
facebook

Cosco: an efficient facebook-scale shuffle service

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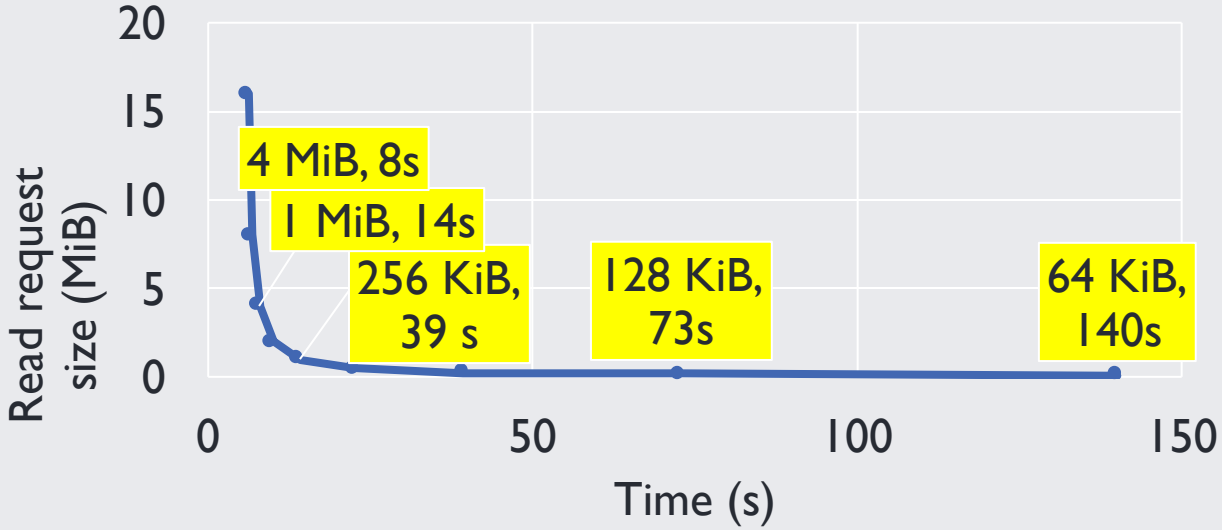
Spark + AI Summit 2019

Disaggregated compute and storage

- Advantages
  - Server types optimized for compute or storage
  - Separate capacity management and configuration
  - Different hardware cycles
- Compute clusters
  - CPU, RAM, no disks for data
  - Spark executors
- Storage clusters
  - Spindle disks
  - DFS (Warm Storage)
    - Permanent data: size dominant, uses less IO
    - Temporary data: IO dominant, uses less space

Spindle disk storage

- A single spindle is used to read/write data on the drive
  - Small IO sizes cause low throughput as seek times dominate



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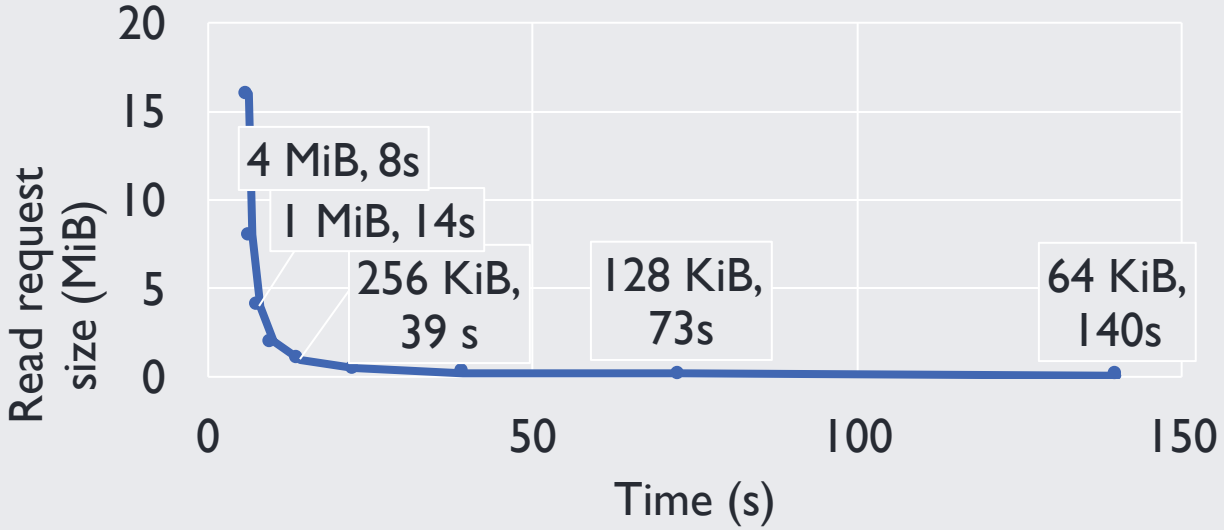
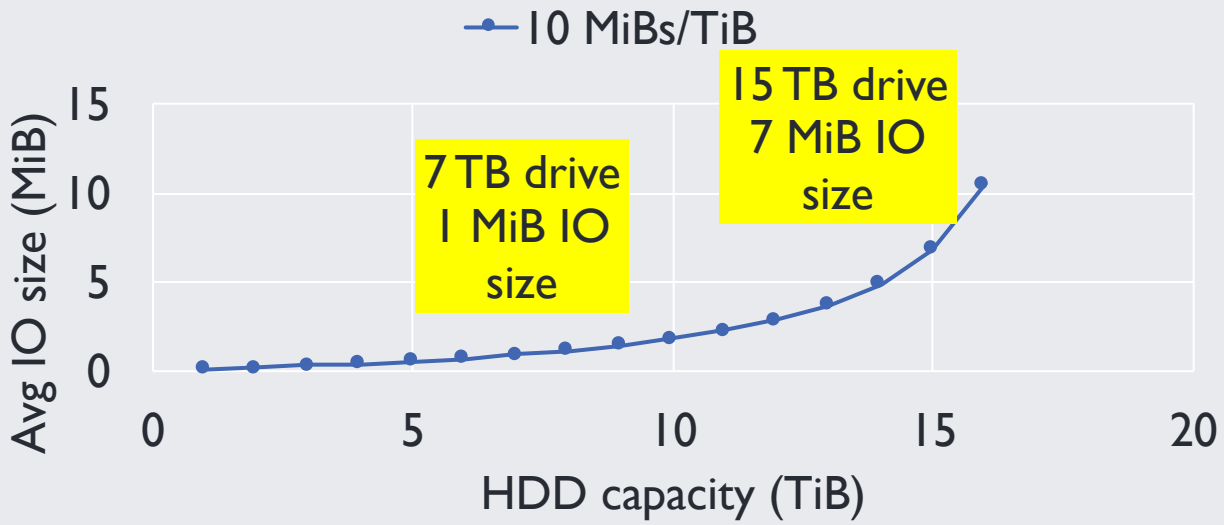


