Delta Lake data layout optimization

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databricks

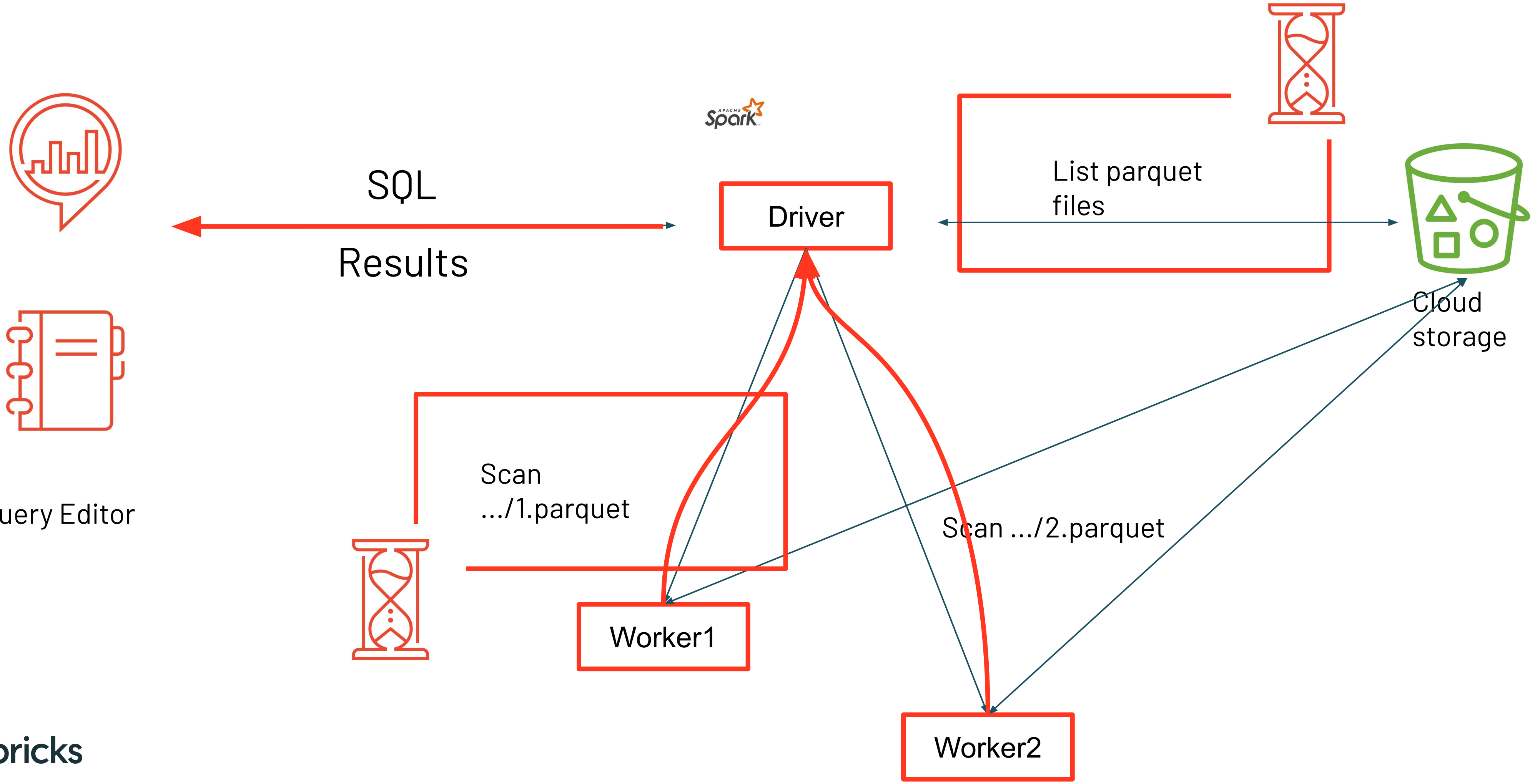
About Databricks and the presenter

Databricks: founded by the original creators of Apache Spark™ with 2000+ employees (engineering in San Francisco, Amsterdam, Toronto, Seattle and Berlin).

Sabir Akhadov: Software Engineer @ Databricks Amsterdam since 2019

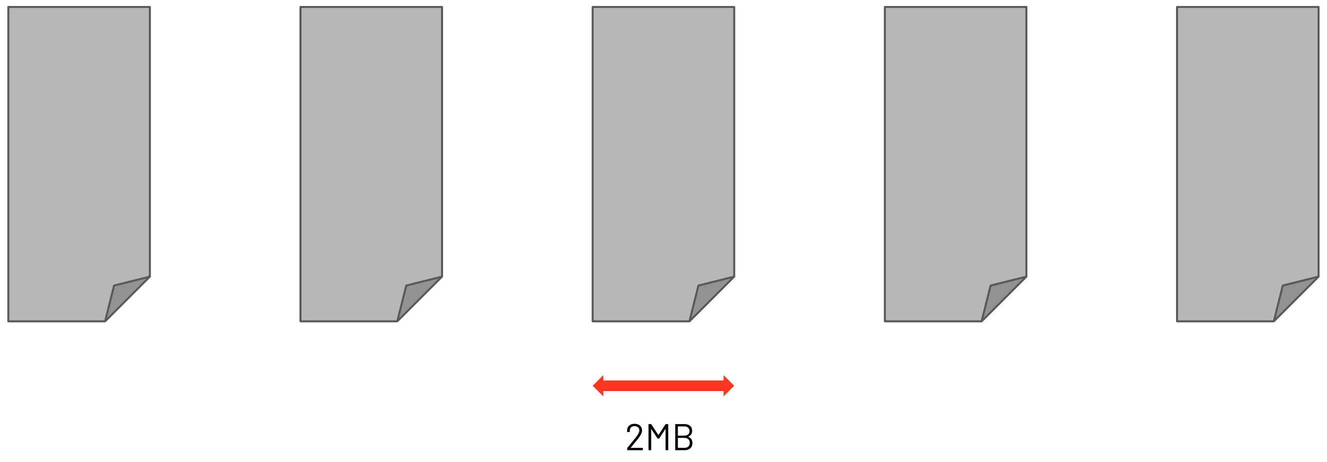
Data layouts team - data organization for the best read/write performance

