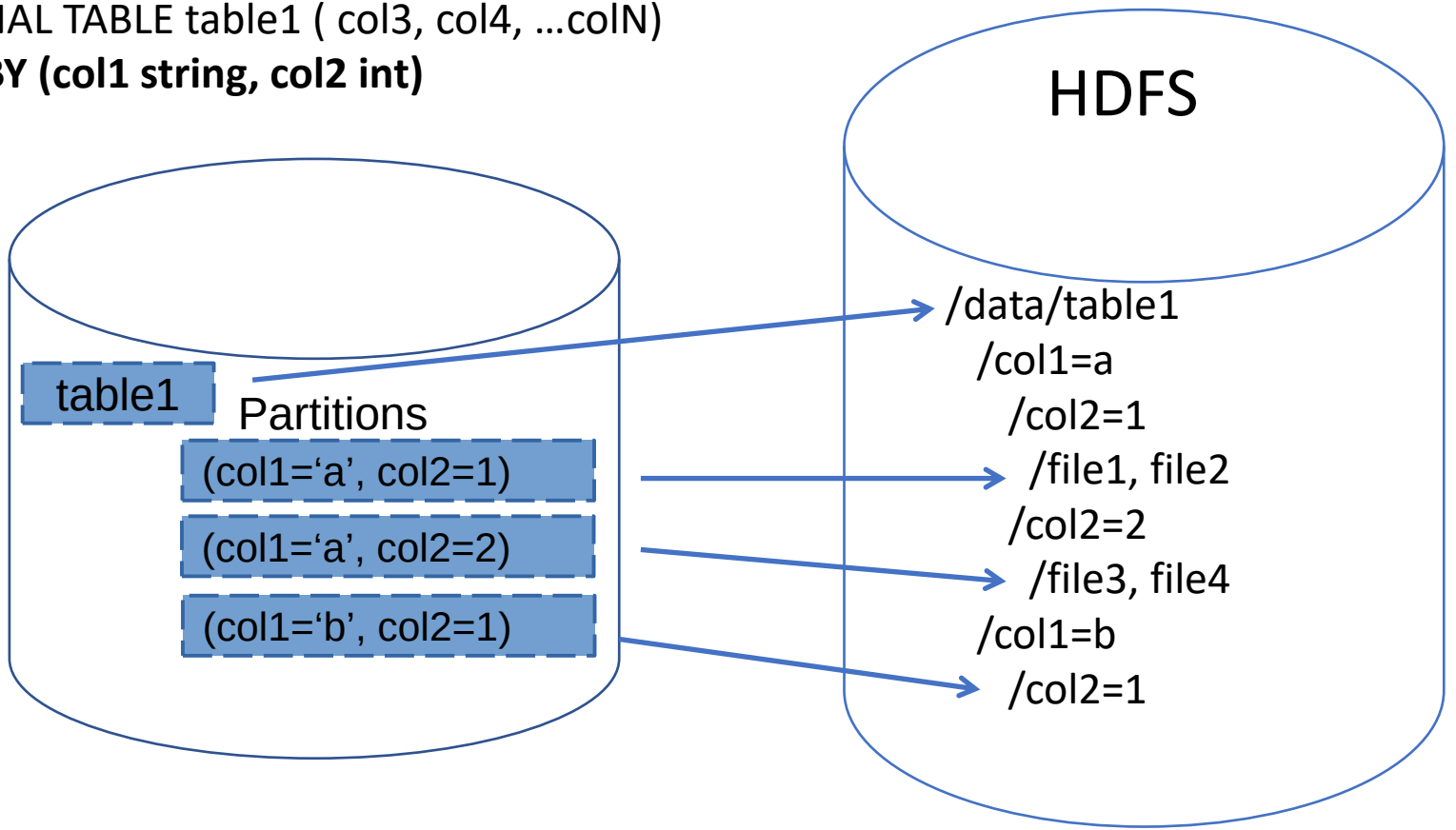
Table Scope
for update
(~Transactional)

Hive Partition

Hadoop
Directory

PARTITIONED BY (col1, col2)

CREATE EXTERNAL TABLE table1 (col3, col4, …colN)
PARTITIONED BY (col1 string, col2 int)



Alter table ADD PARTITION / MSCK REPAIR TABLE

Need EXPLICIT add !!
Otherwise dir/files not scanned => 0 result

Sql>
ALTER TABLE .. **ADD PARTITION** (col1='a', col2=1);
… Or
MSCK REPAIR TABLE ..; -- (inneficient rescan all)

Discover.partitions ??
… False good idea

ALTER TABLE … SET TBLPROPERTIES ('discover.partitions' = 'true')

hive-site.xml
  metastore.partition.management.task.frequency=600

  … => INNEFICIENT : Polling metastore thread every 10mn to scan HDFS, and alter
  + Spark still using explicit partitions

What if you have Peta bytes, with millions of dirs?

Optim: Partitions Pruning

Sql> select … from db.student where promo=2020 and …

Condition on partitioned column

Scan only files in
/data/student/promo=2020/**

Skip others
/data/student/promo=2019/
/data/student/promo=2018/
…

Partition: what for ?

NOT for searching faster !! (Not-only)

(worst than parquet Predicate-Push-Down)

Granularity of Save mode Overwrite

… adapt to your batch scope

DO NOT define too (>2) many partition levels

Daily Batch =>
Partition Dir /date=yyyy-MM-dd

/data/table1

/date=2021-12-25  Partition for today

batch today 

relaunch Failed batch ?? 

/date=2021-12-24/ 

Already computed
from yesterday's batch
(do not update)

/date=2021-12-23/ 

…older history

Immutable history

More Complex Daily Batches

/data/table1

/date=2021-12-25

/scope=x/*.*

/scope=y/*.*

/date=2021-12-24/

/date=2021-12-23/

…older history

sub-partitions
for N batches scope

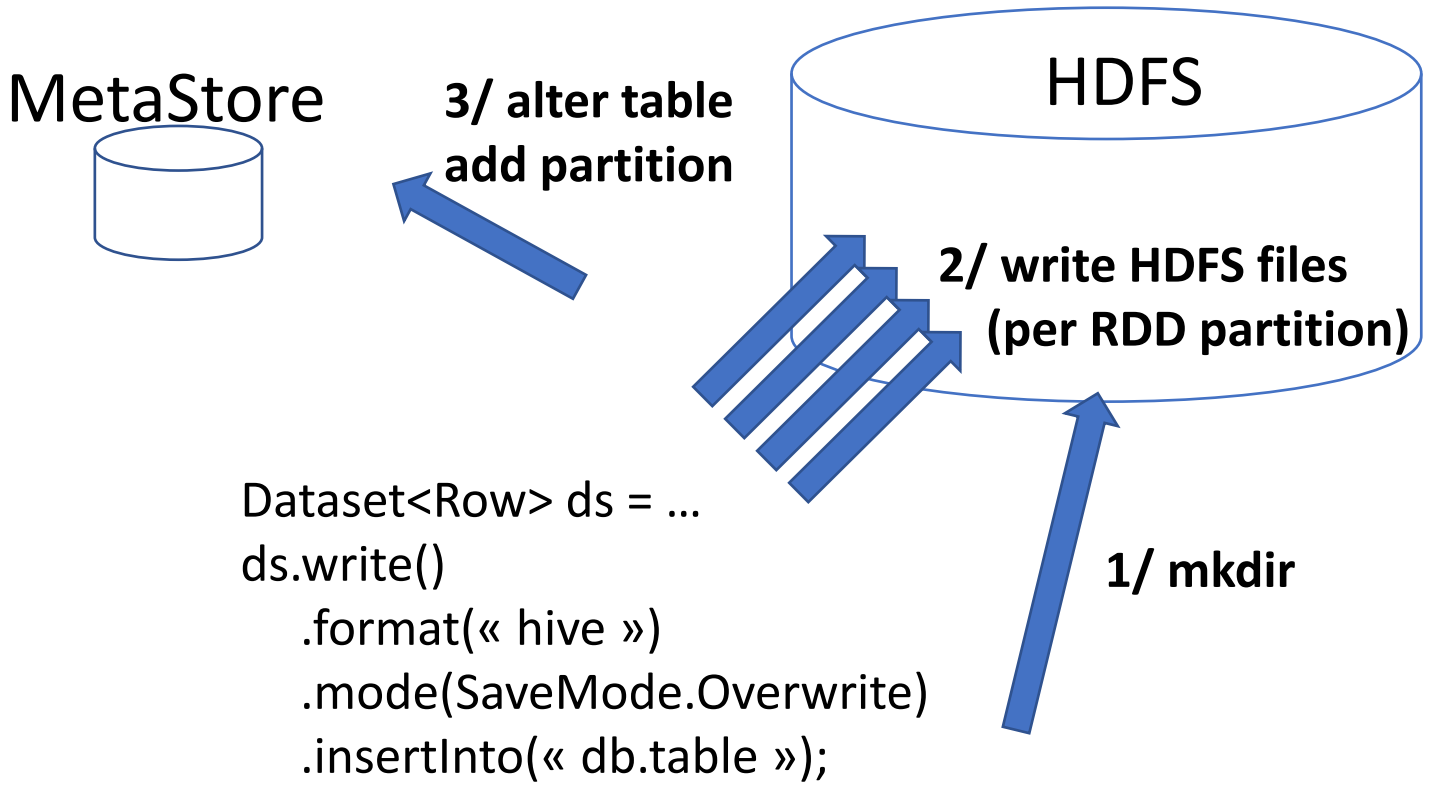
Already computed
from yesterday's batch
(do not update)