- Drive sizes increase over time
  - Must increase IO size to maintain the same throughput per TB



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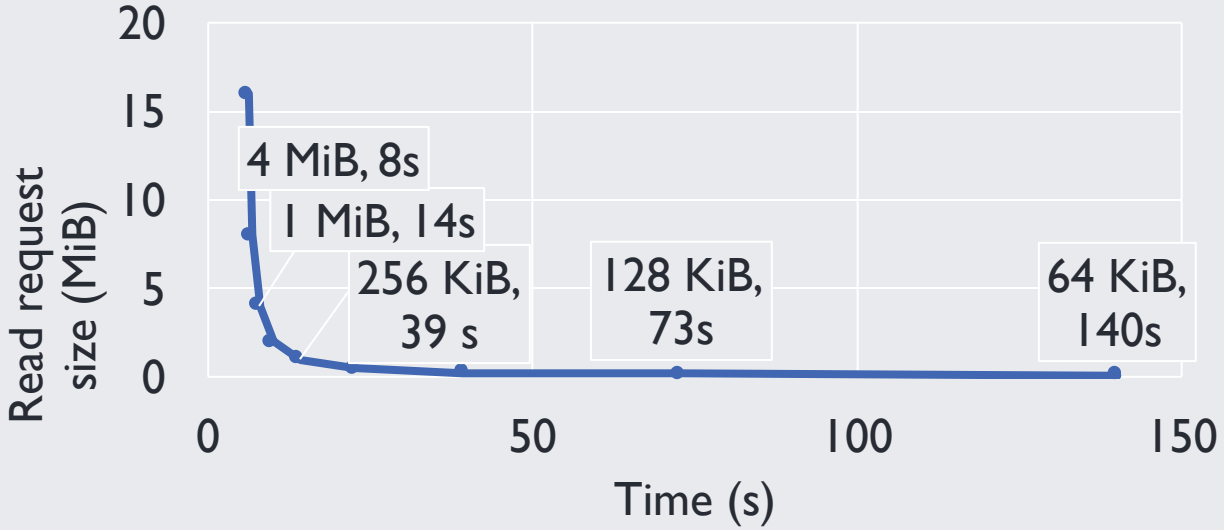
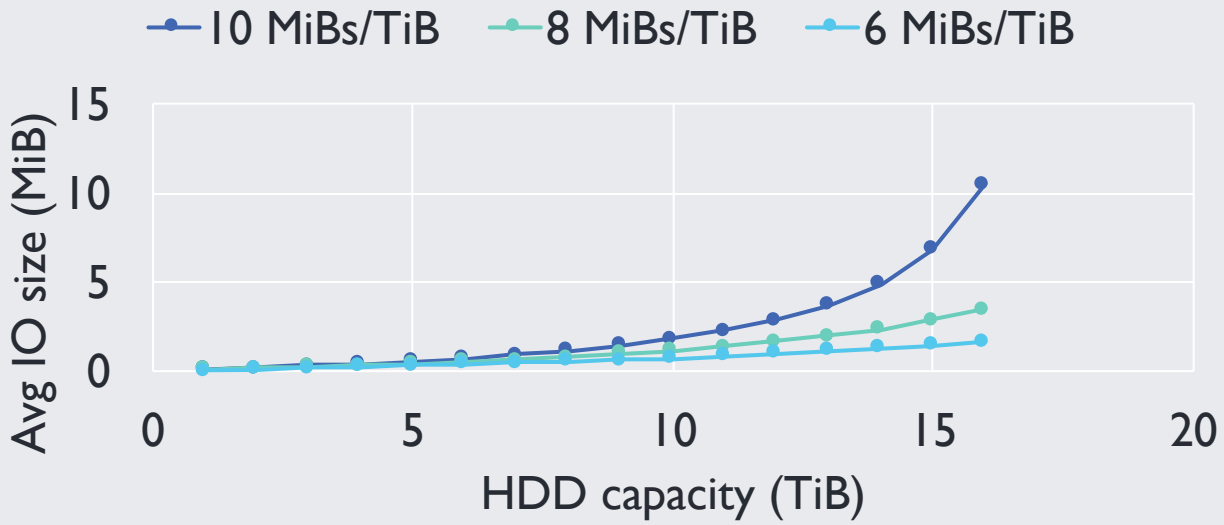


- Drive sizes increase over time
  - Must increase IO size to maintain the same throughput per TB, or
  - Read/write less data to reduce throughput demand



Spindle disk storage: key metrics

- A single spindle is used to read/write data on the drive
  - Small IO sizes cause low throughput as seek times dominate