Query execution Spark + Parquet



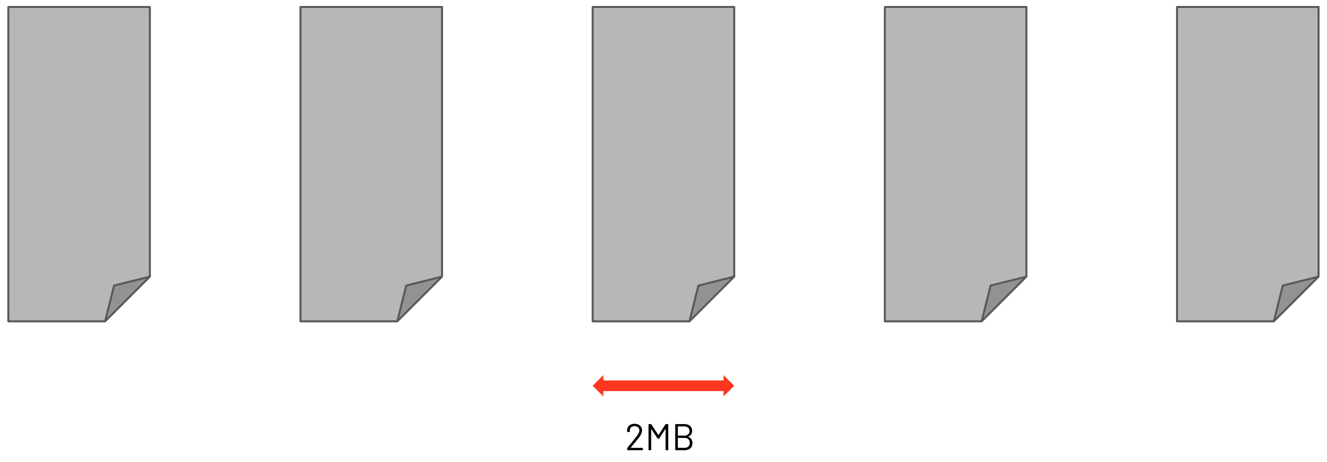
Data layouts

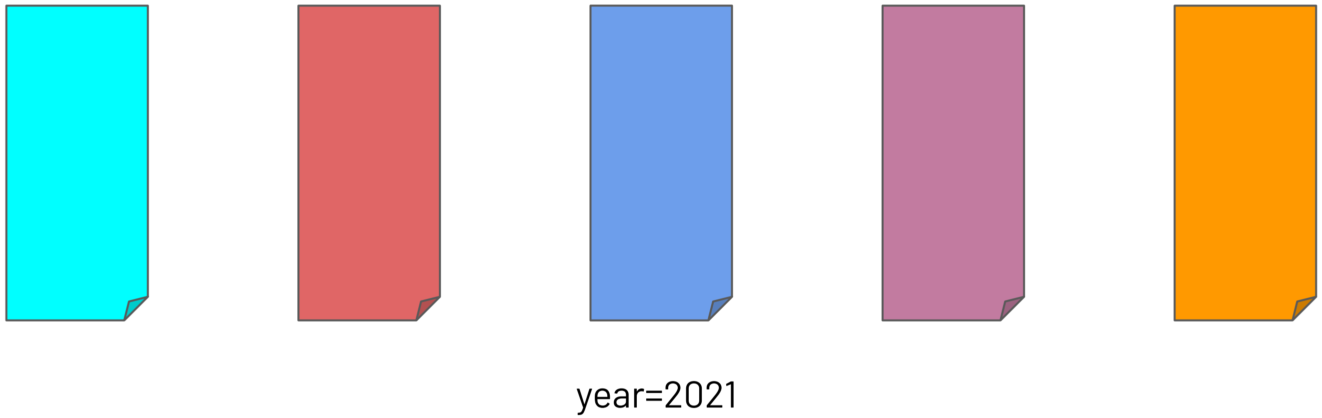
FILE SIZE - I/O overhead



Data layouts

FILE SIZE - I/O overhead

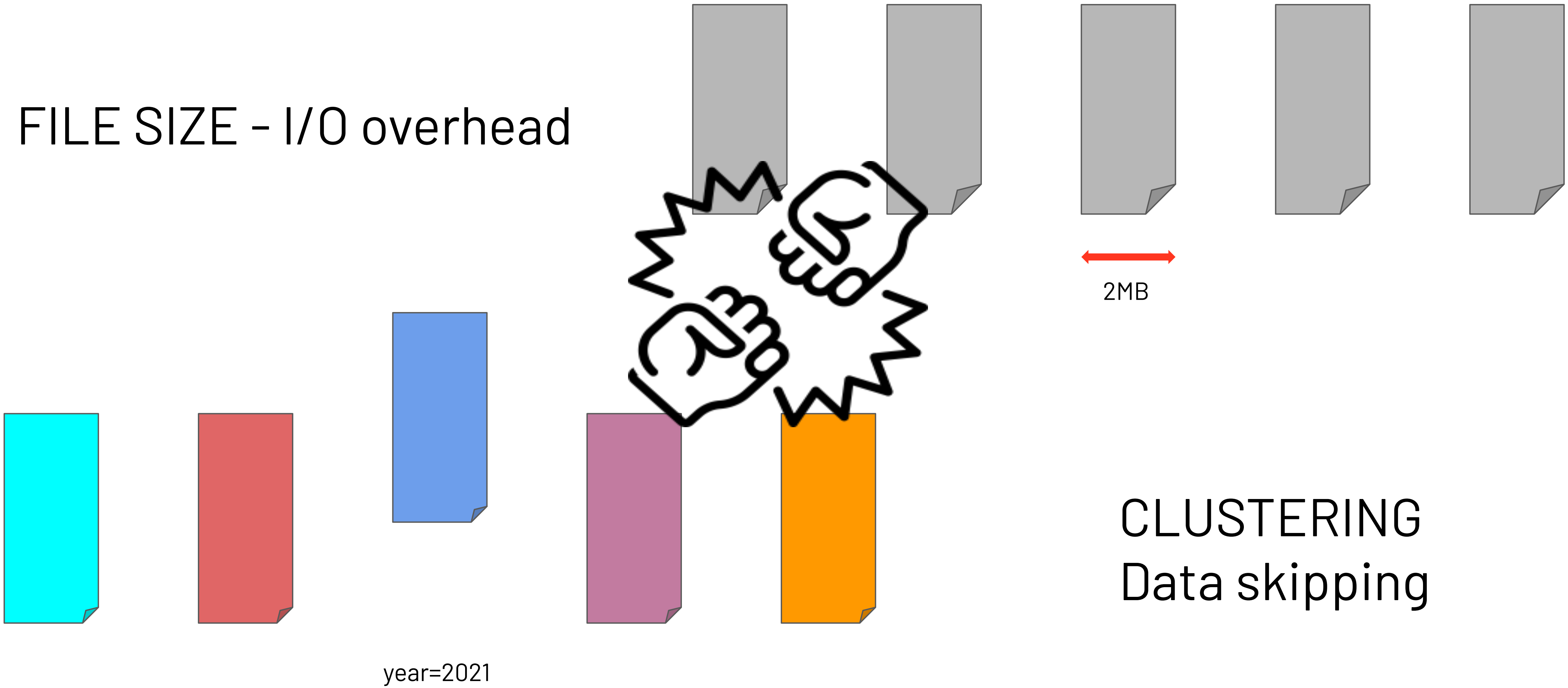




CLUSTERING
Data skipping

Data layouts

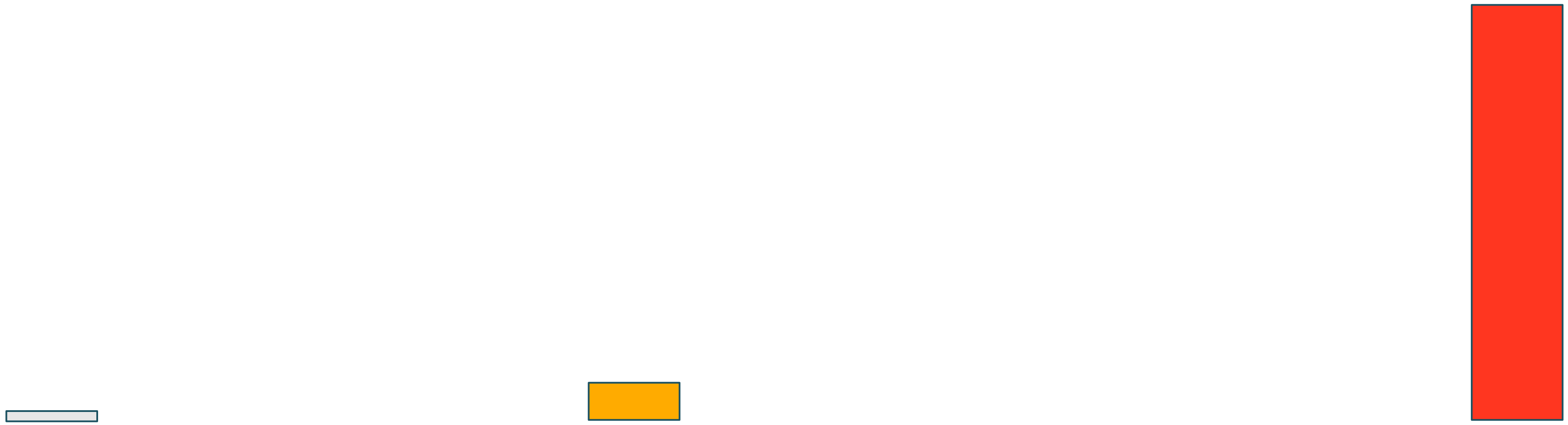
FILE SIZE - I/O overhead



CLUSTERING

Data skipping

Per-file overhead



~40-100ms

S3 fetch request

3-10 seconds

Scan 16 files

x 250MB

2-2.5minutes

Scan 16000

x 250KB

4 workers, 16 cores cluster

This talk

- Parquet tables, data skipping
- Delta lake
- Advisor/Auto optimizations
- Star schema optimizations

Parquet tables

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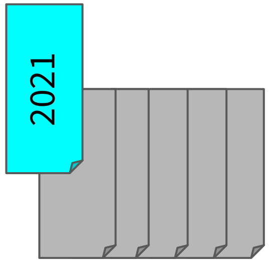
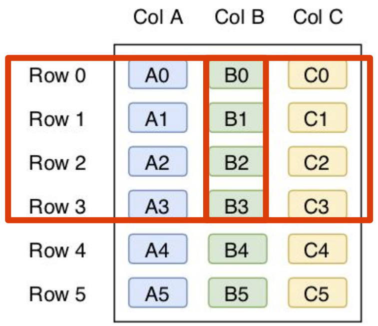
Data filtering

- Partitions
- Buckets
- Files
- File “chunks”

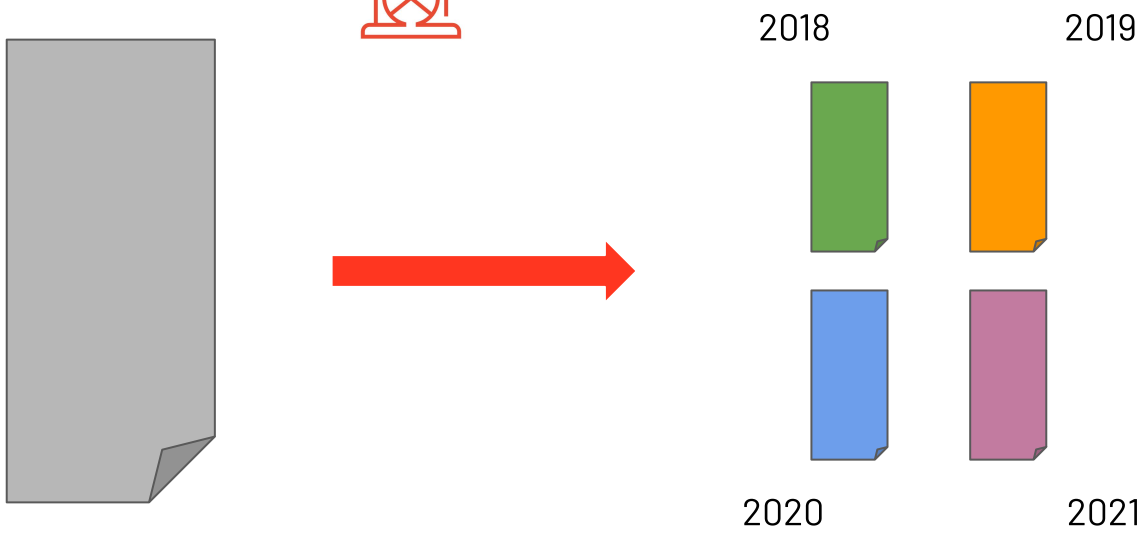




Partitioning

LIST FILES IN /

LIST FILES IN /2021/



year >= 2018 and year <= 2021

```
year=2021/
    file1.parquet
    file2.parquet
year=2020/
    file3.parquet
year=2019/
    ...etc...
```

```sql
SELECT * FROM table WHERE year = 2021
```

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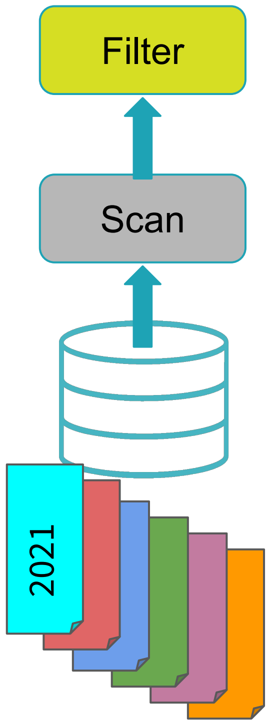
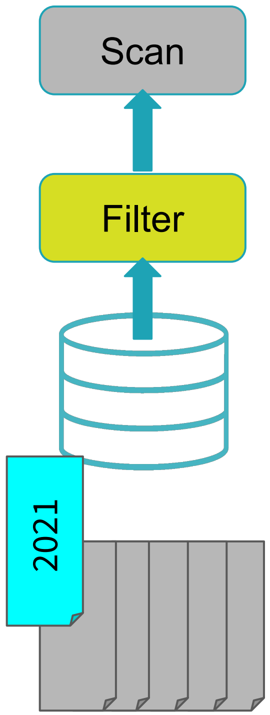
Static partition pruning

```
SELECT * FROM table WHERE year = 2021
```



Partition files



Partition files

year=2021/
  file1.parquet
  file2.parquet
year=2020/
  file3.parquet
year=2019/
  ...etc...

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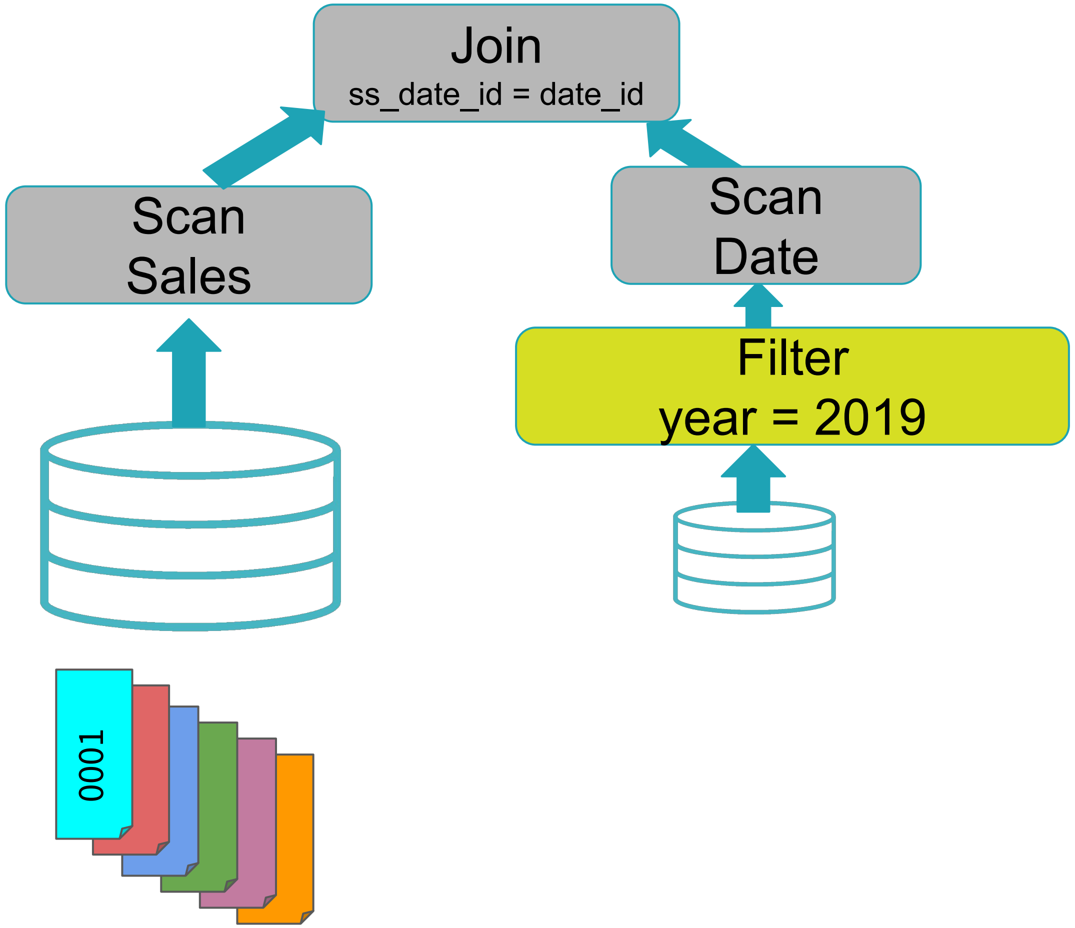
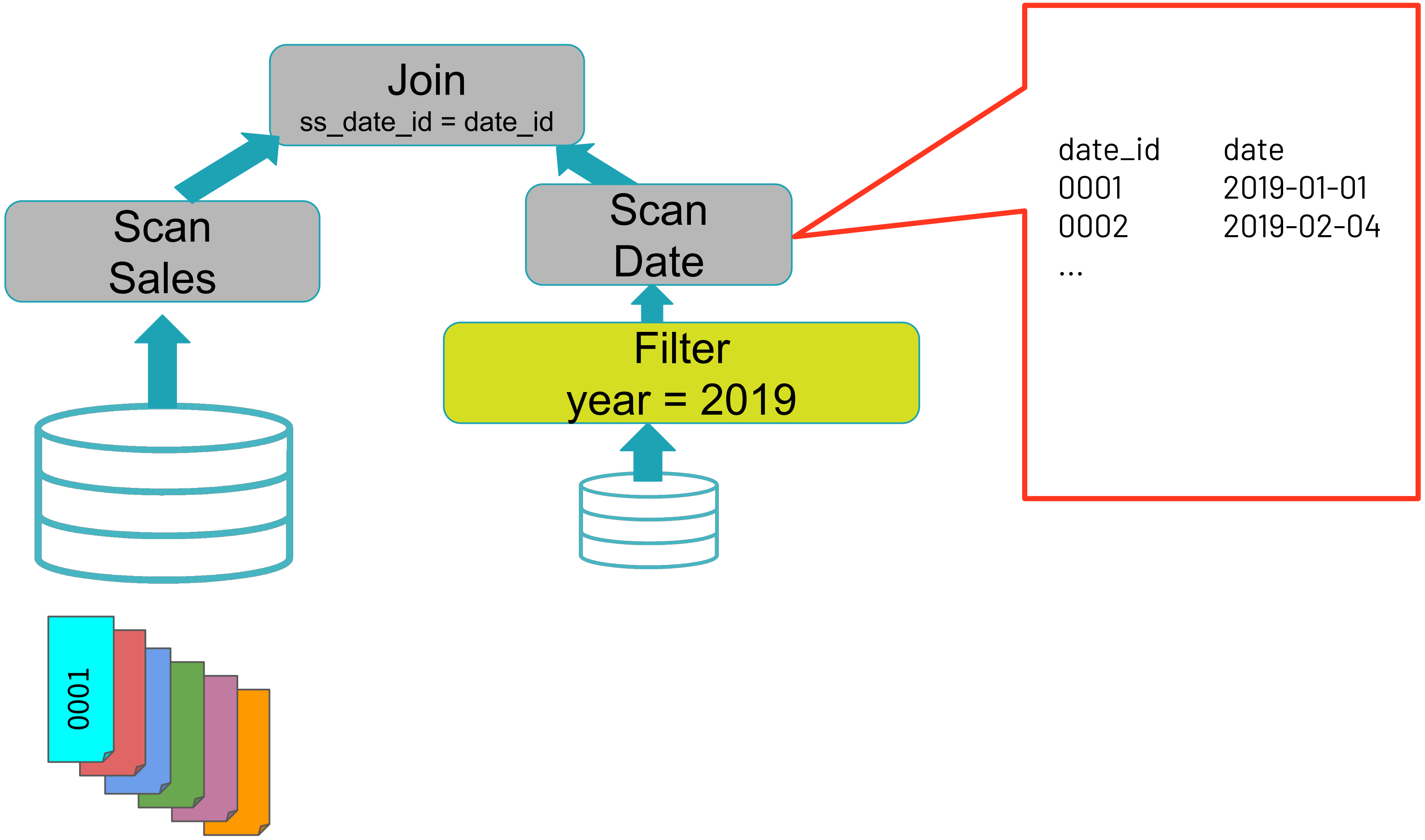
Dynamic partition pruning

ss_date_id=0001/
  file1.parquet
  file2.parquet
ss_date_id=0002/
  file3.parquet
ss_date_id=0003/
  ...etc...