Immutable history

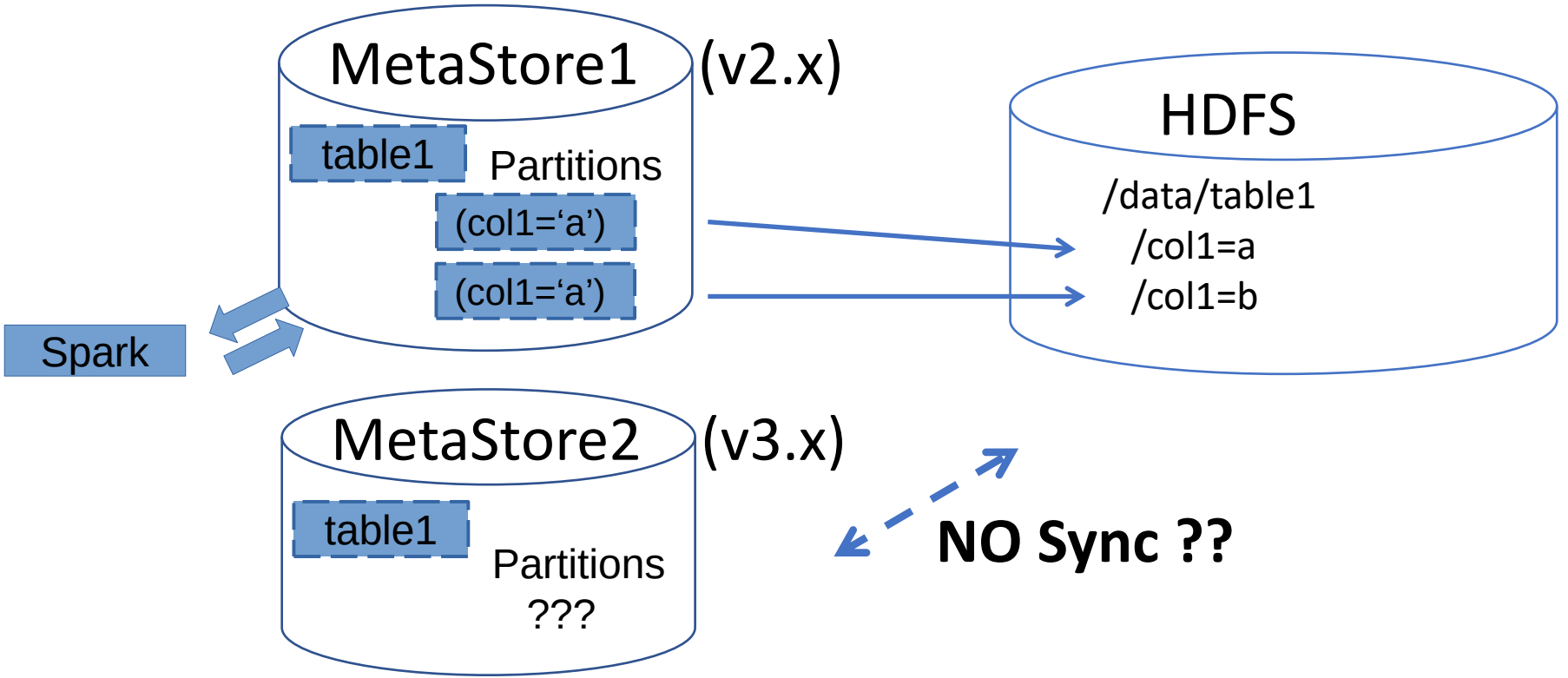
batch today scope=x

batch today scope=y

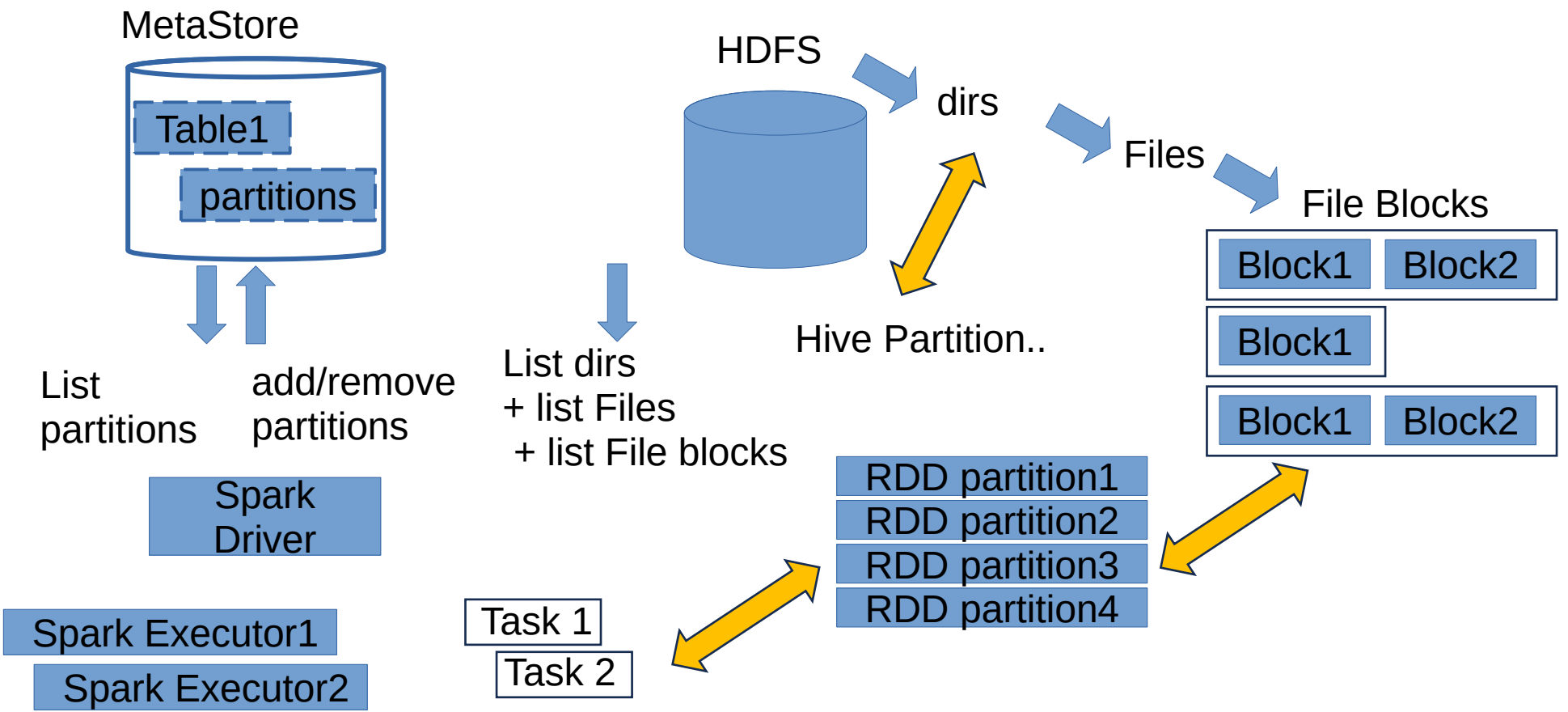
Spark .save()
=> mkdir + write Files + add partition



Synchronize HDFS with several MetaStores?