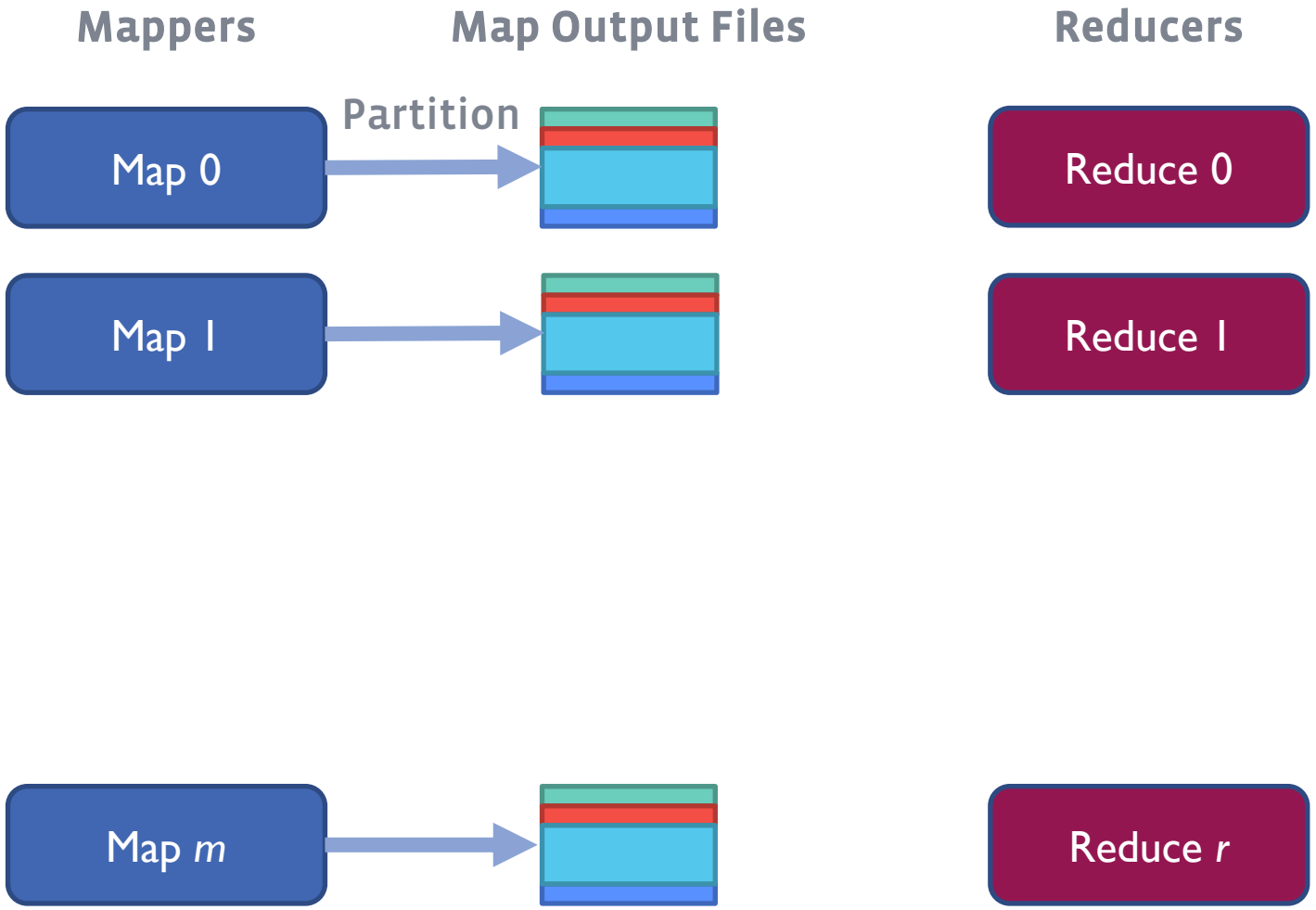
➢Disk service time

➢Average IO size

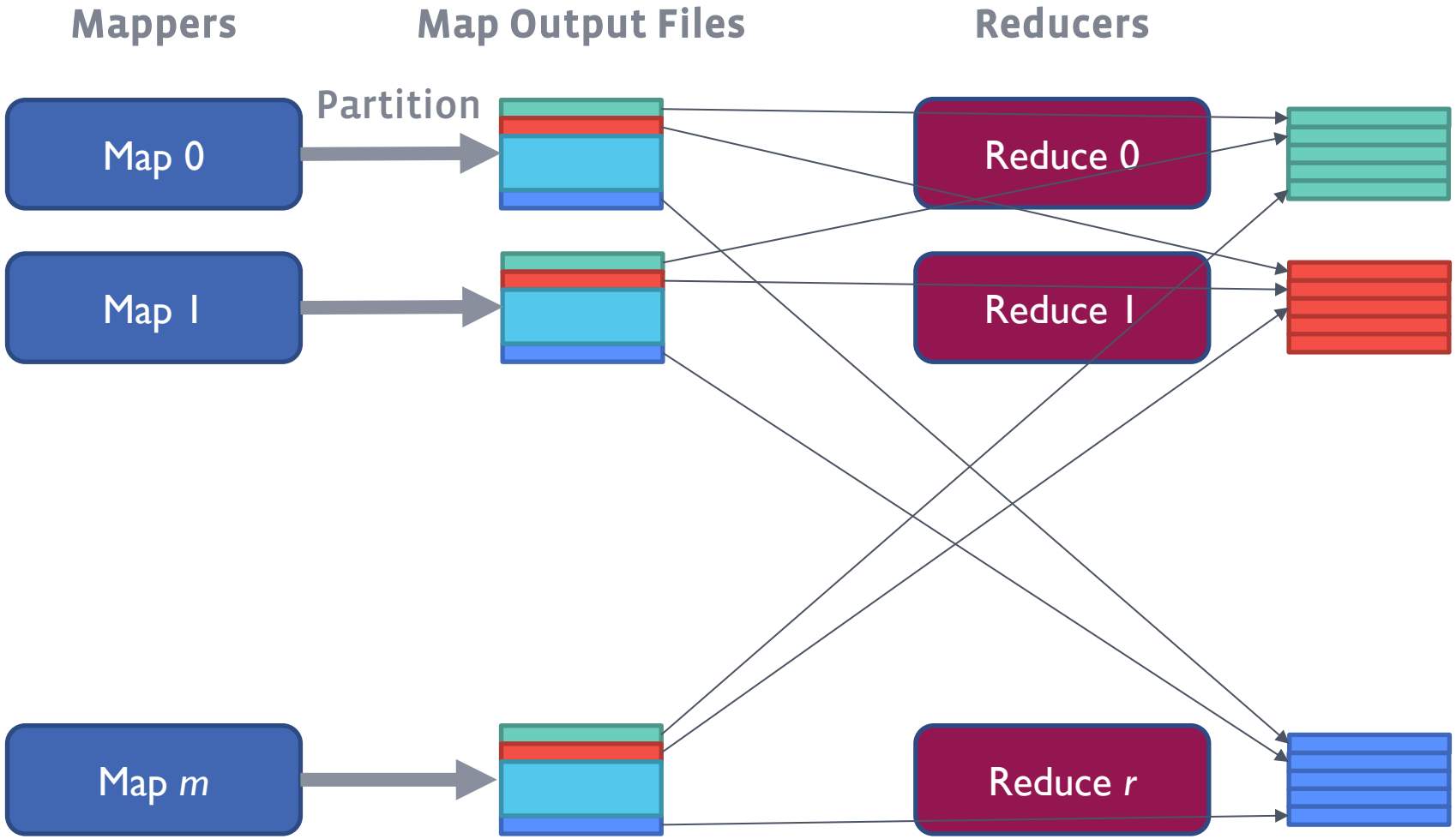
- Drive sizes increase over time
  - Must increase IO size to maintain the same throughput, or
  - Read/write less data to reduce throughput demand