Dynamic partition pruning



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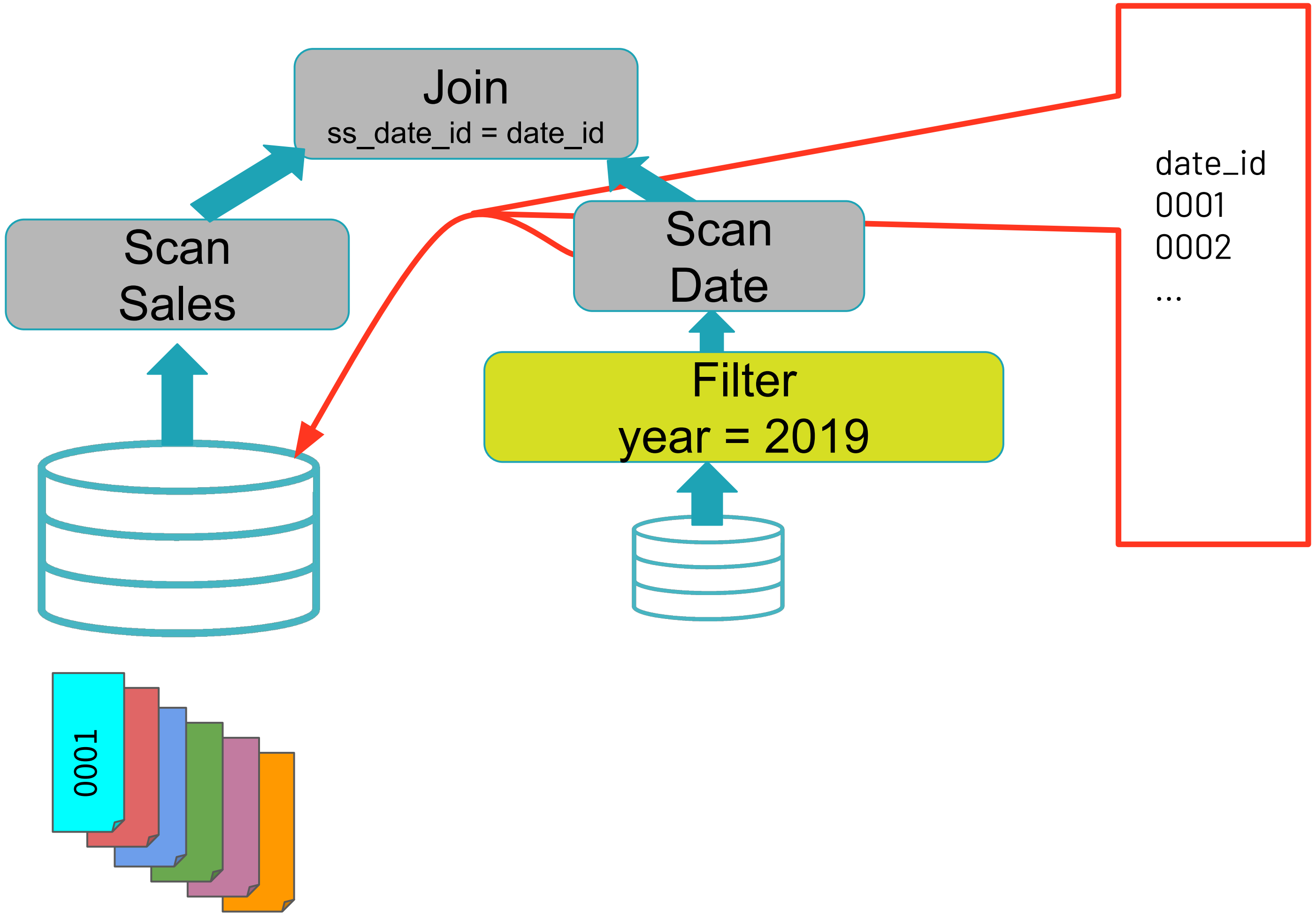
Dynamic partition pruning



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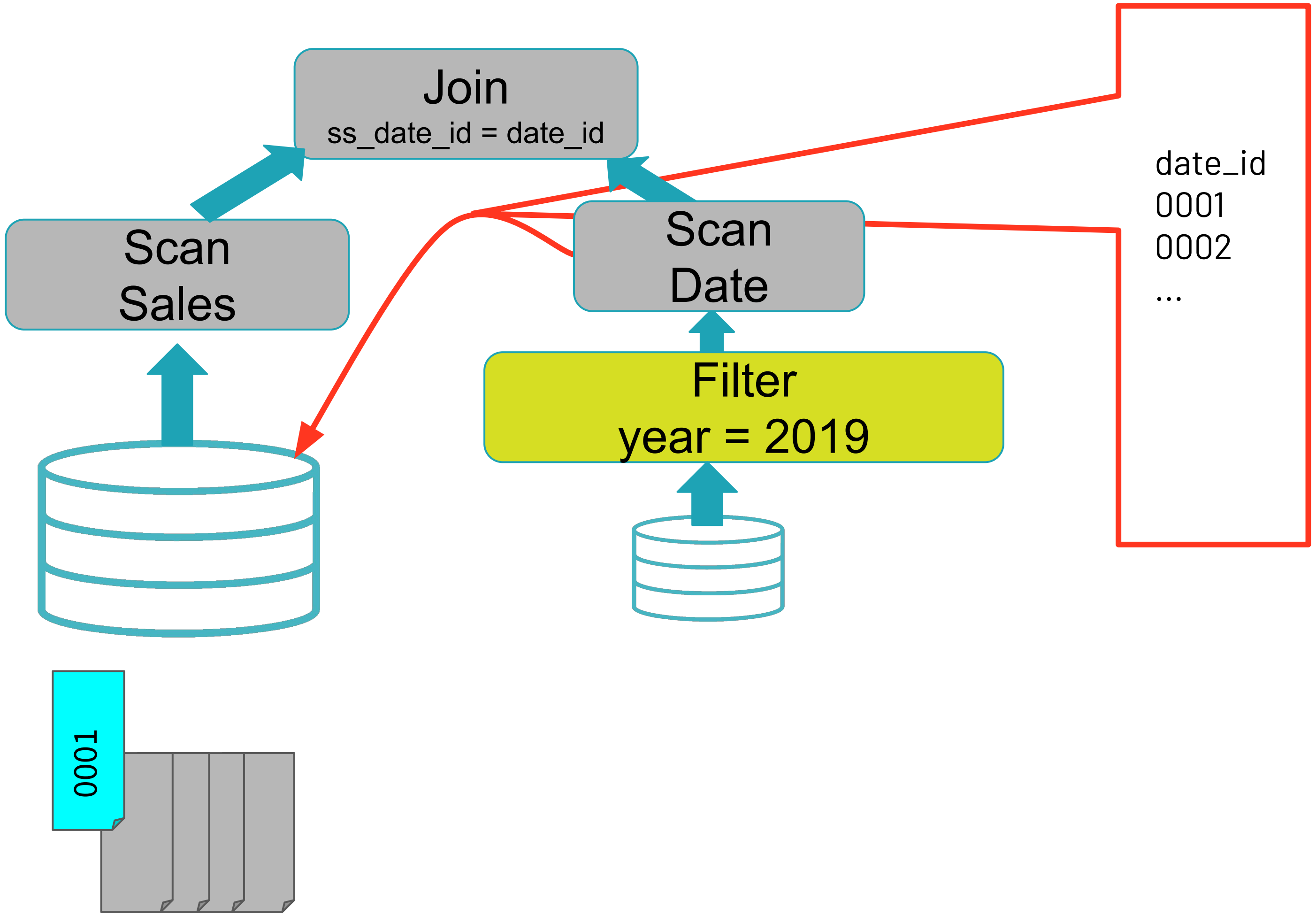
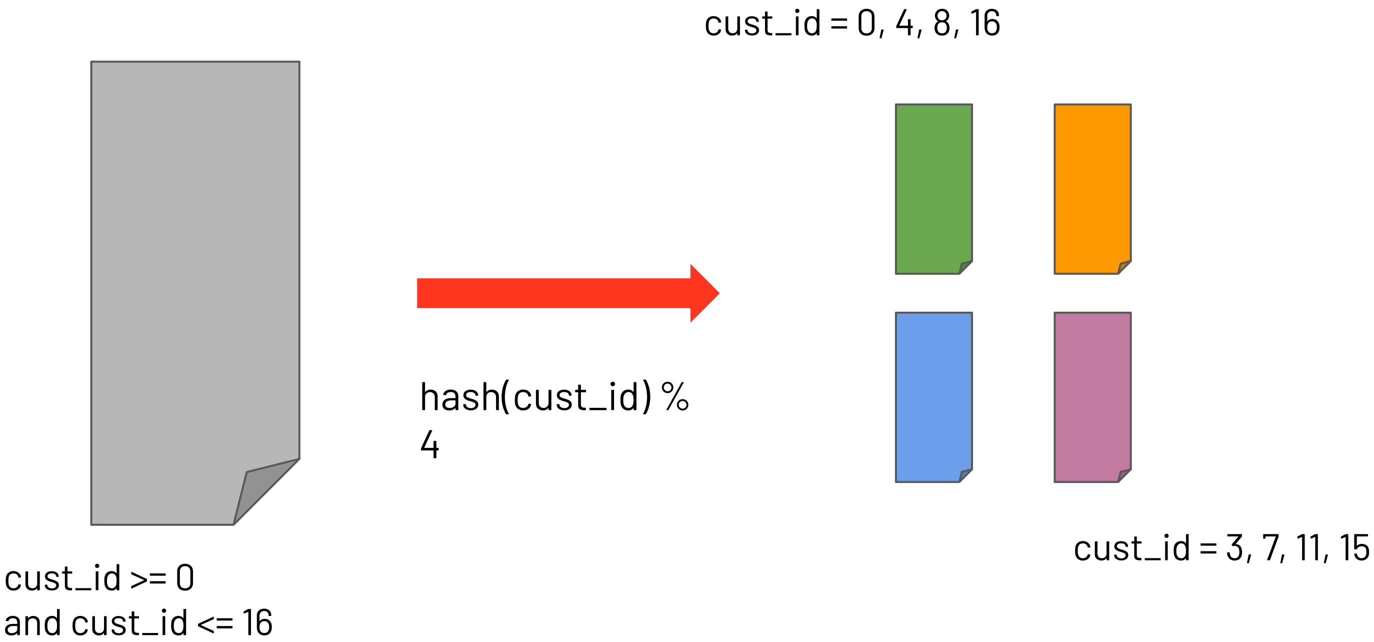
Dynamic partition pruning



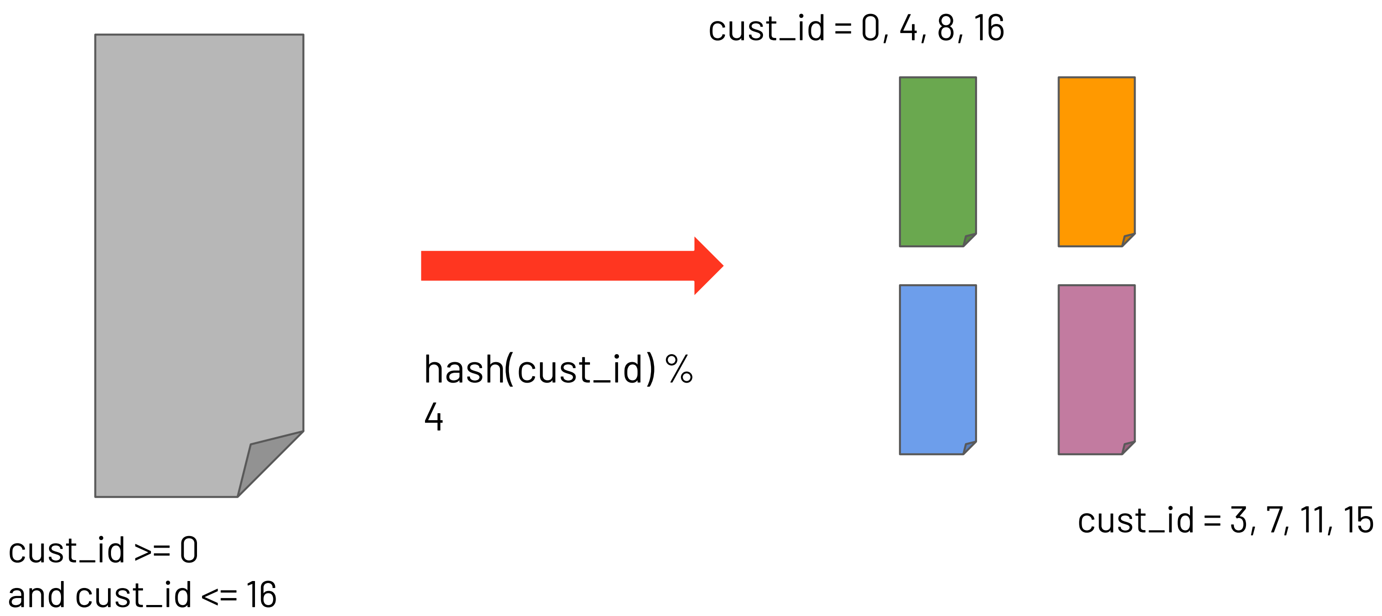
Partitioning disadvantages

- Low cardinality columns only - overpartitioning
- Data skew
- Underpartitioning - large files
- Static - data evolves, know your workloads at table creation