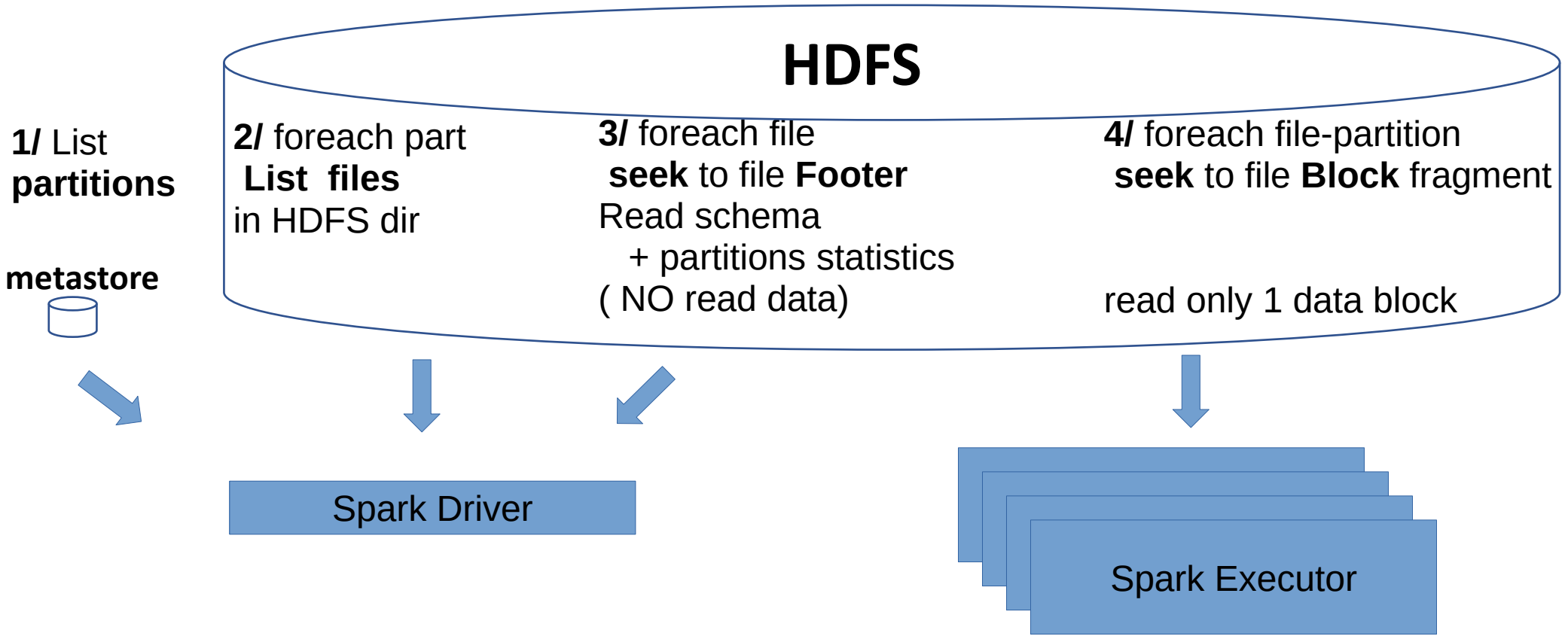


Spark RDD Partitions / MetaStore Partitions



Assign 1 partition to 1 executor = 1 Task (= for 1 File Split ~ Block)

Spark RDD Partitions
= MetaStore Partition * Files * Blocks



ANNEXE

Iceberg

Spark SQL extension for UPDATE,DELETE

ANNEXE

Do You really "UPDATE" data ?

Remarks :

In general **NO**

Better to **insert a new version** of the object

example: Financial Transactions
... you never "UNDO" the history of a payment,
but you can reimbourse, by new payment in opposite direction

Databases actually work like this
ex: Oracle, PostgresQL have "transaction logs" and multi versions
you can read "as of" in the history

ANNEXE

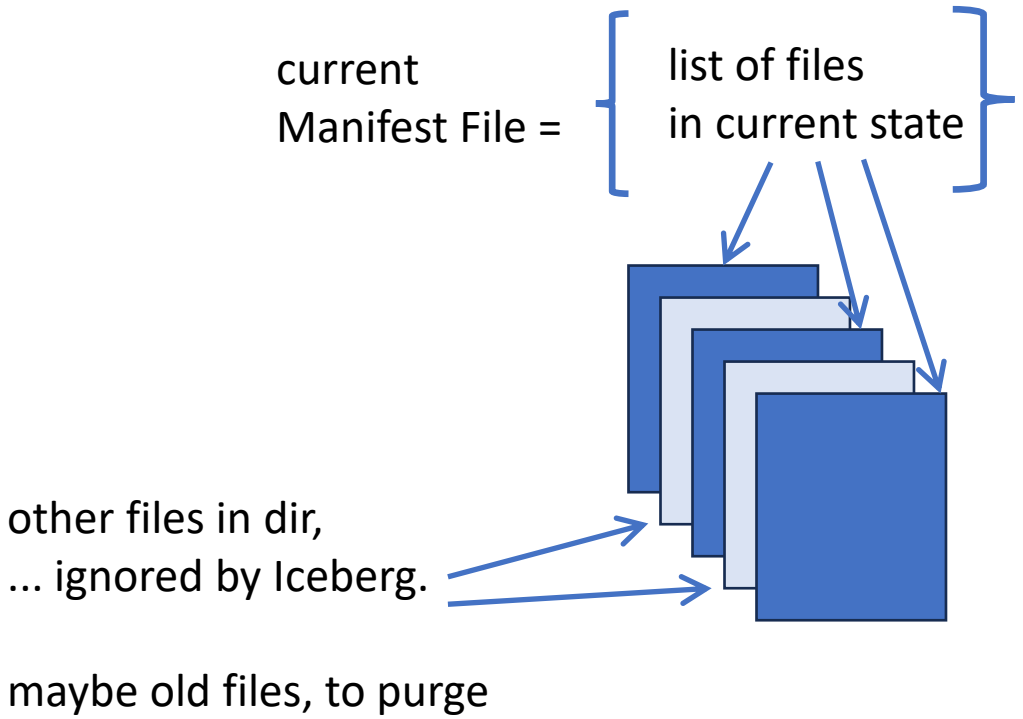
Iceberg ... Transaction Log Files

Iceberg = use its own custom MetaStore

not based on listing all Files in a Directory (like in Hive)
BUT by keeping a transactionLog (in json files)

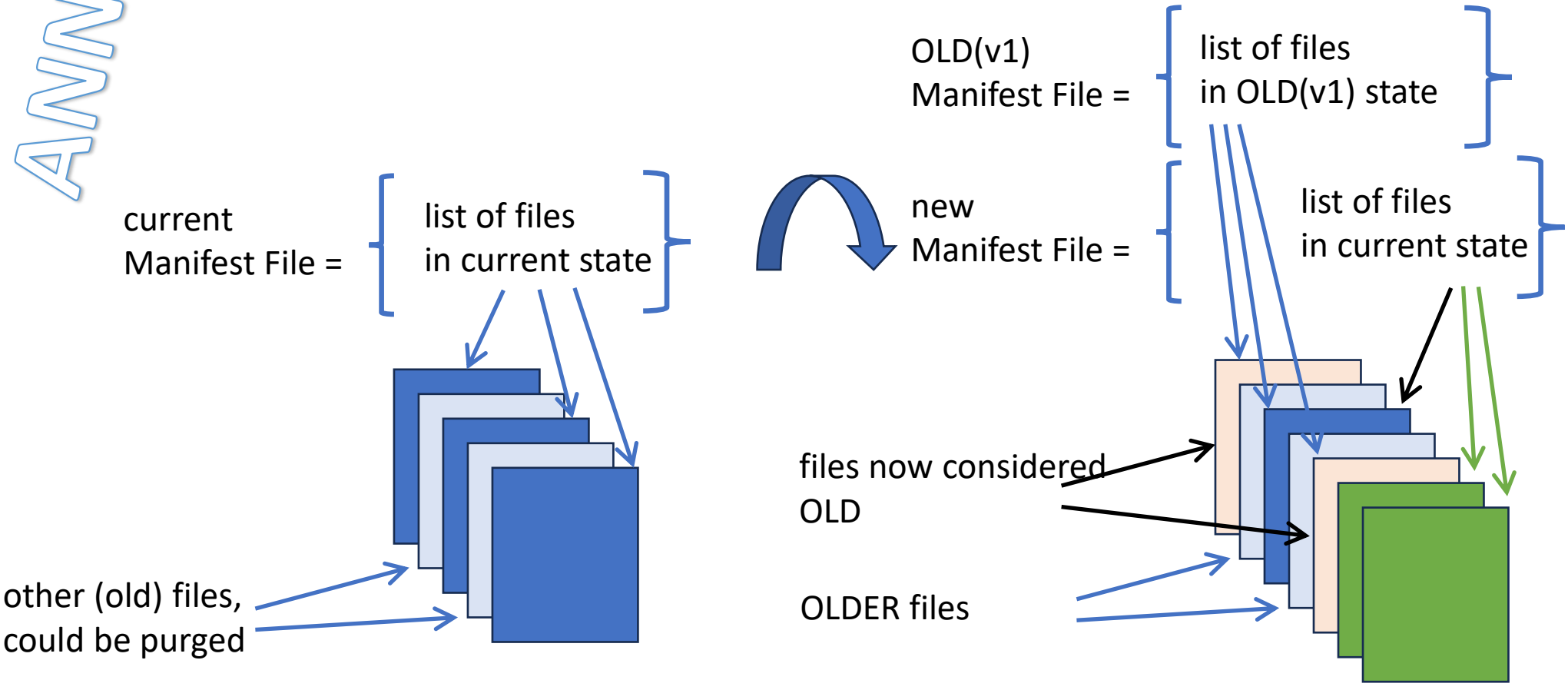
ANNEXE

Iceberg Manifest File State



ANNEXE

Iceberg Update = Transaction to disable (old) Files, and add new Files



ANNEXE

Iceberg
to Update 1 row of a File
=> duplicate 100000 rows in a new file !

Files number Explosion Problems ...