➢Write amplification

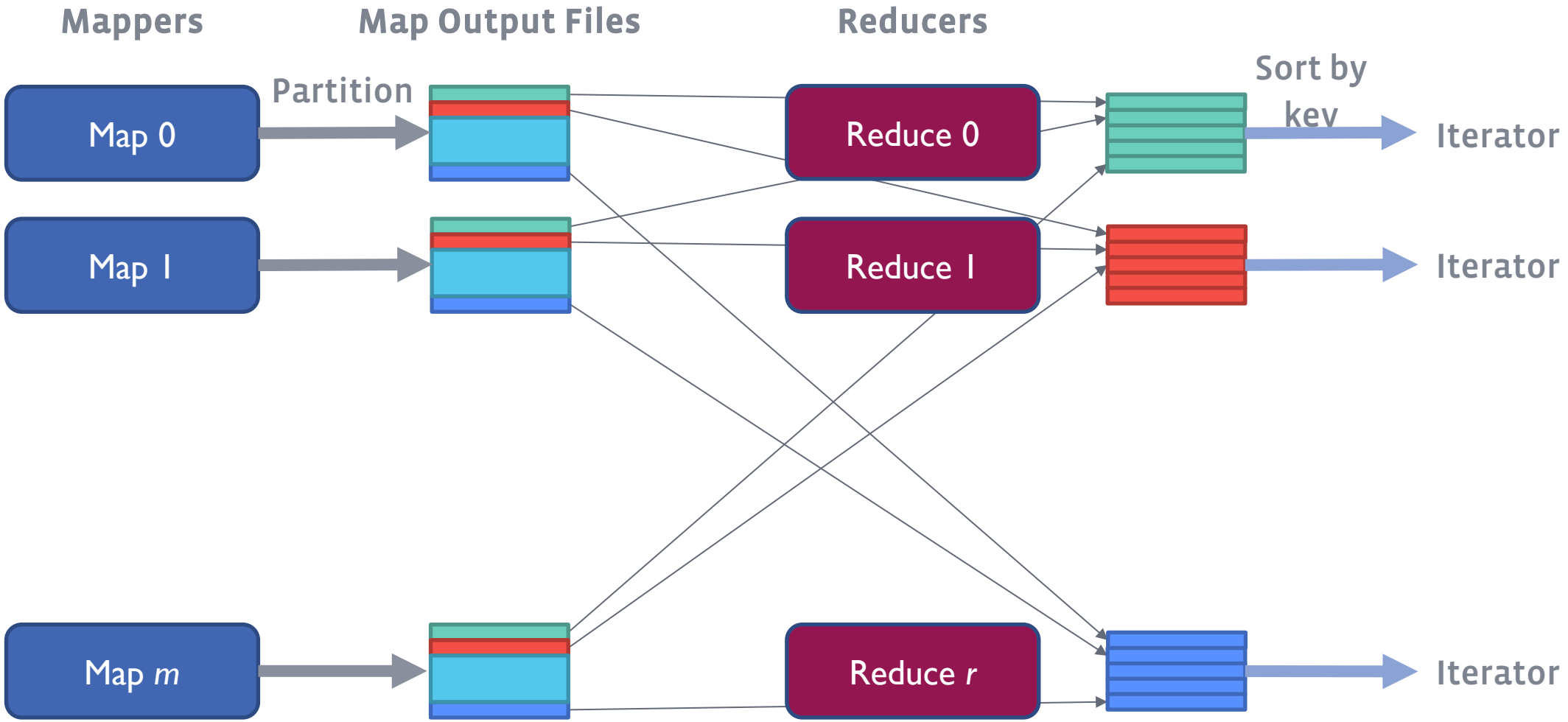
Spark shuffle recap



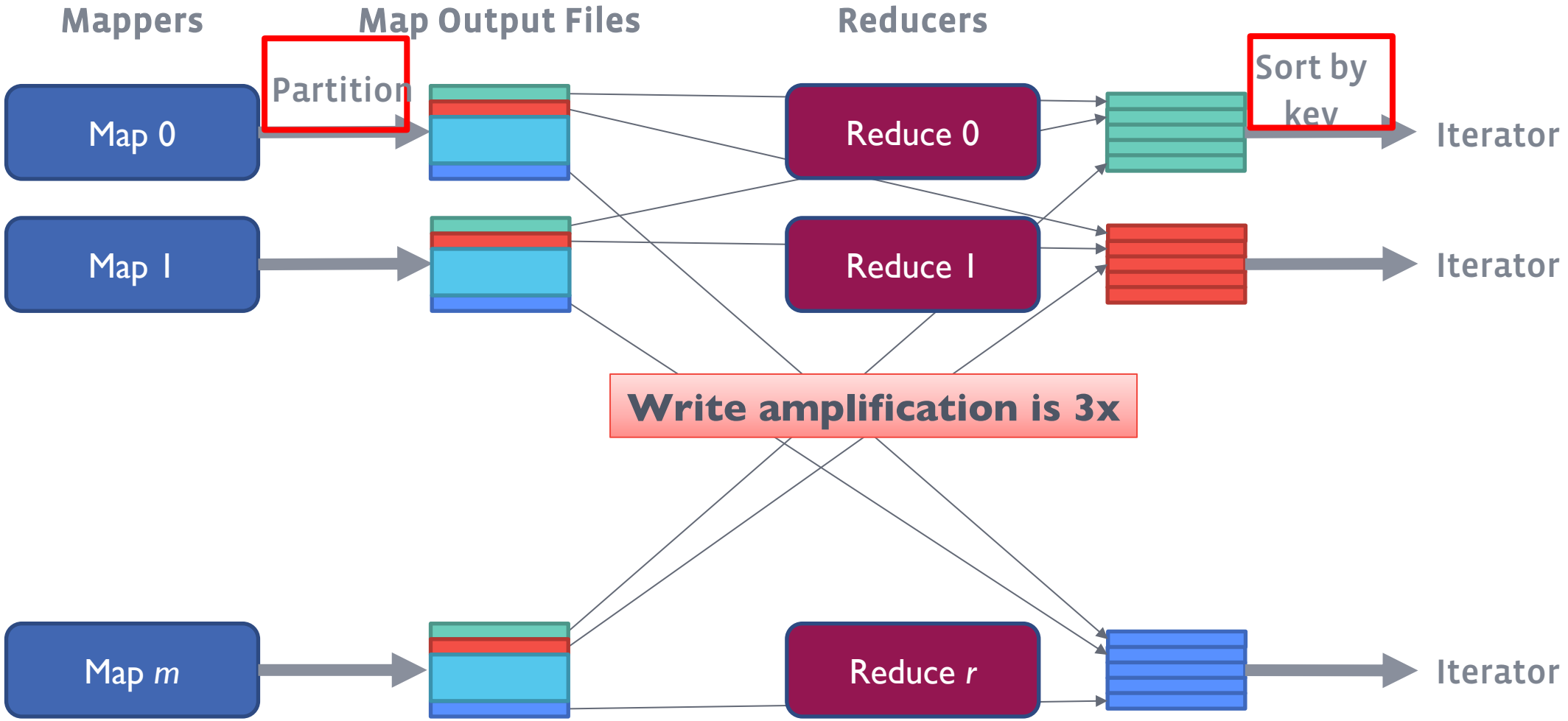
Spark shuffle recap