Bucketing

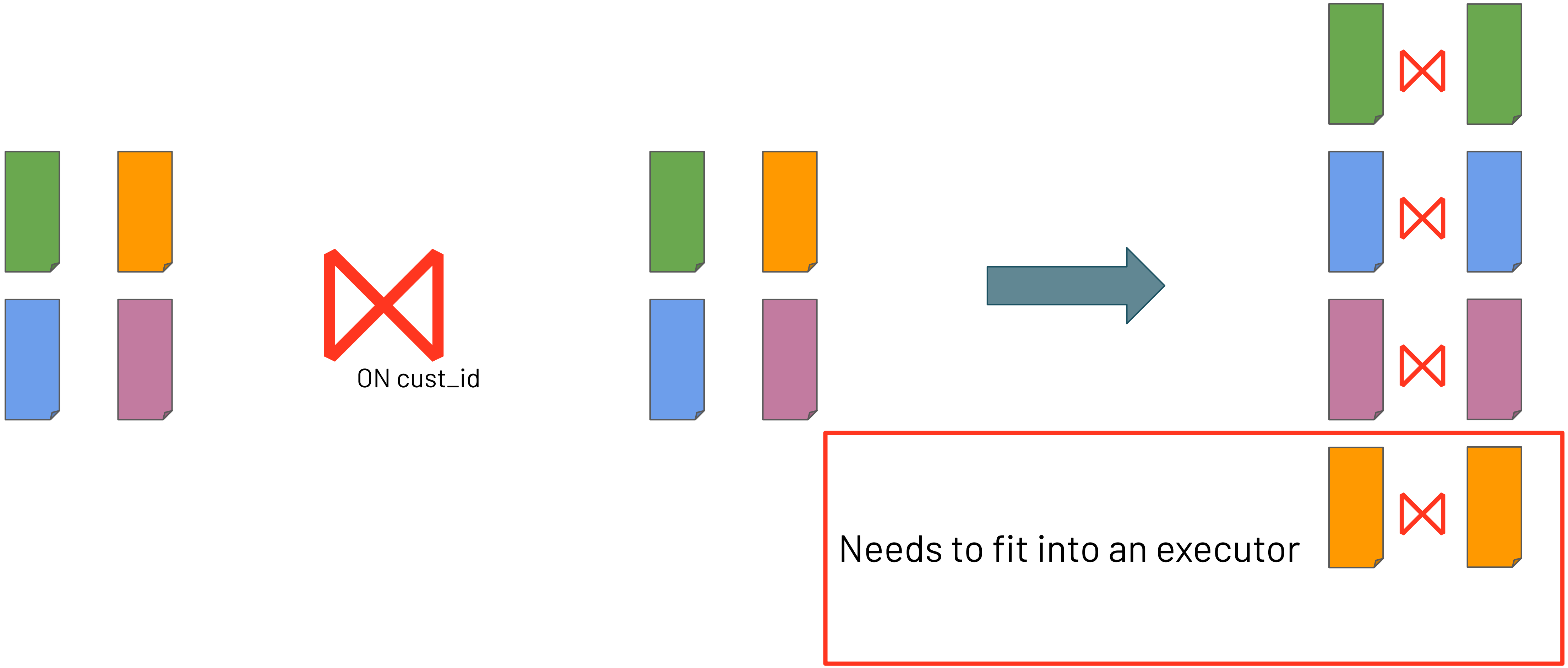

cust_id = 0, 4, 8, 16
hash(cust_id) %
4
cust_id >= 0
and cust_id <= 16
cust_id = 3, 7, 11, 15

Bucketing



- Good for high cardinality columns - every write produces exactly the same number of files
- Pinpoint queries cust_id = 1

Bucketed join



Bucketing disadvantages

- Static, hard to evolve
  - How many buckets?
  - Adding new bucket key requires rewrite
- Data skew
- No range scans

File skipping

- Determine from parquet footer if a file ***could contain*** values

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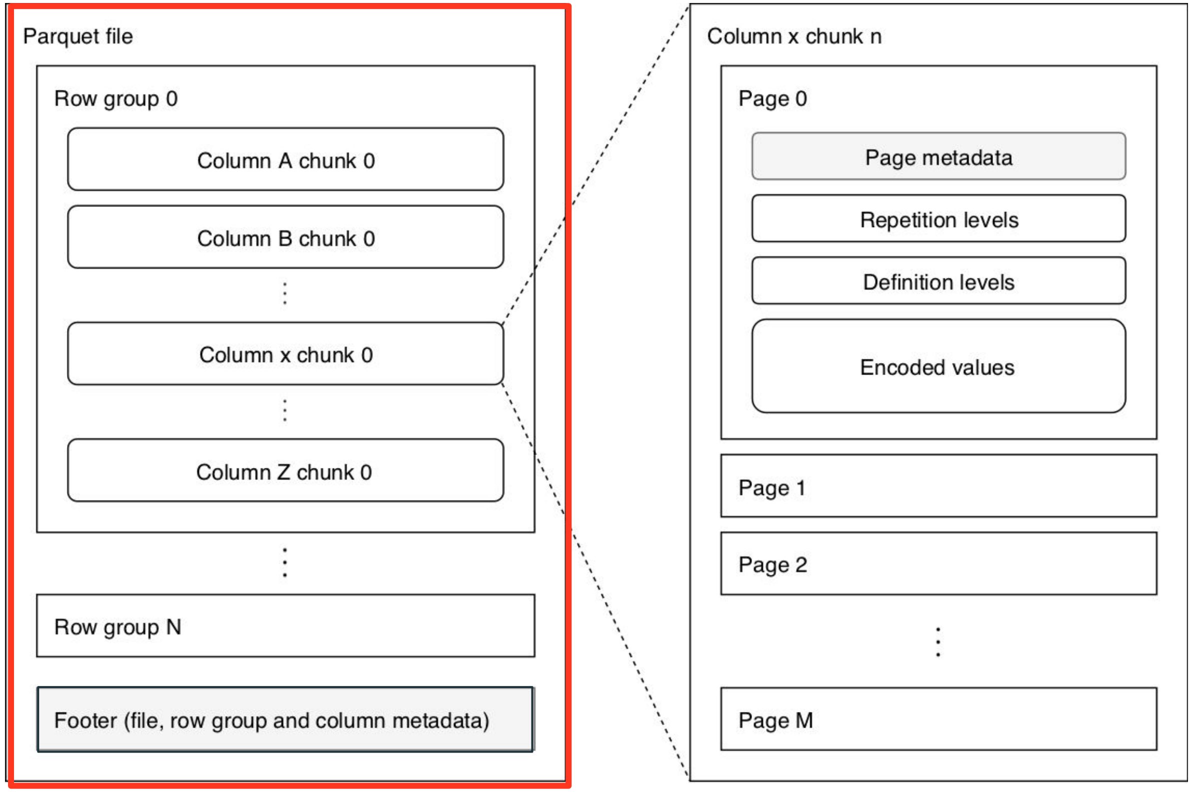
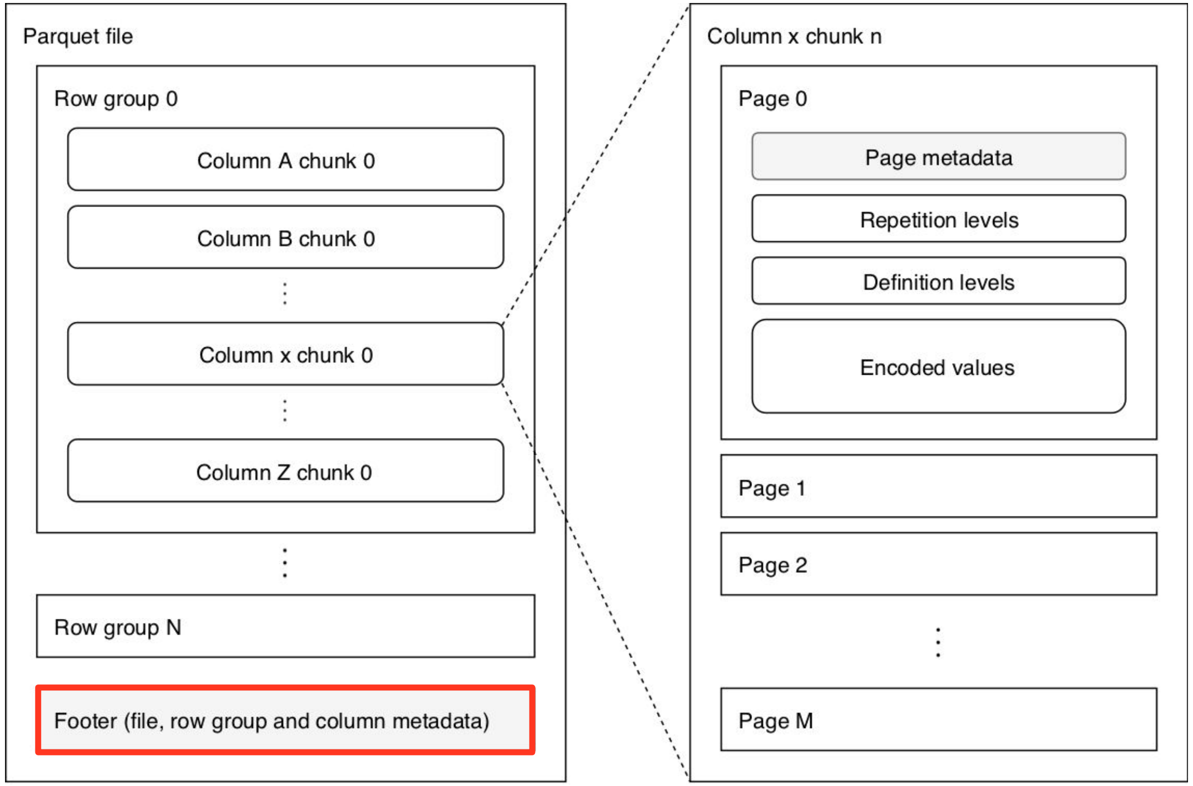
Parquet internals

- File



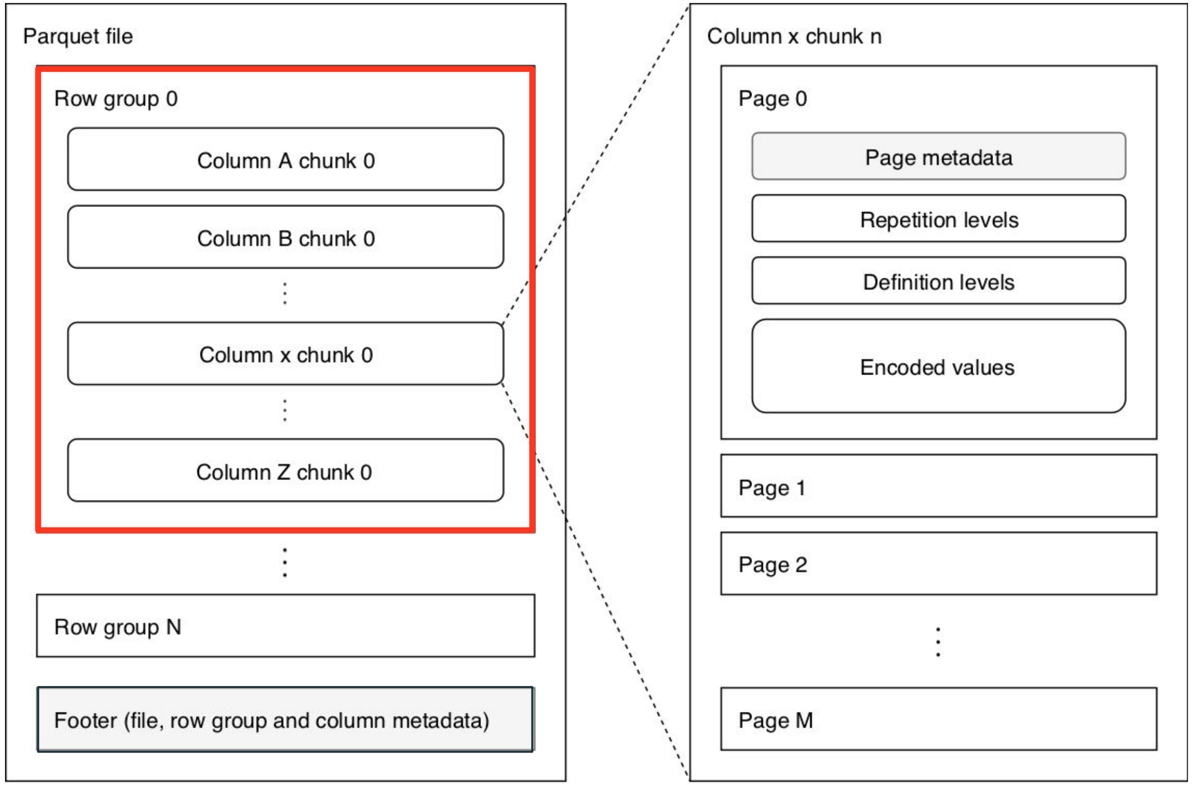
Parquet internals

- File
  - Footer
    - row-group min max stats



Parquet internals

- File
  - Footer
    - row-group min max stats
  - Row group
    - Column chunks
      - Pages - stats



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File skipping

- Min-Max row-group statistics
- Determine from footer if a row group ***could contain*** values

```
SELECT * FROM table WHERE x > 5

Row-group 0: x: [min: 0, max: 9]
Row-group 1: x: [min: 3, max: 7]
Row-group 2: x: [min: 1, max: 4]
```

File skipping

- Min-Max row-group statistics
- Determine from footer if a row group ***could contain*** values

I have to read a file in order to skip it?!

Need to schedule Spark tasks to read files.