Need Purge mecanism
exemple: retention to 7 days of history

ANNEXE

Iceberg = JSON + Parquet Files

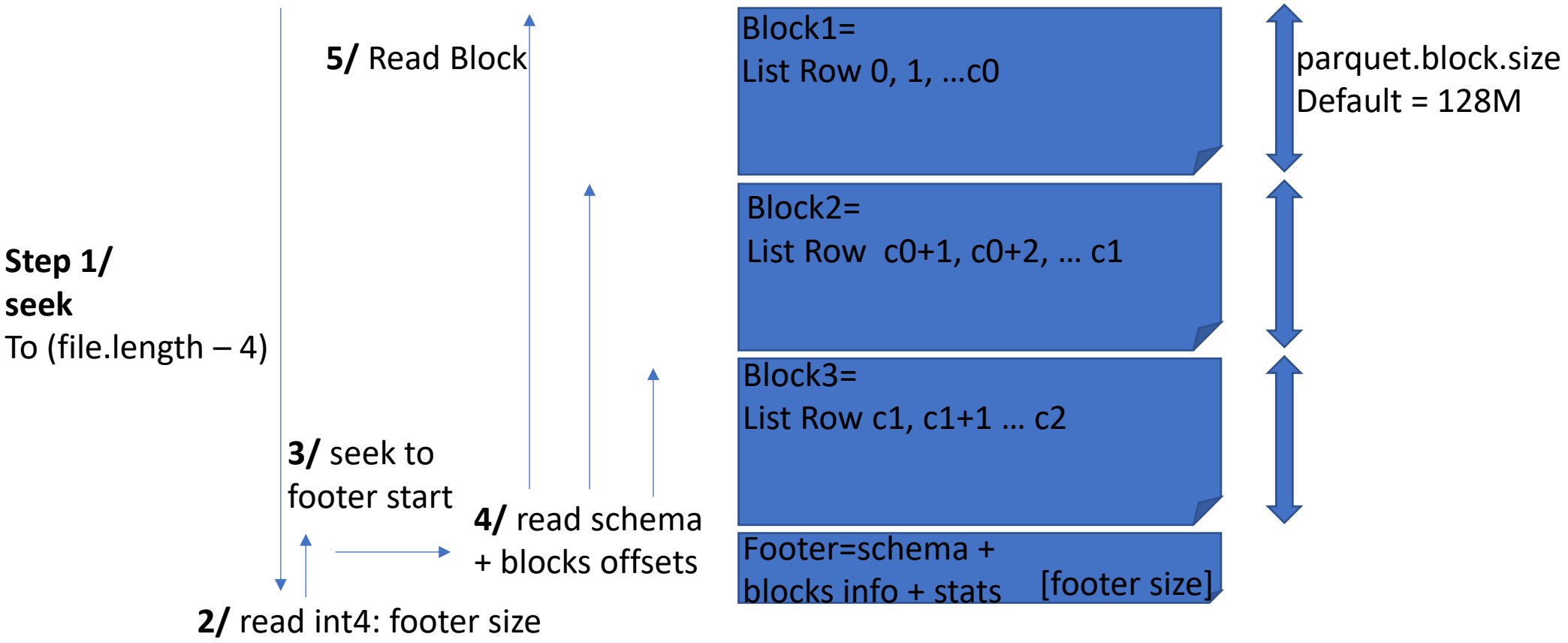
JSON File for storing Metadata (transaction logs)

Parquet Files for storing Data (like plain old spark + Hive did well)

Transactions no more handled by "directory listing"
No Need "hive partition"
Only need Hive "DDL"

PARQUET File Format

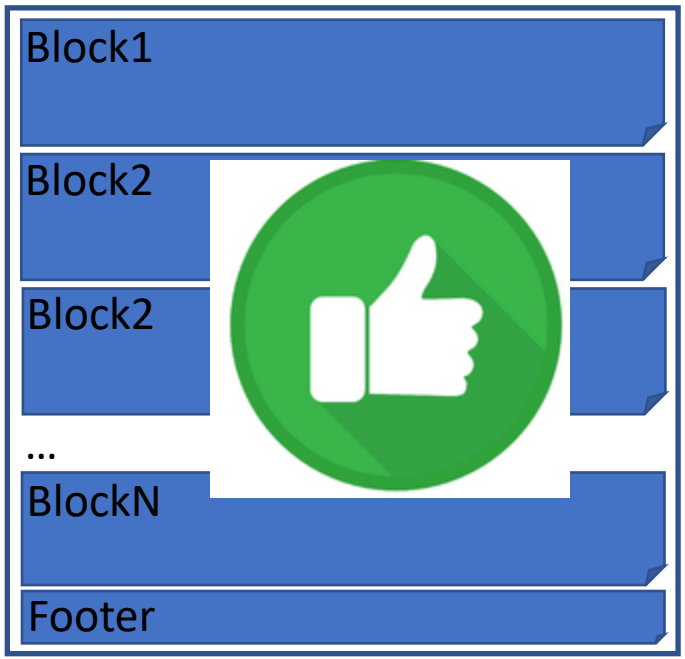
Splitteable File Format



Performances

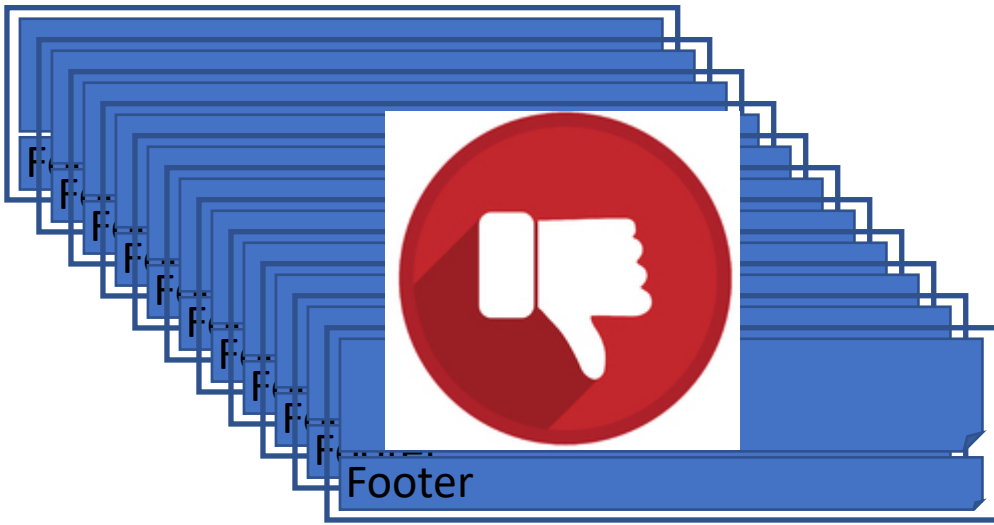
File Blocks >> MetaStore + HDFS Dir + Files

Better to
have 1 Huge HDFS file
(several Go)



than

Too MANY
Too Small files
(few 128+1 Mo)



Typical Partition / Files Volumes

For daily batch

1 partition per day … 5 year of data = ~1500 partitions OK

1 file per partition … OK, even if strange to have 1 file per directory

(maybe 2,3 files per partition … if no fit in spark executor mem)

File may be >= several Giga bytes …. OK great

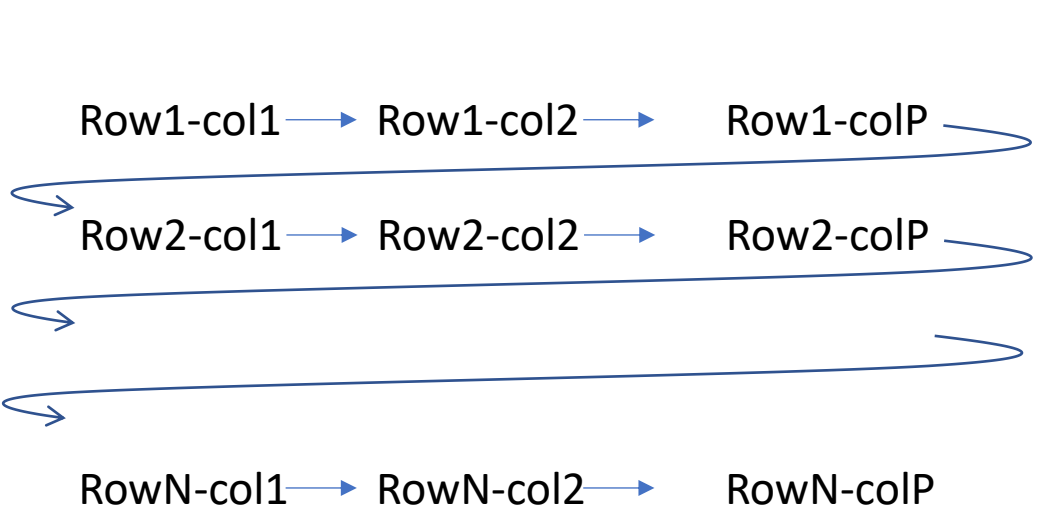
File parquet.block.size = 16M, 32M (? overwrite default 128M)

compromise:
Smaller => more dictionary encoding,
better PPD, maybe less compression
Bigger => less partitions

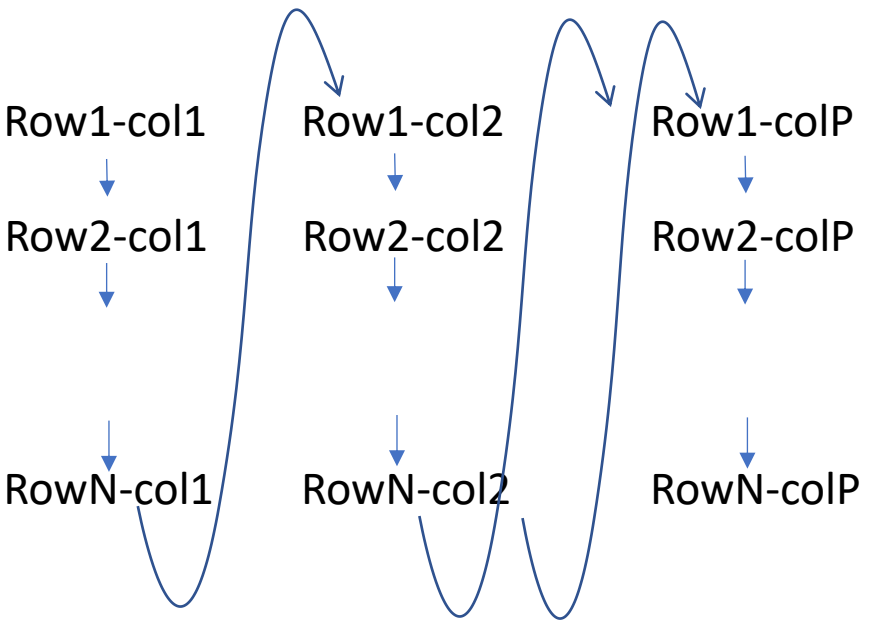
« Columnar » Storage File

Content = List<Row> = row1, row2, .. rowN * Row=col1, col2, … colP

Classic (row-storage) file



Columnar-storage file



Why columnar ?