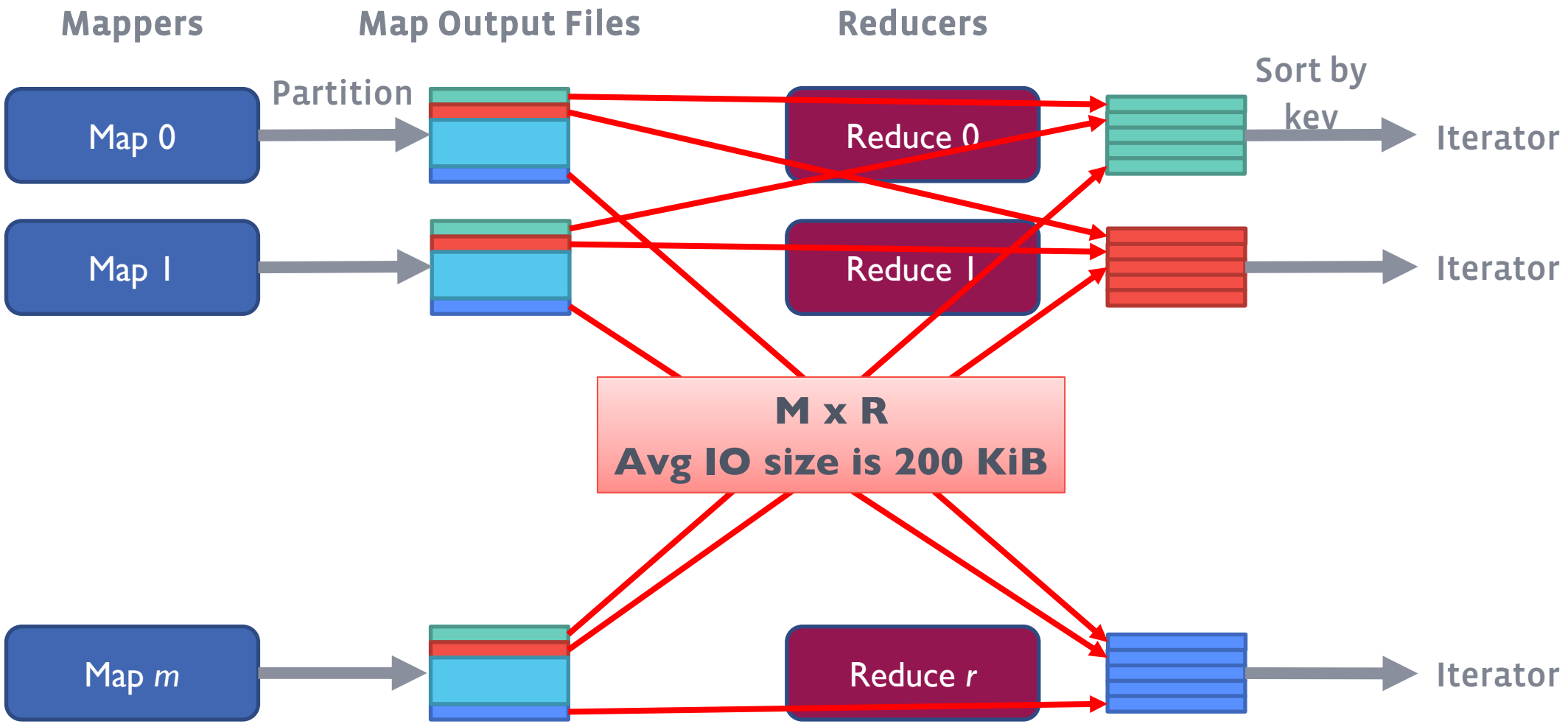
Spark shuffle recap



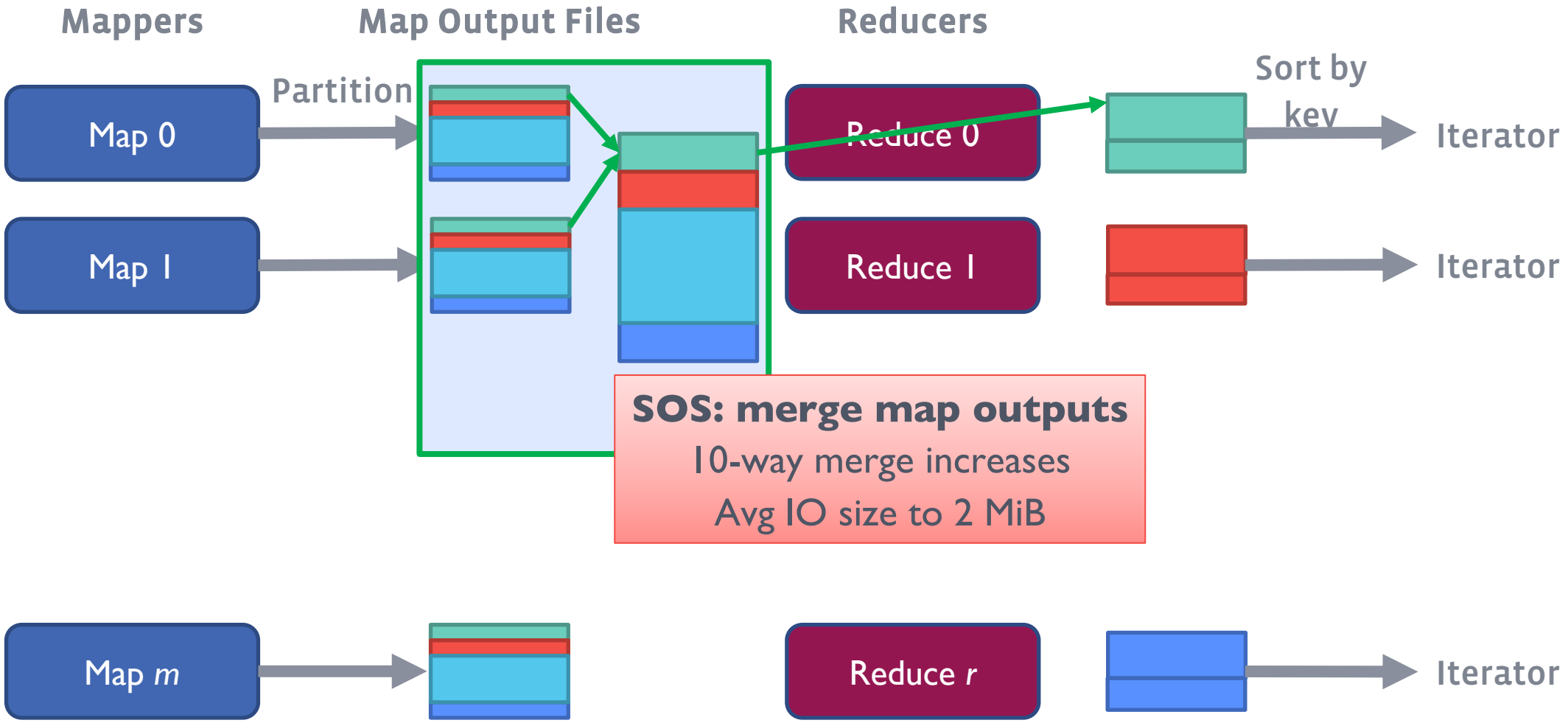
Spark shuffle recap: Write amplification