Delta Tables

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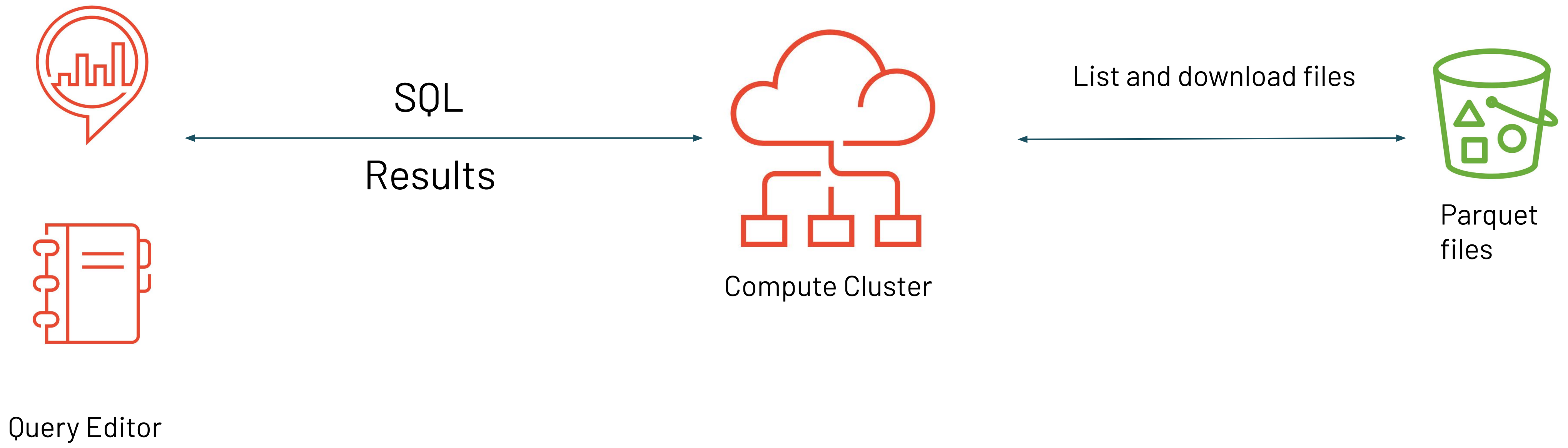
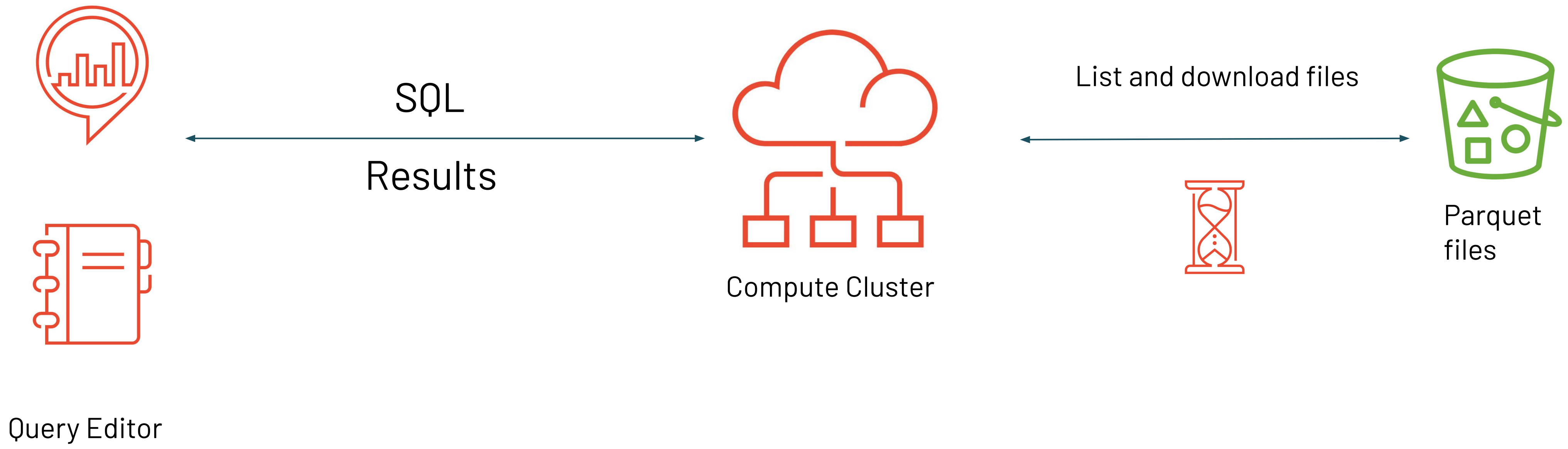
File listing is slow



File listing is slow



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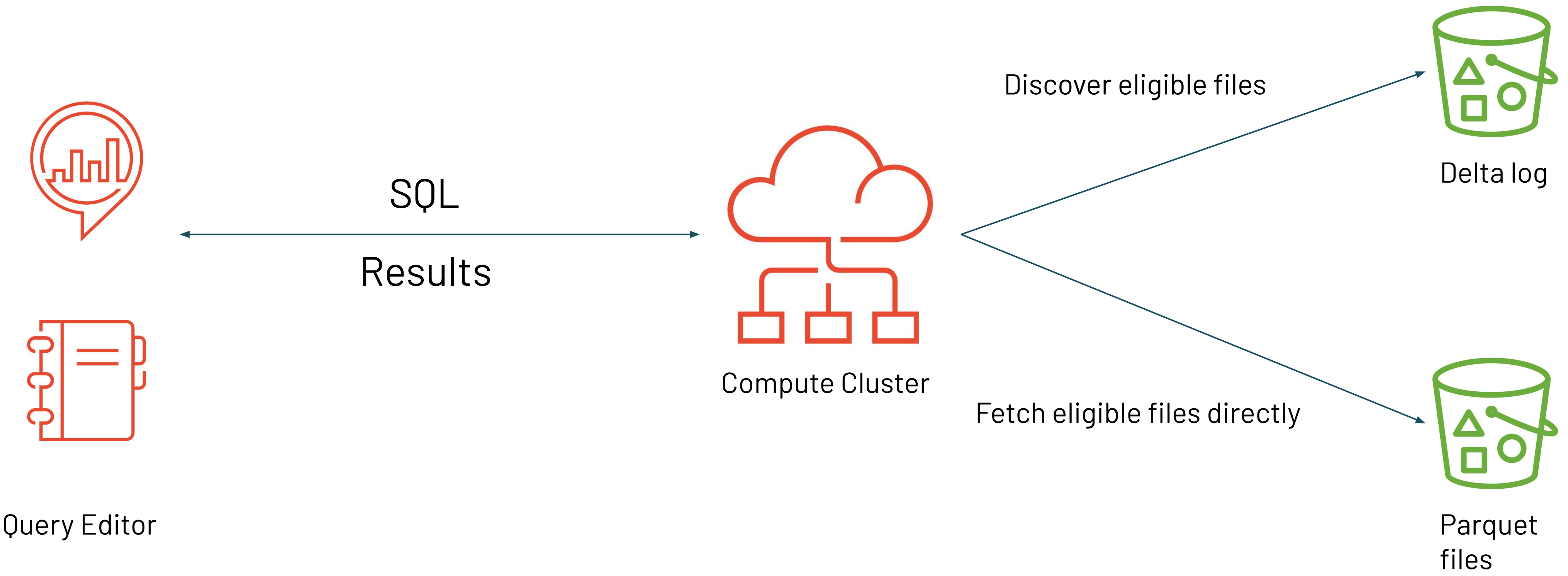
Delta Log


SQL
Results
Query Editor
Compute Cluster
Discover eligible files
Fetch eligible files directly
Delta log
Parquet files

Delta Table

DELTA LAKE

Transaction log

Partition directories(optional)

Data files

- my_table/
  - _delta_log/
    - 000000.json
    - 000001.json
    - ....
    - 000010.checkpoint.parquet
  - year=2021
    - file-01.parquet
    - file-02.parquet
    - ...
  - year=2020
    - file-00.parquet

    ...

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Delta log functions

- ACID transactions
- History - time travel
- **Files present**
- **File statistics**

Inspecting delta log - added files

```
import com.databricks.sql.transaction.tahoe.DeltaLog
import org.apache.spark.sql.catalyst.TableIdentifier

val db = "tpcds_sf100_delta"
val table = "store_sales"
val deltaLog = DeltaLog.forTable(spark,TableIdentifier(table, Some(db)))
deltaLog.snapshot.allFiles.show(3)
```

```
+--------------------+--------------------+-------+----------------+----------+--------------------+----+
|                path|     partitionValues|   size|modificationTime|dataChange|               stats|tags|
+--------------------+--------------------+-------+----------------+----------+--------------------+----+
|ss_sold_date_sk=2...|{ss_sold_date_sk ...|4234199|   1610537322000|     false|{"numRecords":880...|null|
|ss_sold_date_sk=2...|{ss_sold_date_sk ...|4162372|   1610537322000|     false|{"numRecords":866...|null|
|ss_sold_date_sk=2...|{ss_sold_date_sk ...|4157255|   1610537323000|     false|{"numRecords":865...|null|
+--------------------+--------------------+-------+----------------+----------+--------------------+----+
```

Inspecting delta log - added files

```scala
import com.databricks.sql.transaction.tahoe.DeltaLog
import org.apache.spark.sql.catalyst.TableIdentifier

val db = "tpcds_sf100_delta"
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+--------------------+--------------------+-------+----------------+----------+--------------------+----+
```

Added file stats

```
{
 "numRecords": 88099,
  "minValues": {

...
    "ss_net_profit": -9592
  },
  "maxValues": {
...
    "ss_net_profit": 8301
  },
...
  }
}
```

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Added file stats

```
{
 "numRecords": 88099,
  "minValues": {

...
    "ss_net_profit": -9592
  },
  "maxValues": {
...
    "ss_net_profit": 8301
  },
...
  }
}
```

```
SELECT * FROM store_sales WHERE ss_net_profit < 0
```

Improving data layout for skipping

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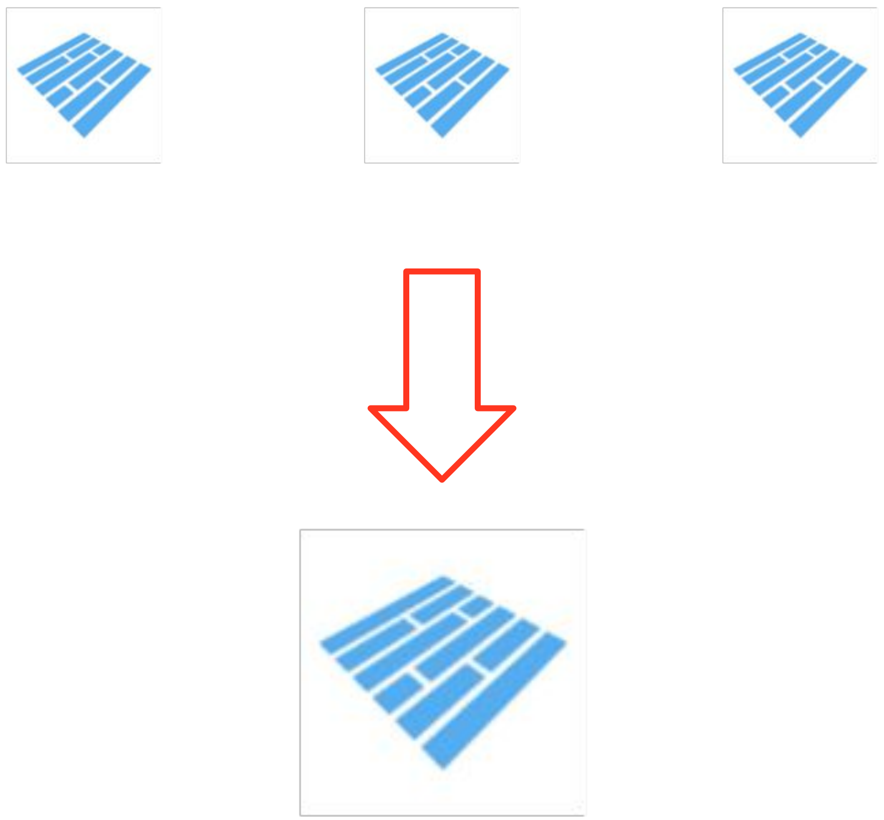
File size

- Files too small -> more IO, delta log processing slower
- Files too large -> cannot skip file, large UPDATE overhead
- 32MB - 128MB and 1GB for large tables > 10TB

Compaction

```python
path = "..."
numFiles = 16

(spark.read
 .format("delta")
 .load(path)
 .repartition(numFiles)
 .write
 .option("dataChange", "false")
 .format("delta")
 .mode("overwrite")
 .save(path))
```