Read only needed columns data

Seek to skip unneeded ones

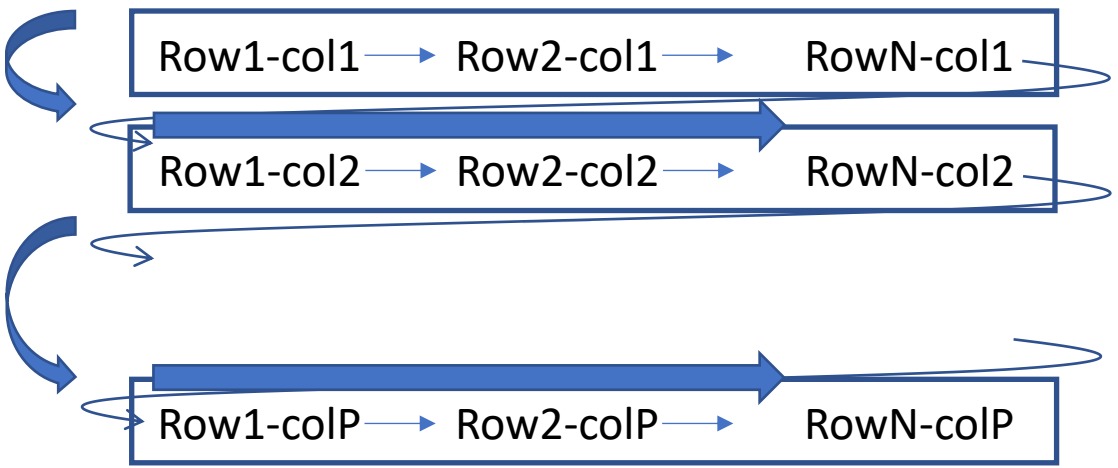
Example: SELECT col2, colP from …

1/ seek() to col2 offset
(Skip sequential bytes for col1)

2/ Full read col2

3/ seek to colP offset
(Skip bytes for col3, col4, … colP-1)

4/ Full read colP

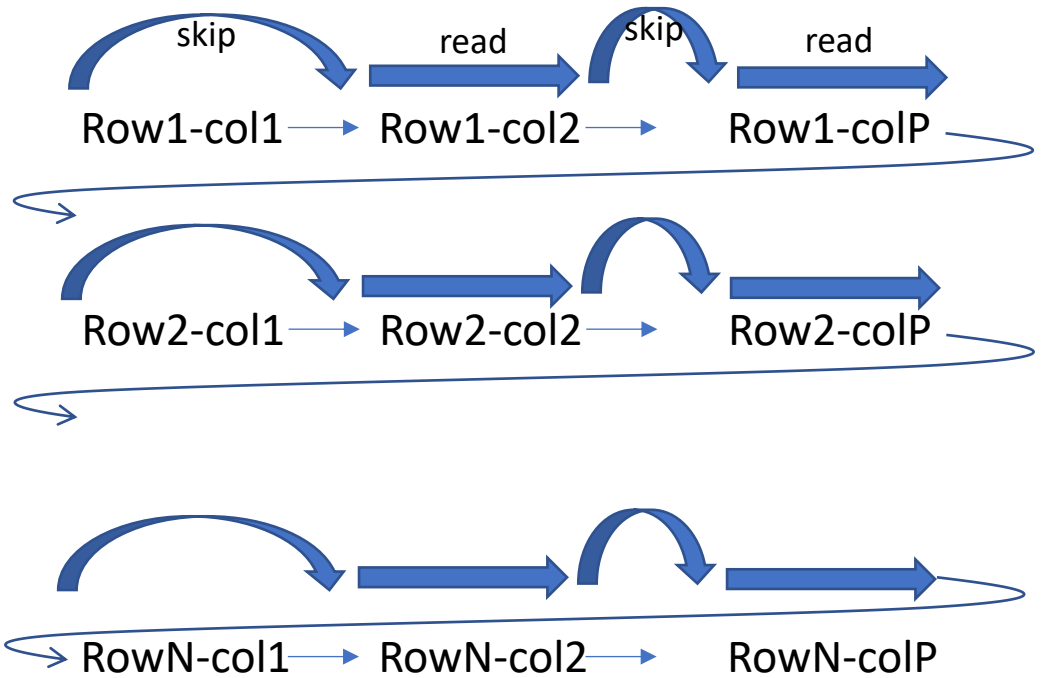


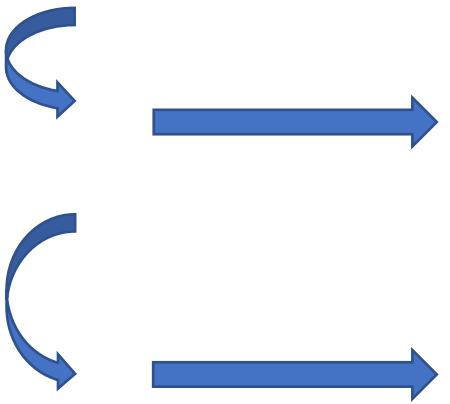
Comparison .. Full Read & Garbage

2*N skips
+ 2*N small unitary reads

vs

2 skips
+ 2 array reads





Much faster
Fewer data IO / fewer ops

Optim: « Column Pruning »

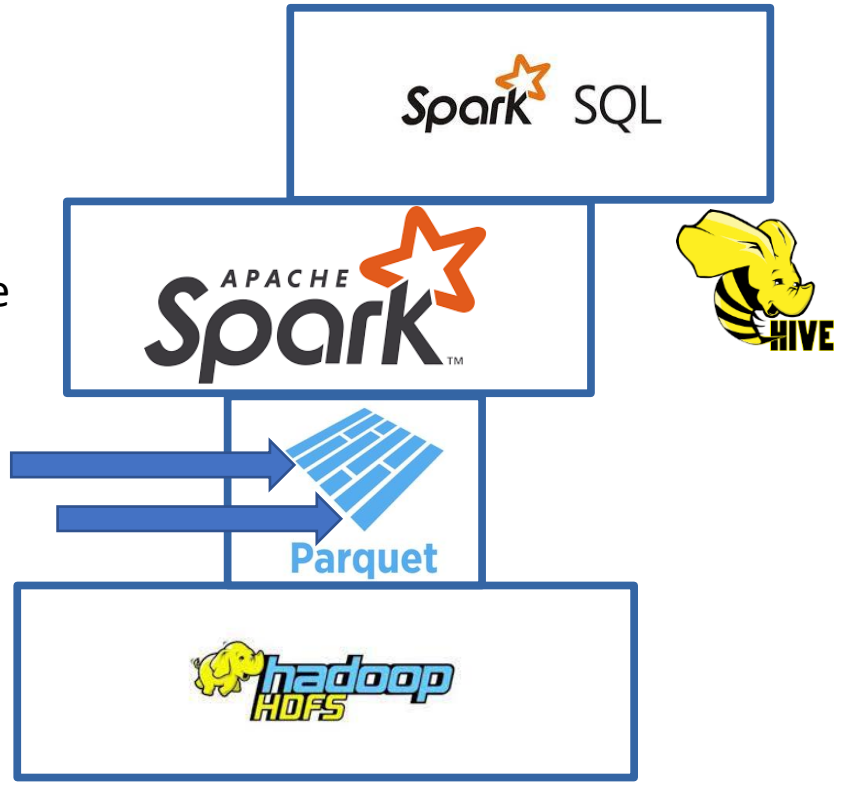
From SQL to Parquet IO .. Hadoop IO

Select col2, colP from table…
(prune all other columns)