Spark shuffle recap: Small IOs problem



Spark shuffle recap: SOS



Spark shuffle using Cosco

- Mappers share a write-ahead buffer per reduce partition
- Reducers can read the written data sequentially

- Solves the small IOs problem
  - Sequential reads: Avg IO size 200 KiB → 2.5 MiB
- Solves the write amplification problem
  - Avoiding spills: Write amplification 3x → 1.2x

Results / Current status

- Hive
  - Rolled out to 90%+ of Hive workloads, in production for 1+ year
  - **3.2x** more efficient disk service time
- Spark
  - Analysis shows potential **3.5x** more efficient disk service time
  - Analysis shows CPU neutral
  - Integration is complete, rollout planned during next few months

Cosco deep dive

Dmitry Borovsky

Spark + AI Summit 2019

Problem

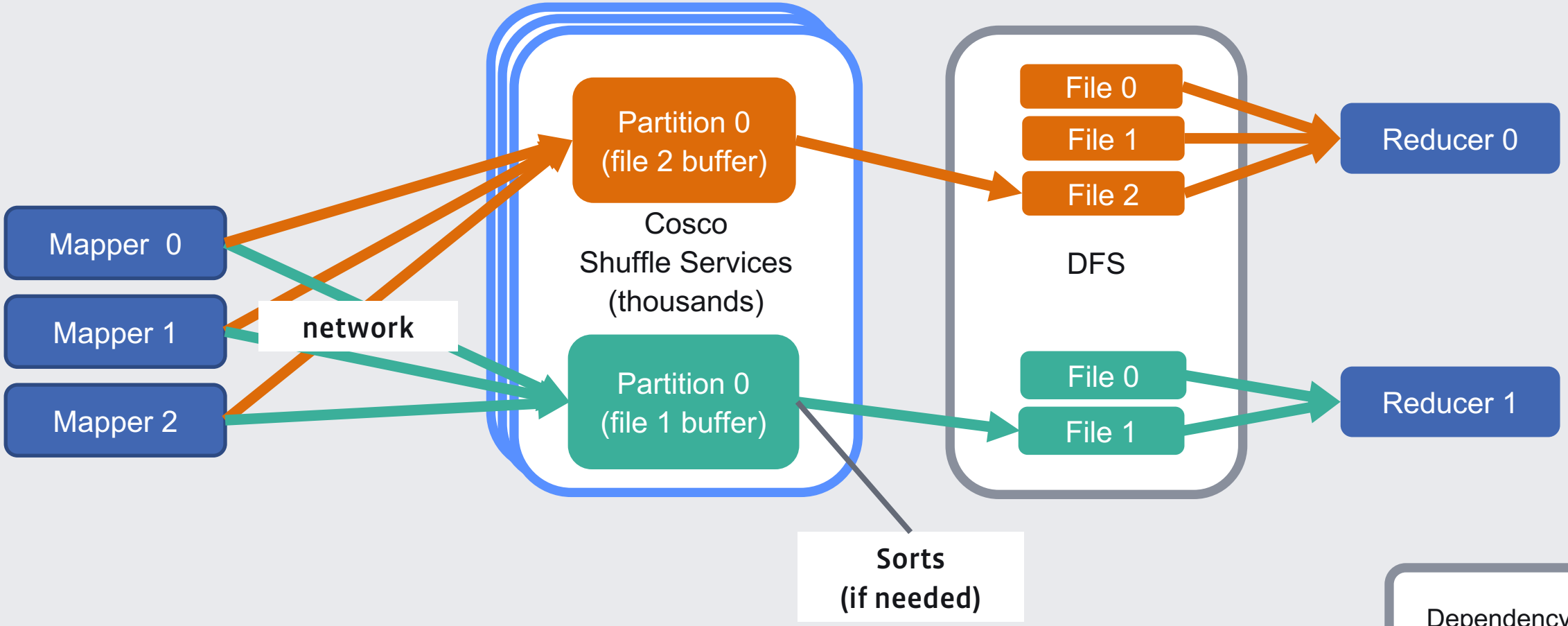
- Shuffle exchange on spinning disks (disaggregated compute and storage)
- Single shuffle exchange scale: PiBs size, 100Ks of mappers, 10Ks reducers
- Write amplification is ~3x (1PiB shuffle does 3PiB writes to disk)
- Small Average IO size: ~200KiB (at least MxR reads)
- IO is spiky (all readers may start at the same time and do MxR reads)
- Cosco is shared between users