Compaction

```python
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 .format("delta")
 .load(path)
 .repartition(numFiles)
 .write
 .option("dataChange", "false")
 .format("delta")
 .mode("overwrite")
 .save(path))
```
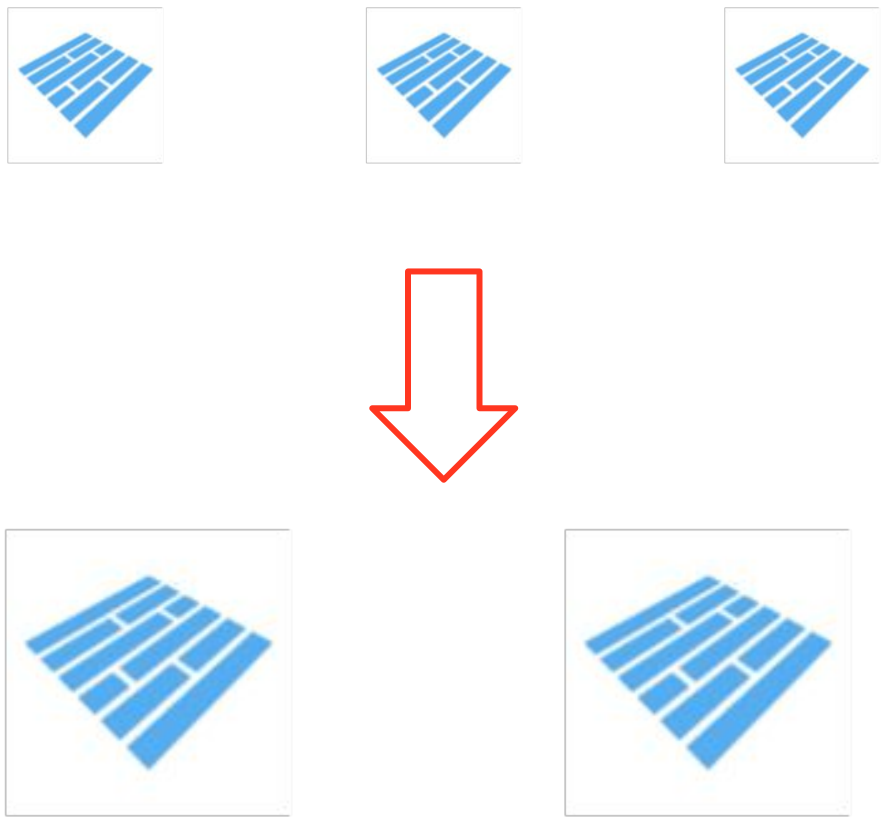
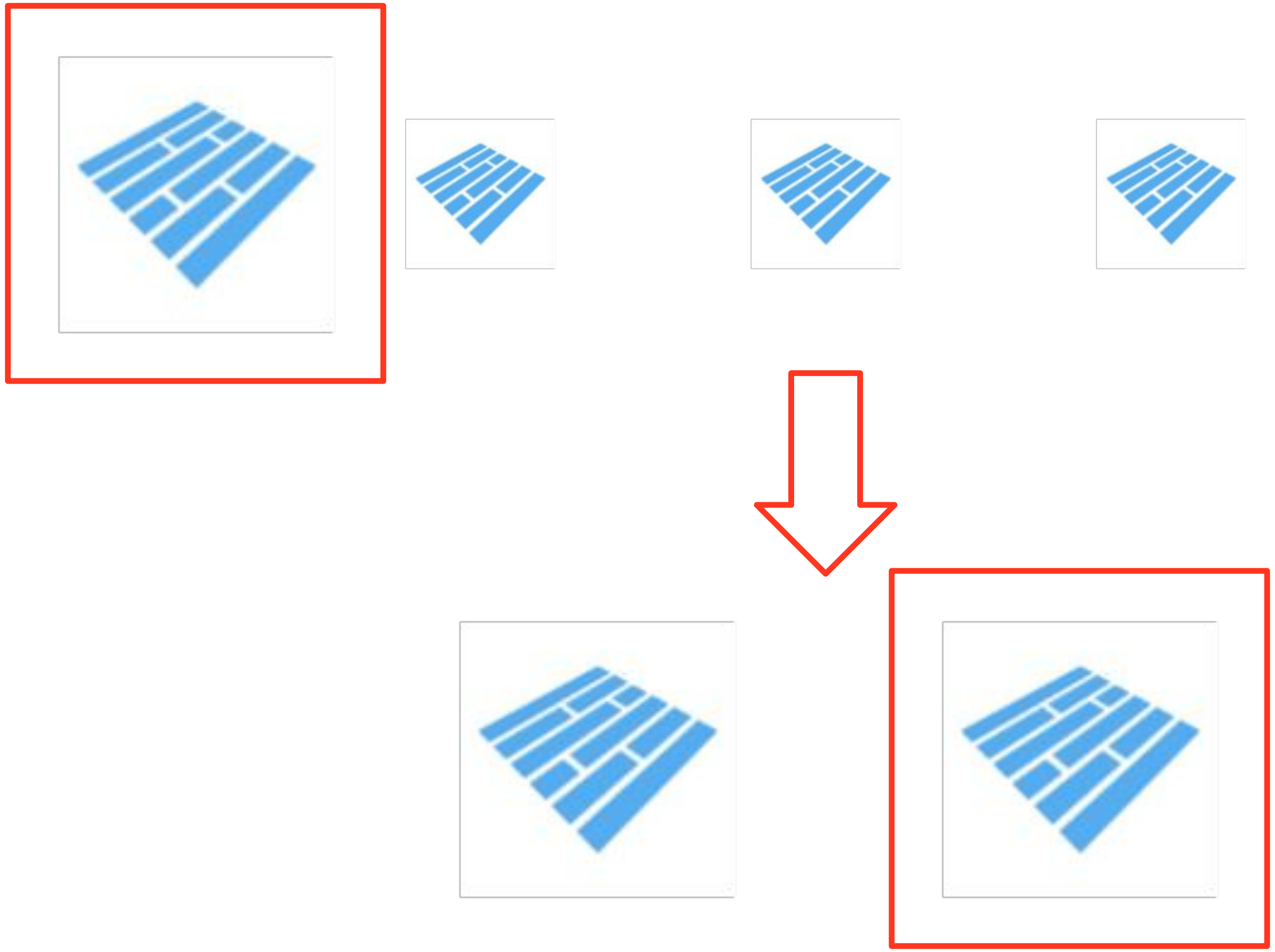

- Number of target files?



Compaction

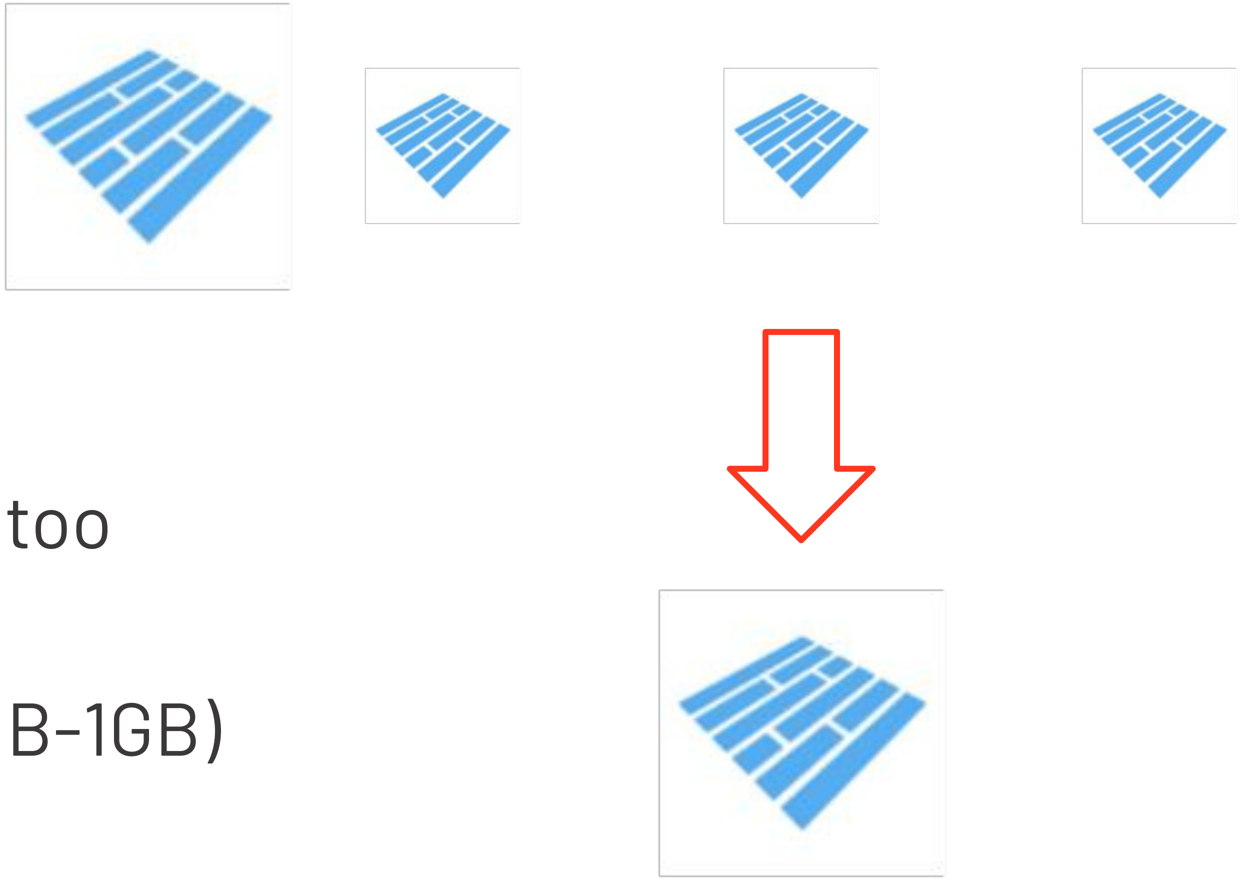
```
path = "..."
numFiles = 16

(spark.read
 .format("delta")
 .load(path)
 .repartition(numFiles)
 .write
 .option("dataChange", "false")
 .format("delta")
 .mode("overwrite")
 .save(path))
```



- Number of files?
- Overwrites the whole table(partition)

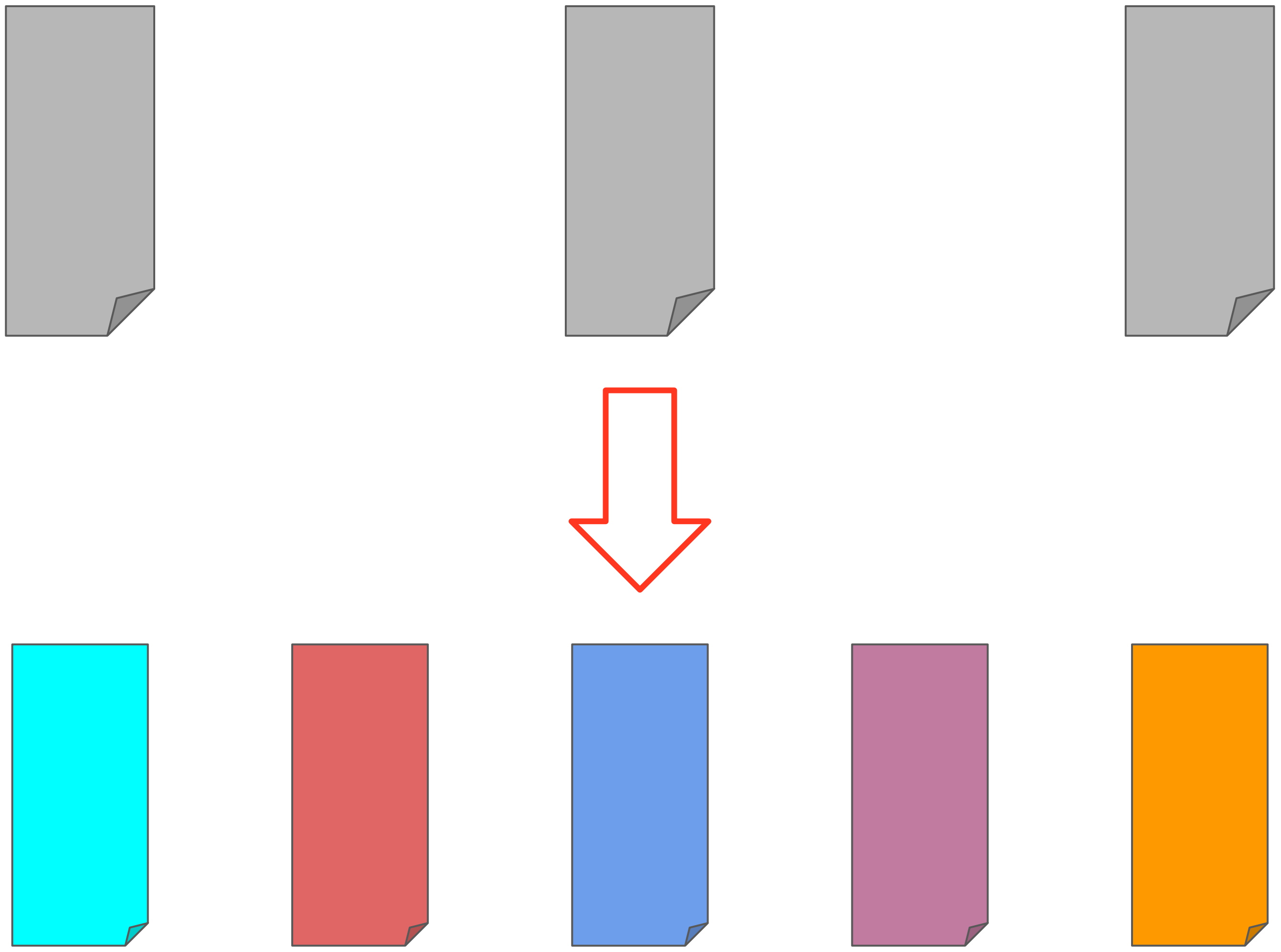
Optimize command

```
OPTIMIZE my_table
```



- Compacts only files that are too small
- Creates “good” file sizes(64MB-1GB)

Data clustering



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Sorting - 1 dimension

X	Y
1	7
1	3
3	4
4	5

000.parquet

x>=1 && x<=4

X	Y
5	1
6	2
6	3
7	5

001.parquet

x>=5 && x<=7

```
SELECT * FROM table WHERE x = 5
```

Sorting - 2 dimension

X	Y
1	7
1	3
1	4
1	5

000.parquet

X	Y
1	1
1	2
6	3
7	5

001.parquet

```
SELECT * FROM table WHERE x = 1 AND y = 3
```

Sorting - 2 dimension

X	Y
1	1
1	2
1	3
1	3

000.parquet

X	Y
1	4
1	5
6	5
7	7

001.parquet

```
SELECT * FROM table WHERE x = 1 AND y = 3
```

databricks

Sorting - 2 dimension

X	Y
1	1
2	2
2	3
3	5

000.parquet

X	Y
4	4
5	3
6	5
7	7

001.parquet

```
SELECT * FROM table WHERE y = 3
SELECT * FROM table WHERE x = 1 OR y = 3
```

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Z-order - Multi dimensional clustering

```
OPTIMIZE store_sales ZORDER BY x, y
```