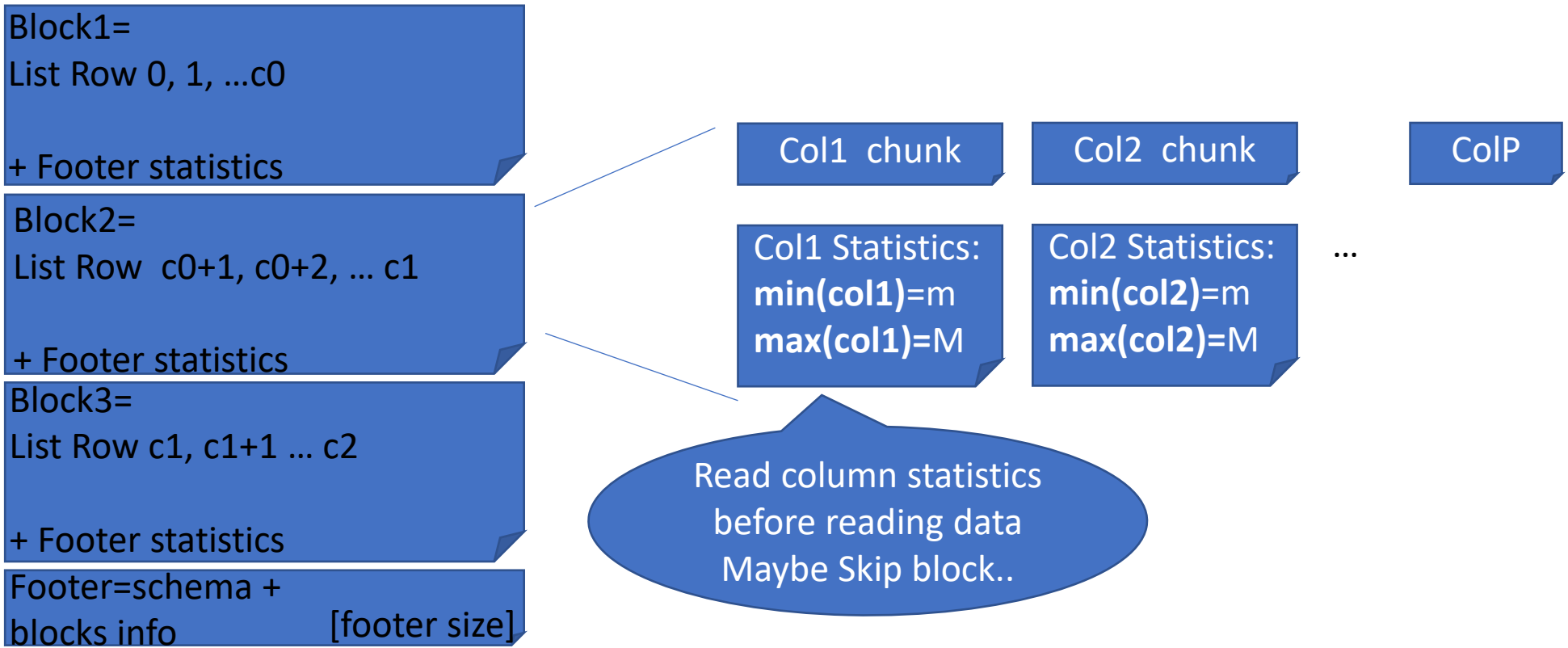
DataSet / RDD on Parquet file

Parquet API
to read columns chunks

Fewer IO

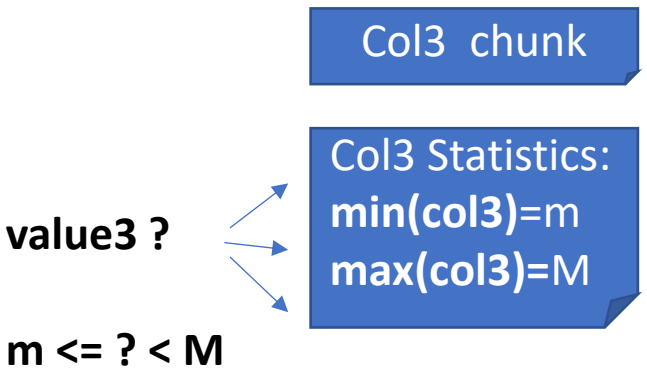


Last but not Least Optim
Using page-column statistics



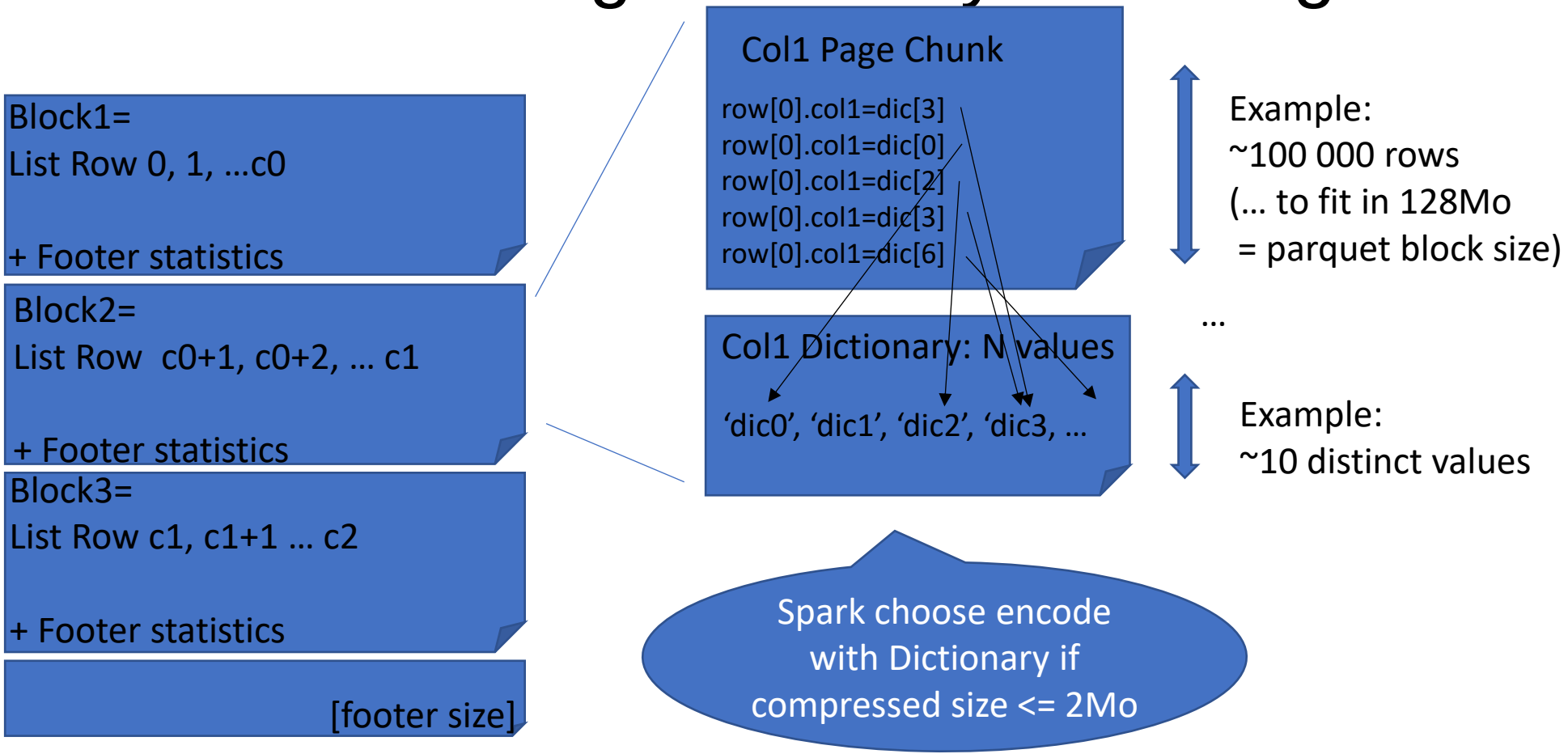
Predicate… skip with statistics (maybe False Positive)

Example:
SELECT col2, colP FROM … WHERE **col3 = value3**



If (**(value3 < m) OR (value3 > M)**)
… AND check for null to please SQL semantic ?!
⇒Impossible to find row in this block
⇒Skip block!

Column with small number of distinct values … Stored using Dictionary encoding



Predicate Push-Down for « col=‘value’ » or « col in [‘value1’, .. ‘valueN’] »

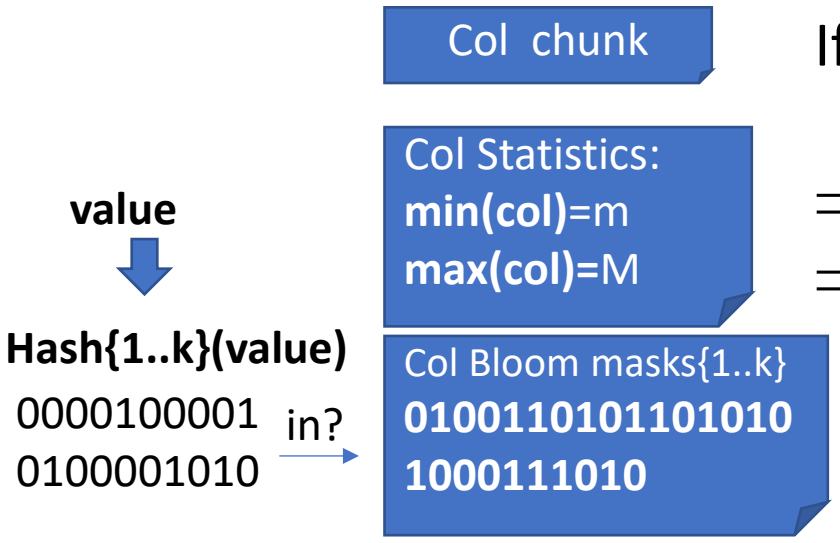
Example:

SELECT col2, colP FROM …

WHERE **col3 = ‘value3’** and **col4 in [‘value1’, ‘value2’, value3’]**

For each page chunk of col3
If encoded as Dictionary
=> read dictionary
then if ‘value3’ not in dictionary
=> SKIP Row Group !!!

Bloom Filter: mask=Union(hash(..))



Bitmask h = hash(value)

If (**(h & bloom) == h**)

… AND check for null to please SQL semantic ?