Sailfish: a framework for large scale data processing

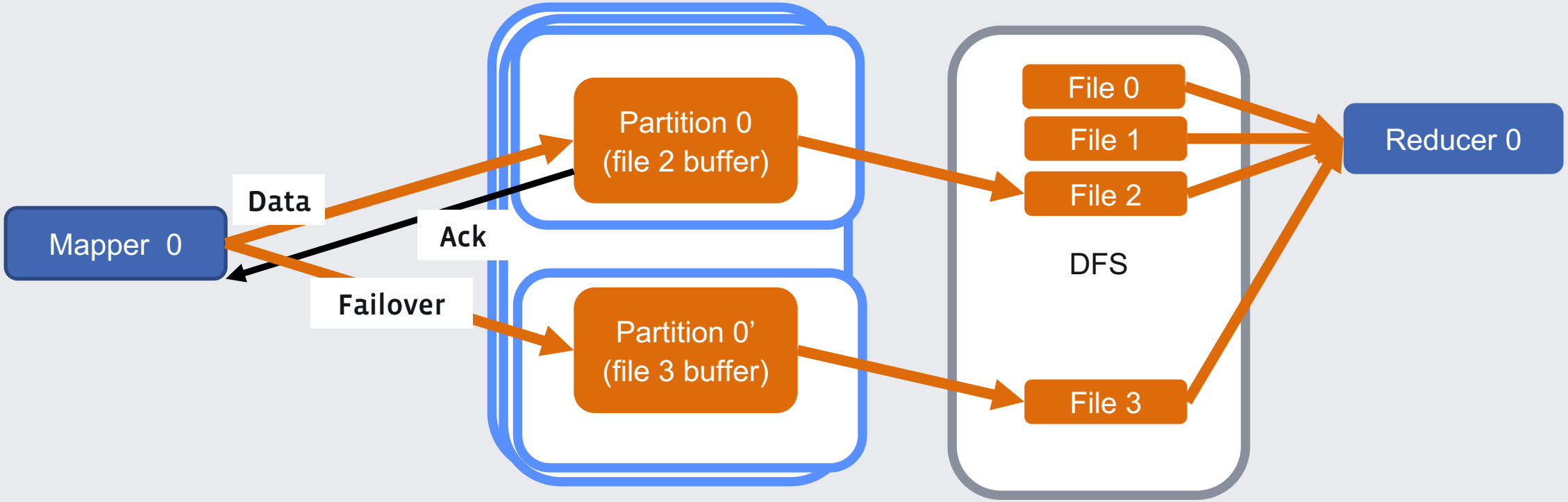
SoCC '12 Proceedings of the Third ACM Symposium on Cloud Computing, Article No. 4, San Jose, California — October 14 - 17, 2012

Source code: https://code.google.com/archive/p/sailfish/

Write-ahead buffers



Exactly once delivery



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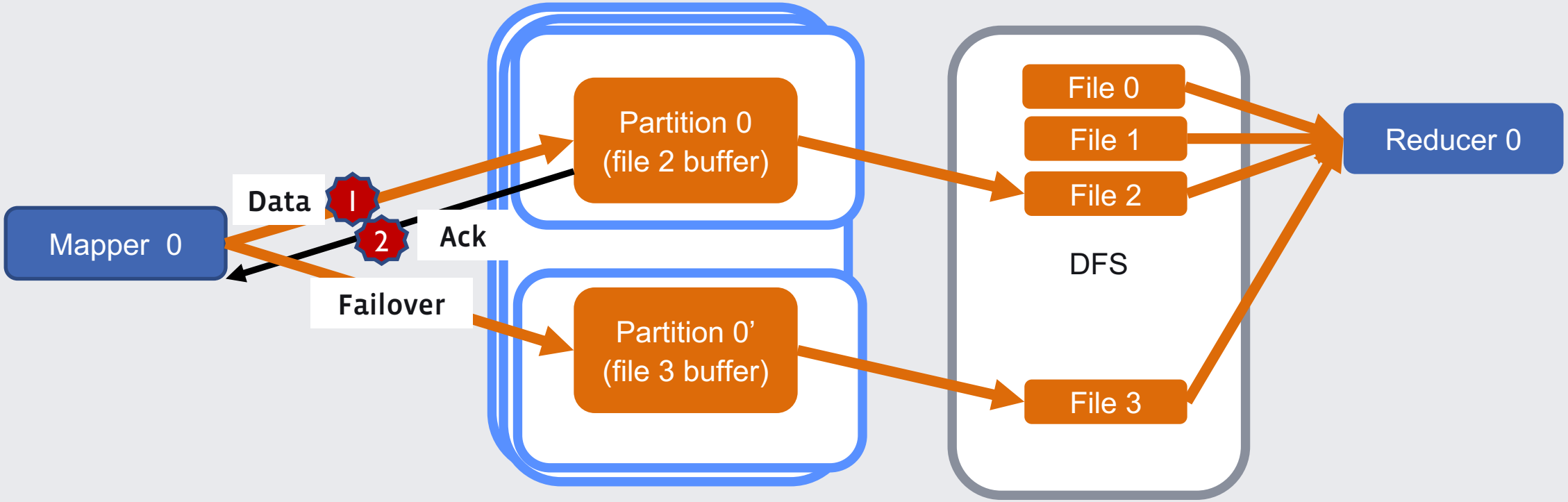
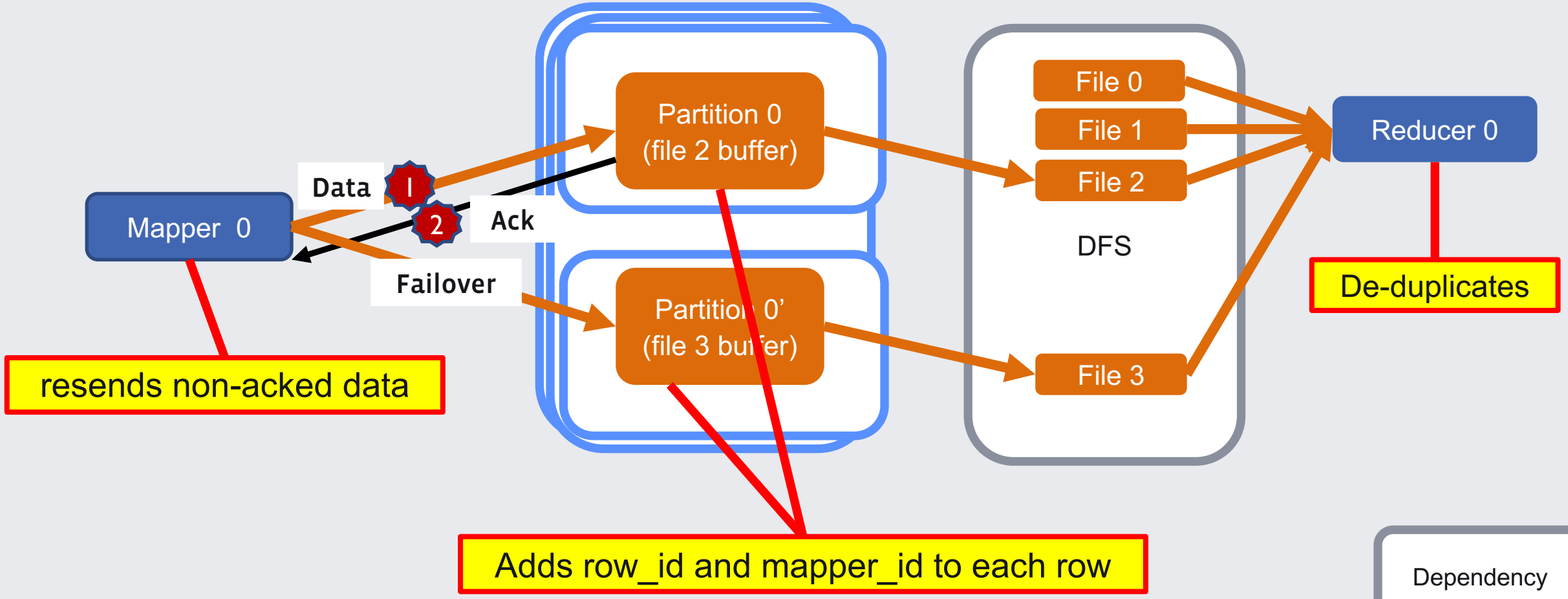
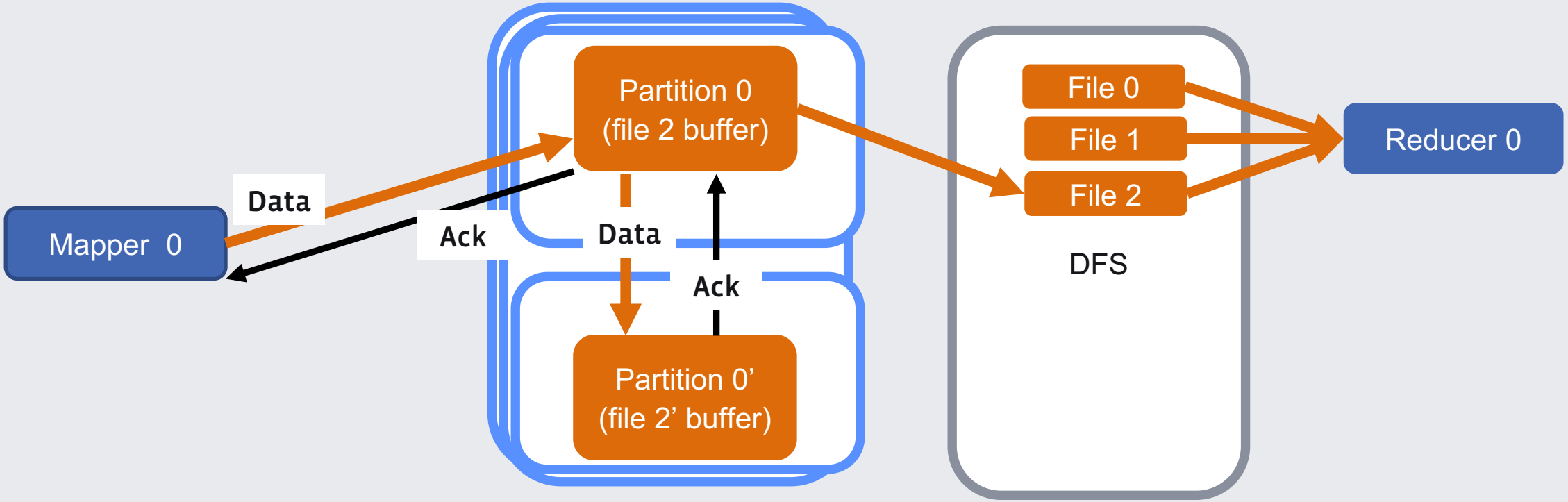