X	Y
1	1
2	2
3	3
5	3

000.parquet

X	Y
3	4
5	4
6	5
7	7

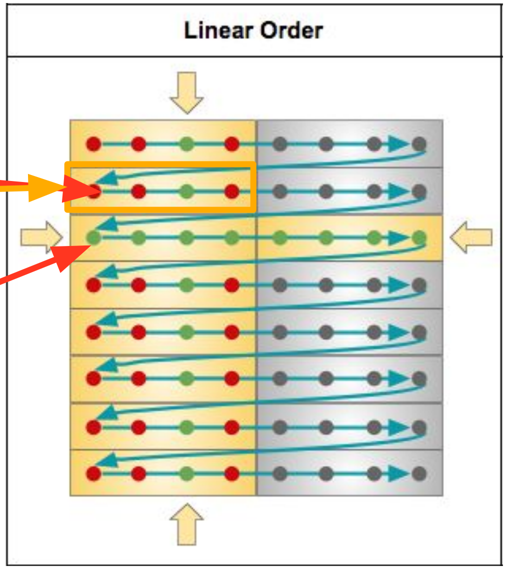
001.parquet

```
SELECT * FROM table WHERE y = 3
SELECT * FROM table WHERE x = 1 OR y = 3
```

Z-order - Multi dimensional clustering

X	Y
1	1
1	2
1	3
1	4

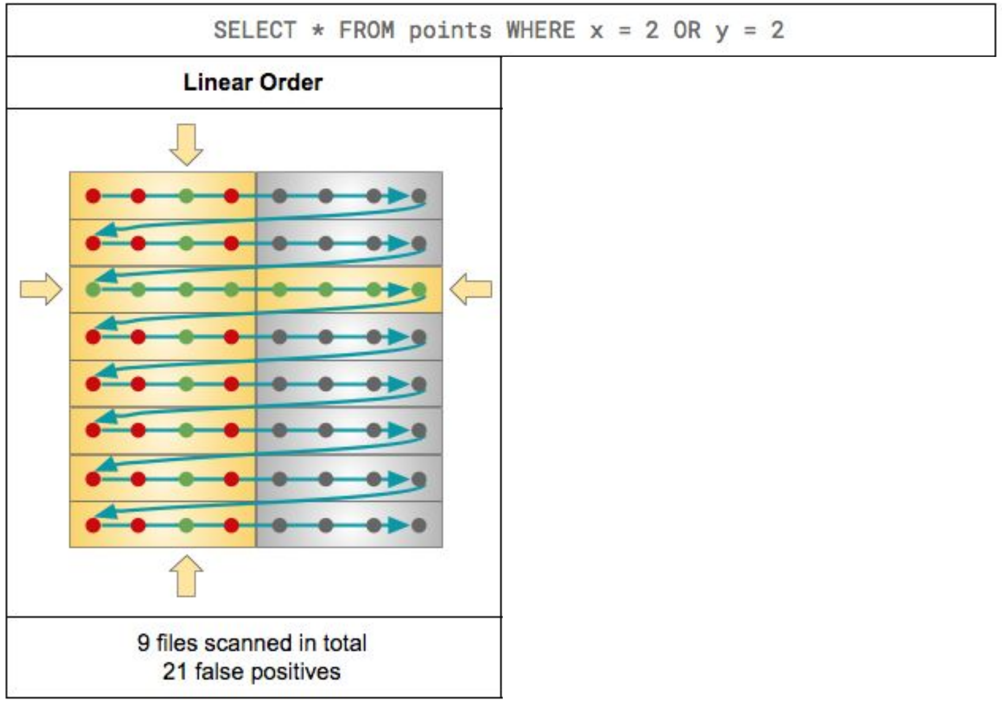
X	Y
2	1
2	2
2	3
2	4



Z-order - Multi dimensional clustering

X	Y
1	1
1	2
1	3
1	4

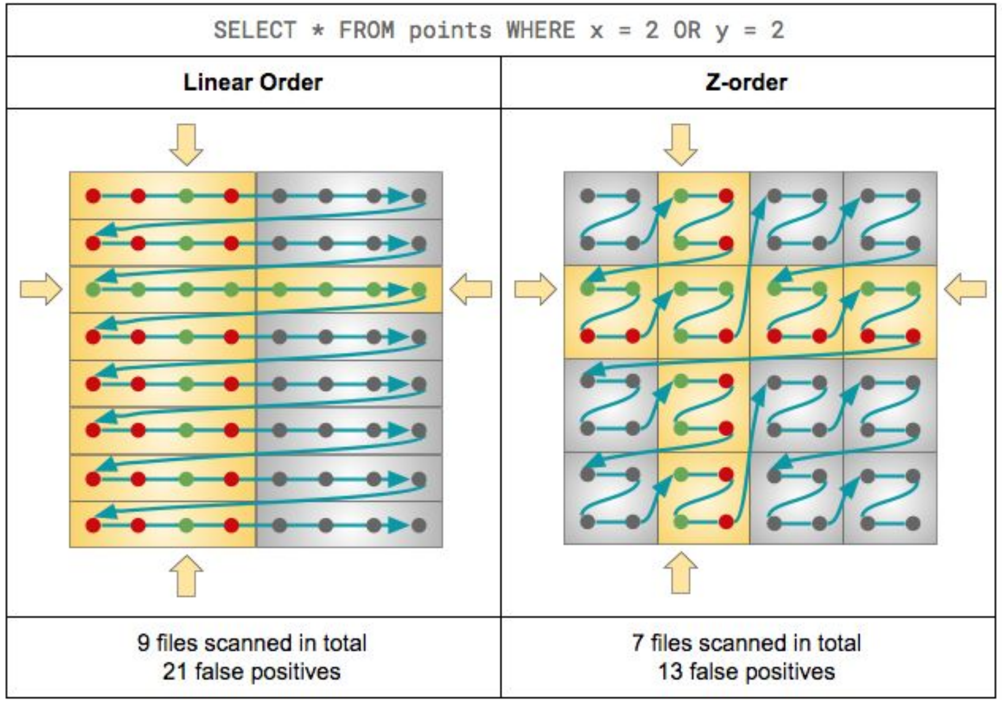
X	Y
2	1
2	2
2	3
2	4



Z-order - Multi dimensional clustering

X	Y
1	1
1	2
2	1
2	2

X	Y
1	1
1	2
2	3
2	4



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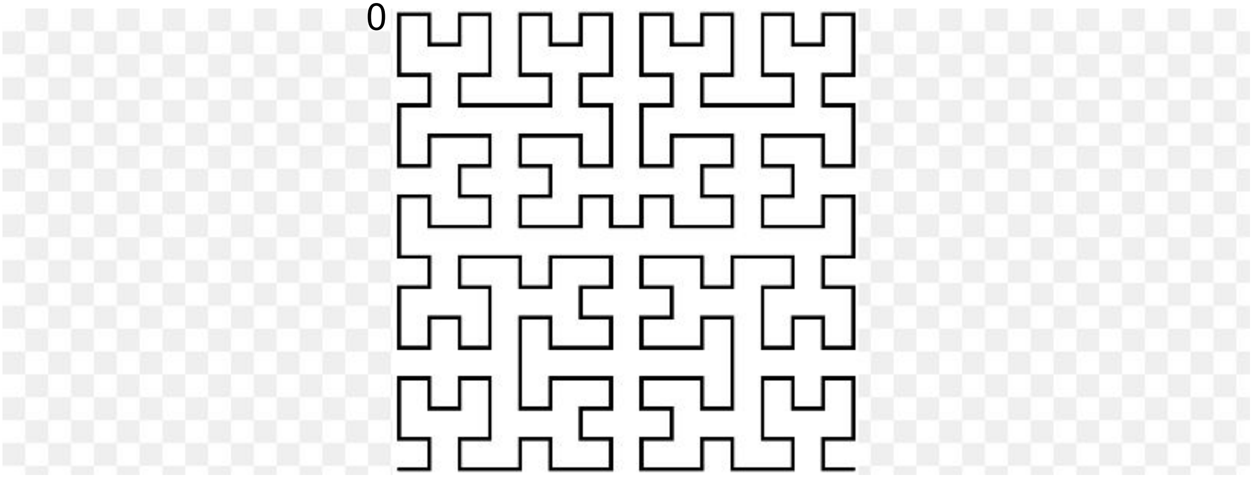
Hilbert curve



Auxiliary index - Bloom Filter

```
CREATE BLOOMFILTER INDEX
ON TABLE my_table
FOR COLUMNS(cust_id OPTIONS (fpp=0.1, numItems=50000000))
```

Is this value in this file?

- ❑ Maybe
- ❑ No

Bloom Filter

0 0 0 0 0

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Bloom Filter

1

0	0	0	0	0
0	0	0	1	0

Bloom Filter

	0	0	0	0	0
1	0	0	0	1	0
3	0	1	0	1	0

Bloom Filter

1
3
7

0	0	0	0	0
0	0	0	1	0
0	1	0	1	0
0	1	1	1	0

Bloom Filter

	0	0	0	0	0
1	0	0	0	1	0
3	0	1	0	1	0
7	0	1	1	1	0

- Is 1 in the bitmap -> MAYBE
- Is 0 in the bitmap -> NO
- Is 2 in the bitmap -> MAYBE - False positive

Data layouts are hard

- Compaction jobs need to be scheduled
- Many knobs to turn
- Workloads change
- Data changes - skew

Steps to automation at Databricks

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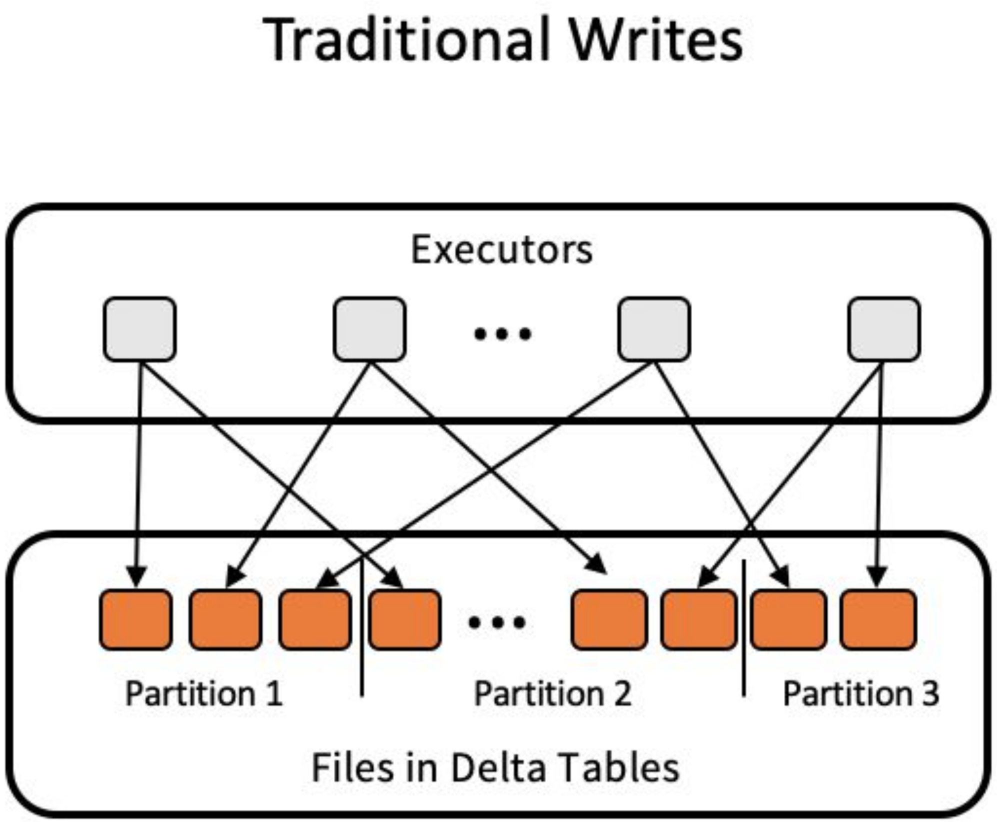
Auto-compaction

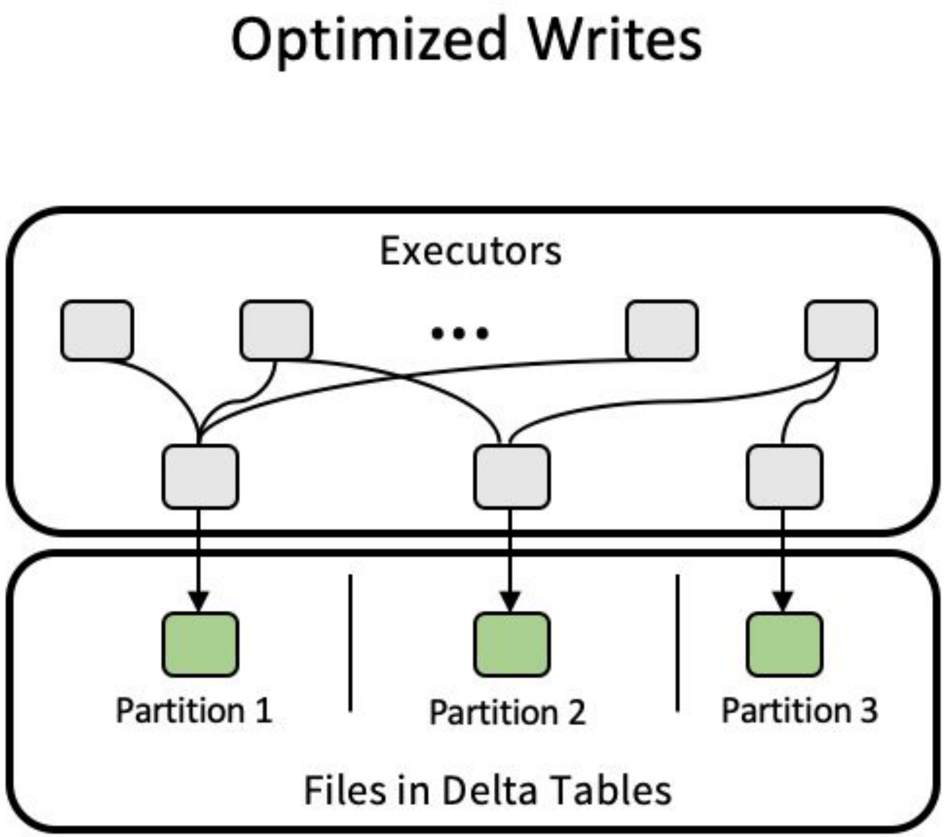
- Compact files after every commit automatically
- Should not run for too long
- Could conflict with other transactions