⇒Impossible to find row in this block

⇒Skip block!

k hashes, m bits, n elements

=> False positive rate ~ $(1-e^{-kn/m})^k$

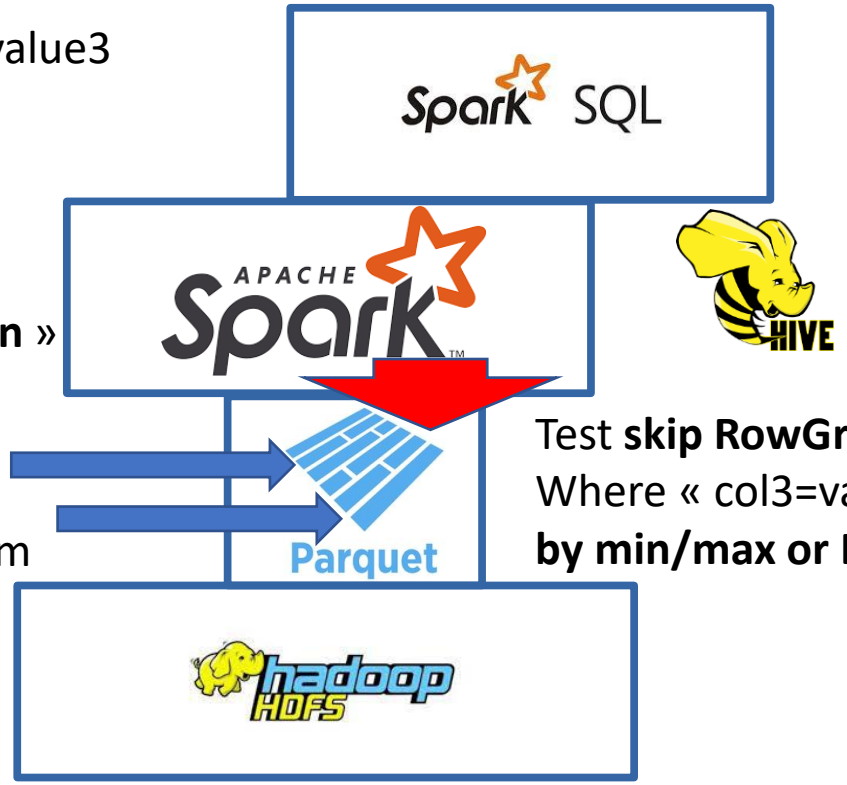
« PPD » : Predicate-Push-Down

Select .. from … where col3=value3

DataSet / RDD on Parquet file
WITH PREDICATE « **pushed-down** »

Parquet API
to read columns statistics+bloom

Fewer IO



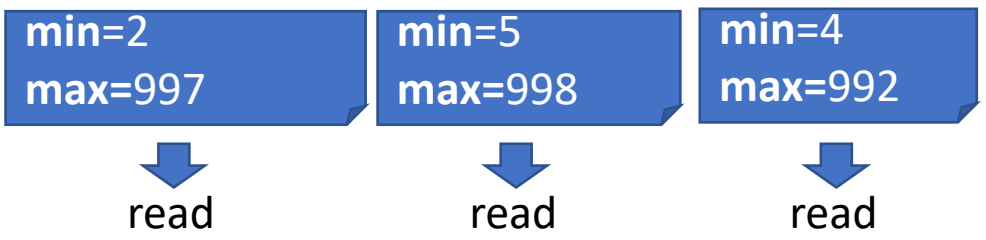
Test **skip RowGroups**(=blocks)
Where « col3=value3 »
by min/max or Bloom

Sort + parquet.block.size for better Predicate-Push-Down

When writting PARQUET files
… think to optimize reads later (PPD)

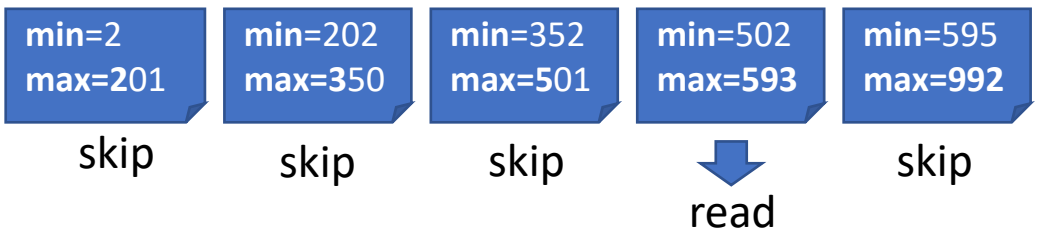
Example: id in range 1..1000 predicate id=542

Unsorted, Big block 128M



… value within min/Max of all blocks
=> NO skipped block … only False positives

Sorted + Small blocks 16M



How to « Write » parquet files : Adapt for best « Reads » later

```
Dataset<Row> ds = spark.sql(« … » );
// ds contains probably 200 partitions (default value after a SHUFFLE)

ds = ds.repartition(1);   // equivalent to « .coalesce(1) »
      // or   ds.repartition(2) //  or 3 … if RDD does not fit in spark.executer.memory !!

ds = ds.sortWithinPartition(« colA », « colB »,   …   « colID »)
      // sort by general columns first « colA » (example portfolio, region, productType…
      //  last by « id » column

ds.write().format(« hive »).mode(SaveMode.overwrite).insertInto(« db.table_name »);
```

Recap 5 Optimizations

1/ typed schema, binary encoding, dictionary + compression

2/ **splittable** file (blocks) = distributed

3/ Hive Metastore **Partition Pruning** = skip/scan dirs

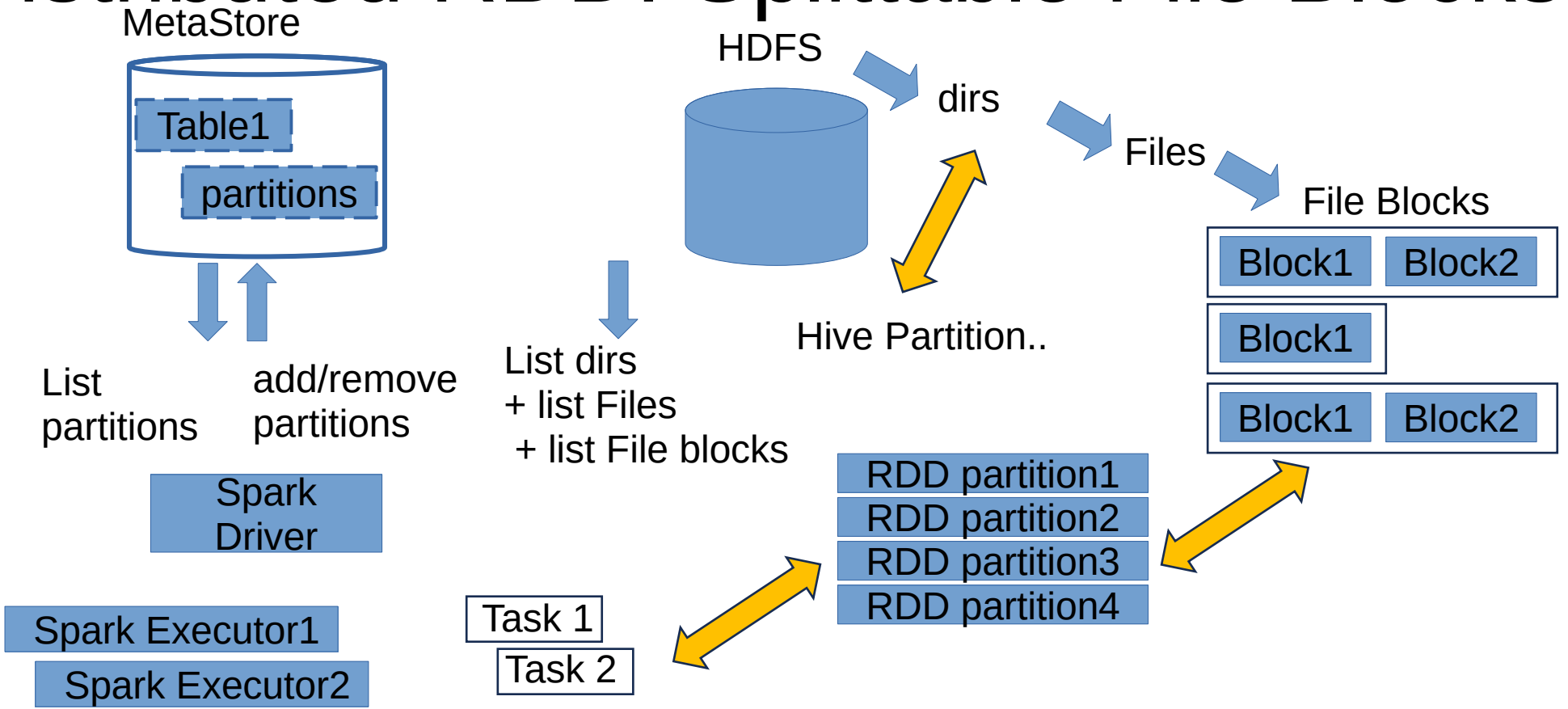
4/ **Column Pruning** (Columnar storage format) = seek + array read

5/ **Predicate-Push-Down** = skip using statistics, bloom filter

Recap Optimizations 1/5
Schema, Binary Encoding, Dictionary

CSV, Xml, ND-JSON	Schema-less file formats ! … innefficient text encoding Redundant <xml> value</xml> or « json »: « value»
PARQUET, ORC	Strongly typed Schema embedded in file … efficient binary encoding Efficient incremental encoding, or Dictionary

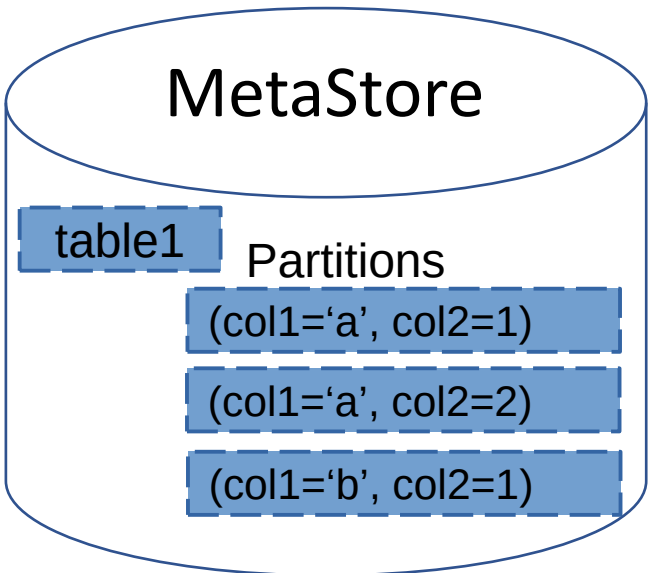
Recap Optimizations 2/5
Distributed RDD: Splittable File Blocks

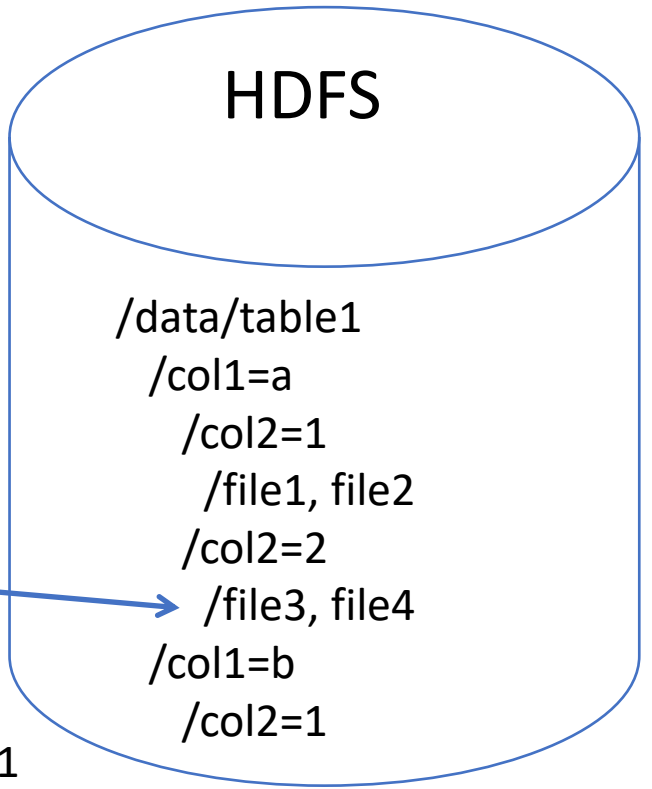


Assign 1 partition to 1 executor = 1 Task (= for 1 File Split ~ Block)

Recap Optimizations 3/5
Hive Metastore Partitions Pruning

CREATE EXTERNAL TABLE table1 (col3, col4, …colN)
PARTITIONED BY (col1 string, col2 int)





Select .. From table1
Where col1=a and col2=2
-- partitioned columns

Recap Optimizations 4/5

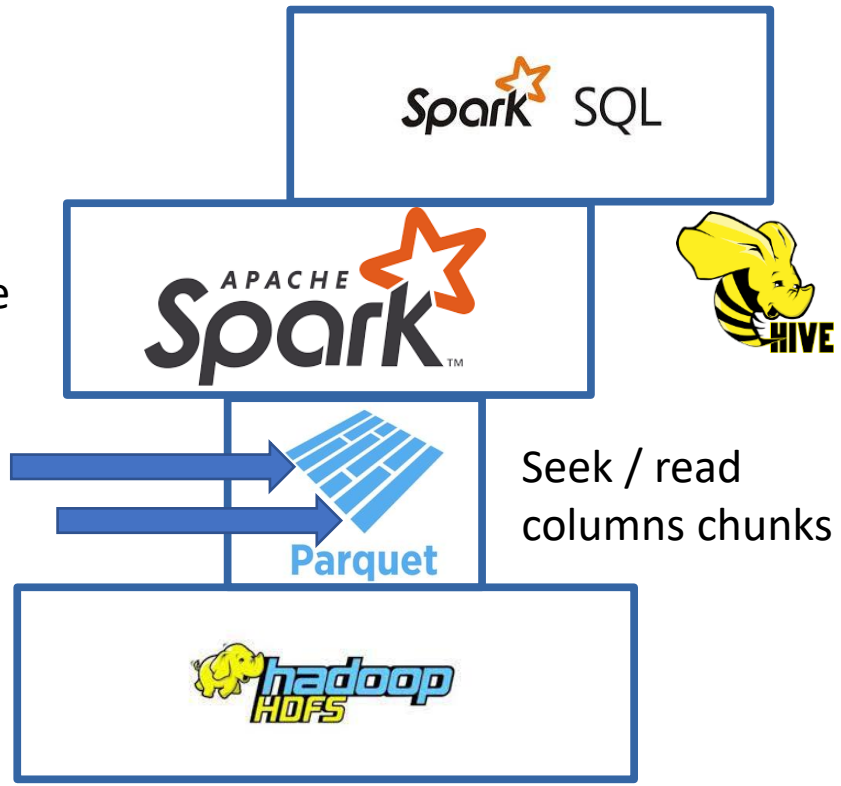
Columns Pruning
(seek in Columnar Format)

Select col2, colP from table…
(prune all other columns)

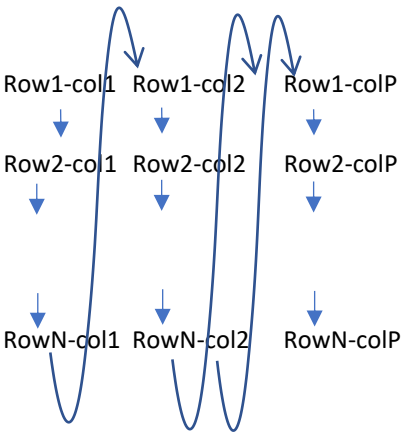
DataSet / RDD on Parquet file

Parquet API
to read columns chunks

Fewer IO



Seek / read
columns chunks



Recap Optimizations 5/5

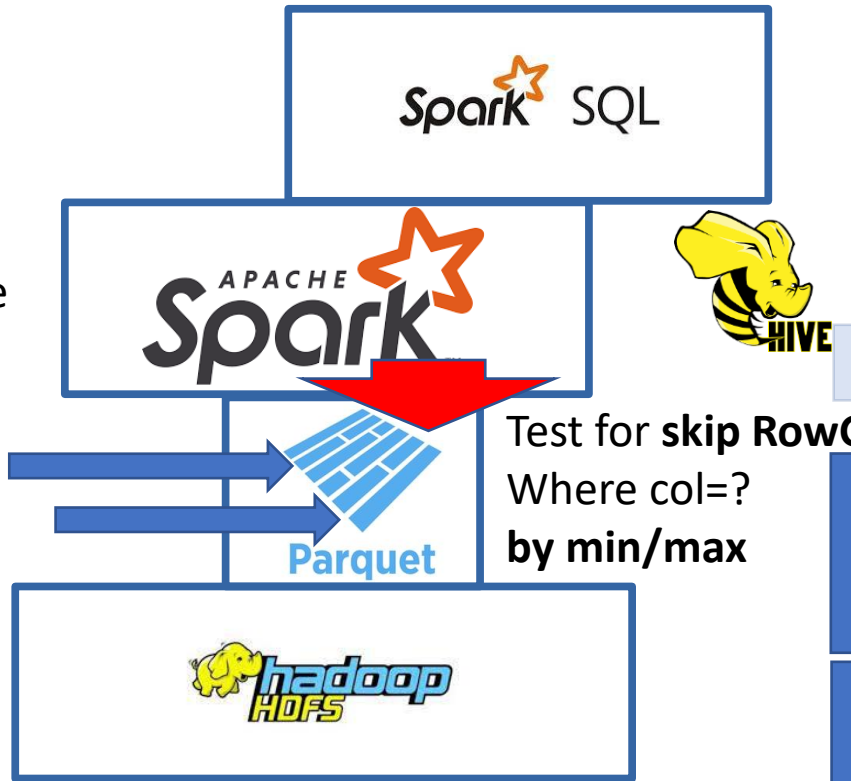
PredicatePushDown (min-max statistics/Bloom)

Select col2, colP from table…
(prune all other columns)

DataSet / RDD on Parquet file

Parquet API
to read columns chunks

Fewer IO



Test for **skip RowGroups**
Where col=?
by min/max

Col chunk

Col Statistics:
min(col)=m
max(col)=M

Col Bloom masks{1..k}
0100110101101010
1000111010

Next… part 5

Spark