Optimized Writes

- Shuffled writes for partitioned tables
- Keeps files well sized

Optimized Writes

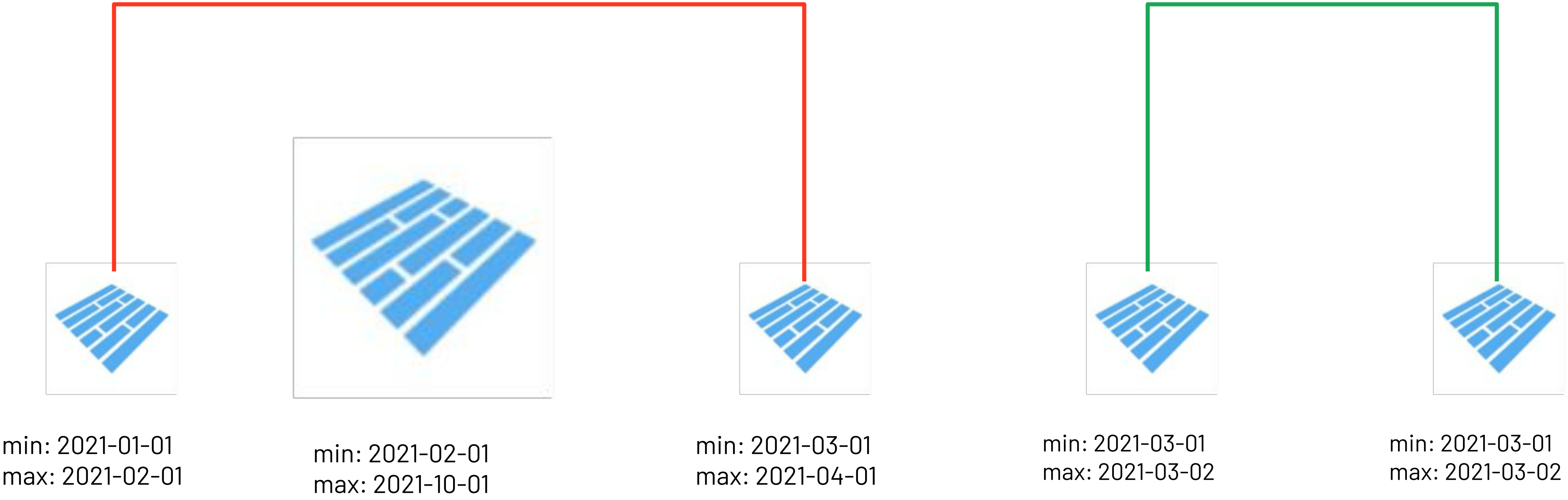




Insertion order

- Preserve the original data clustering
- Good for time series data, event logs

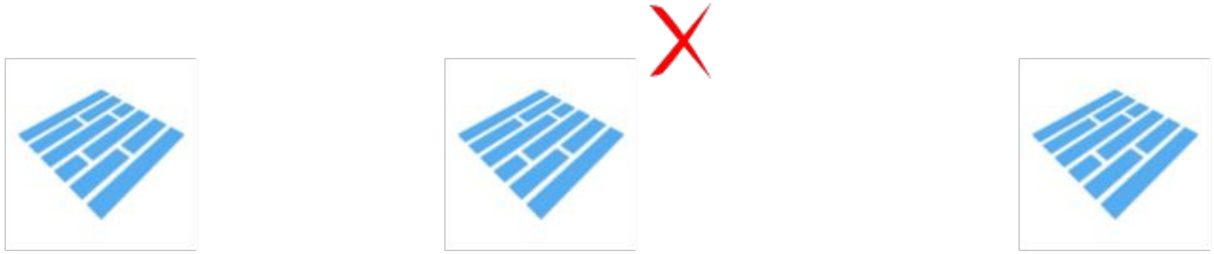
Compaction challenge



- Compact only neighboring files in timeline

Update/Delete challenge

```
DELETE FROM table WHERE date = '2021-02-01'
```

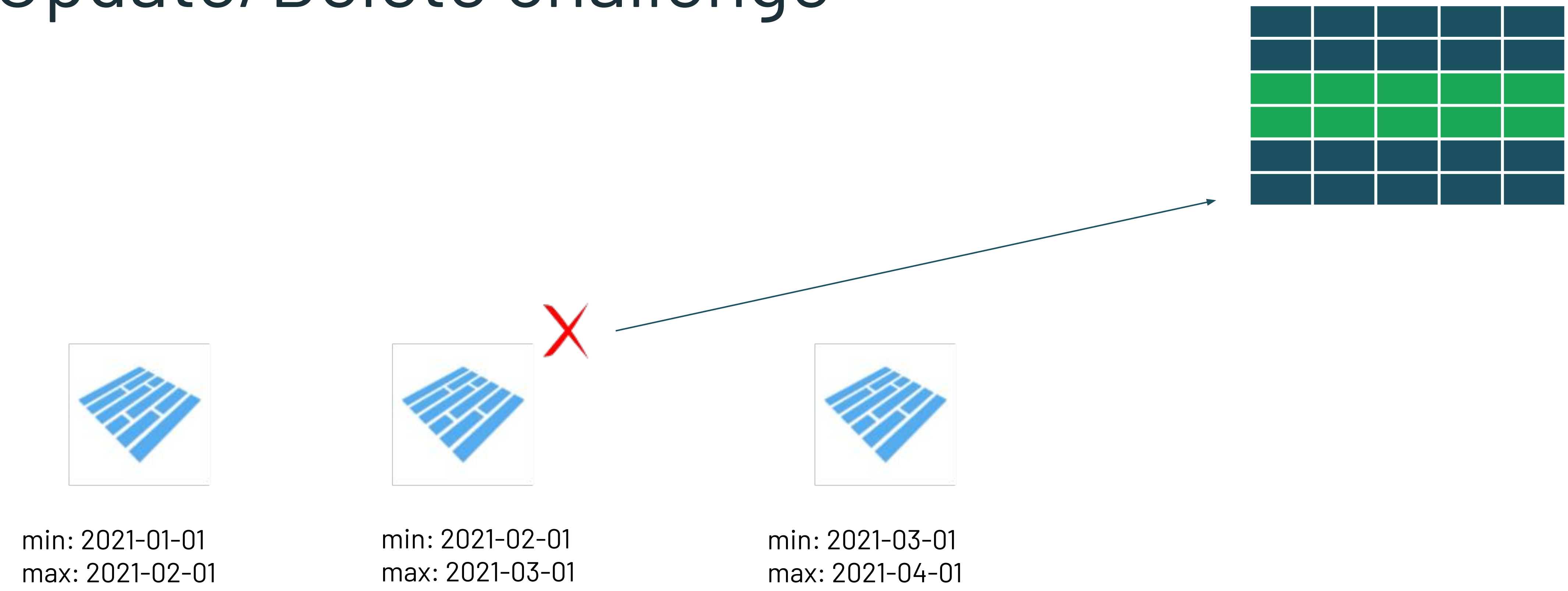


min: 2021-01-01
max: 2021-02-01

min: 2021-02-01
max: 2021-03-01

min: 2021-03-01
max: 2021-04-01

Update/Delete challenge



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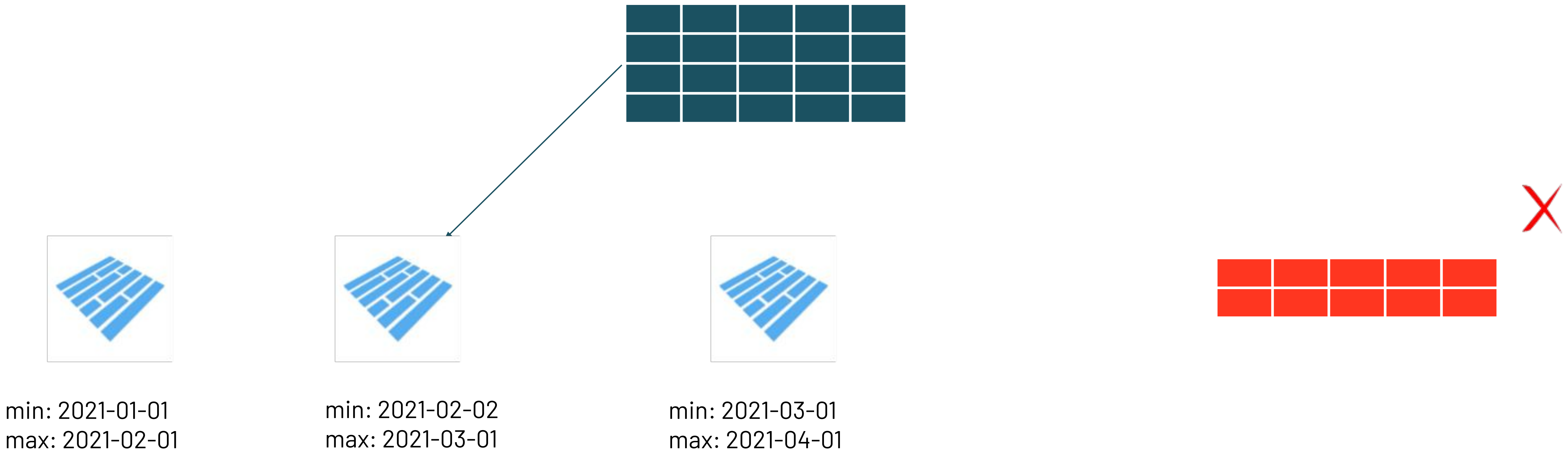
Update/Delete challenge

min: 2021-01-01
max: 2021-02-01

min: 2021-03-01
max: 2021-04-01

Update/Delete challenge

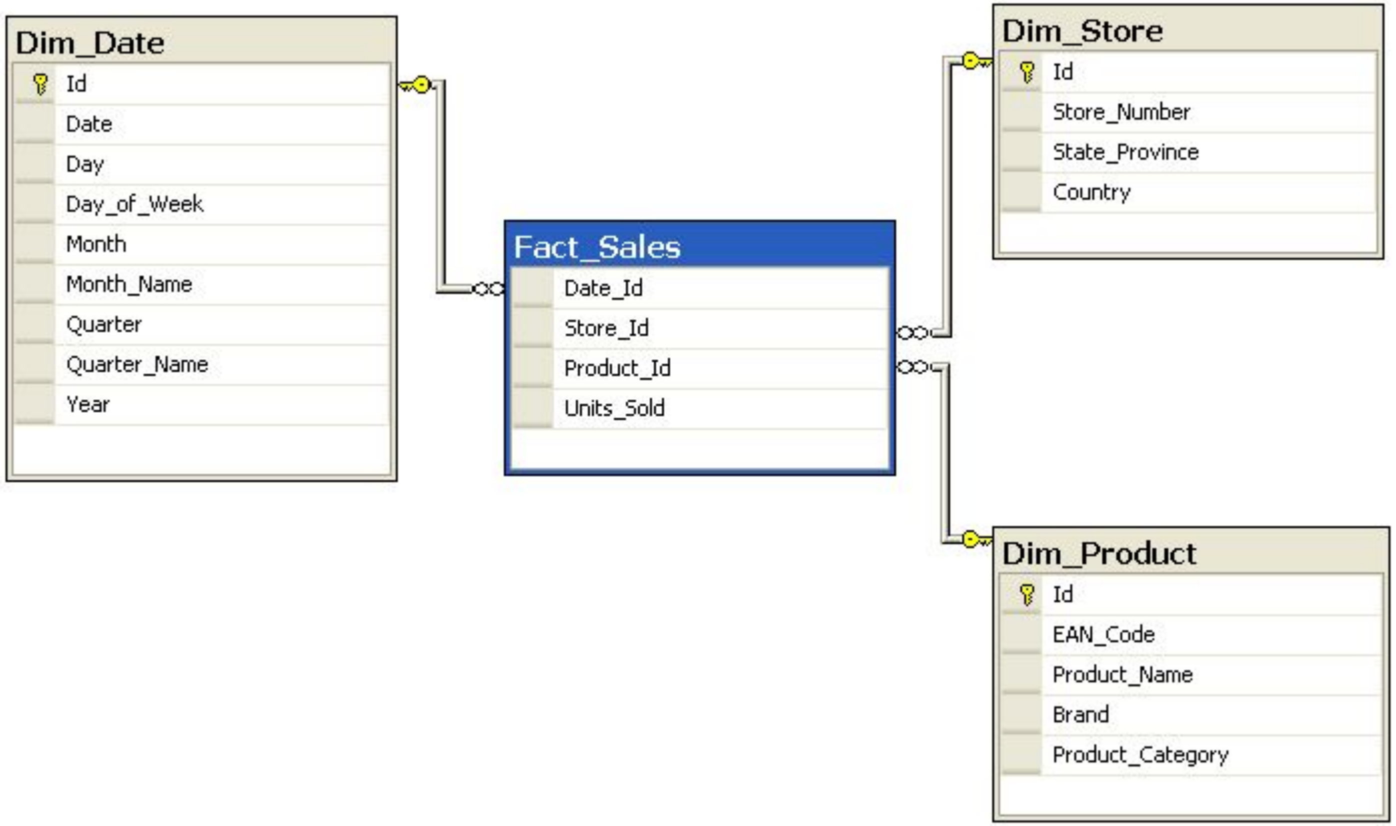


Future: Advisor/background optimizations

- Recognize common query patterns
- Propose optimal data layout
- Run in the background on idle machines

Star schema pattern

Star schema



https://en.wikipedia.org/wiki/Star_schema

Star schema

- Consider denormalizing, precomputed joins, storage is cheap
- Use DELTA for your fact and dimension tables
- OS Delta: partition the fact by date and compact files from time to time
- Z-ORDER fact table by "foreign" keys columns
- Z-ORDER dimension tables by "primary" key columns
- Consider creating bloom filter index for pinpoint predicates

Thanks!

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