At least once delivery and deduplication



Replication

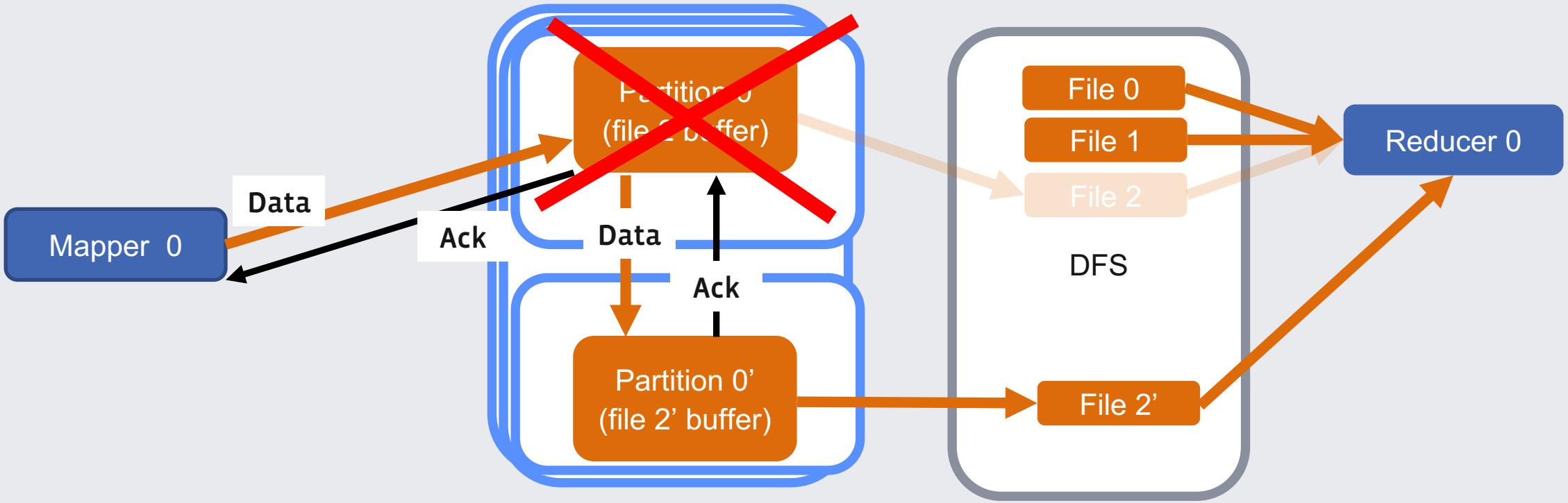


Dependency

Cosco process
(shared between apps)

Spark process
(cosco client)

Replication



```
// Driver
shuffle = new CoscoExchange(
  shuffleId: String,
  partitions: int,
  recomputeWritersCallback: (mappers: long[], reason: String) -> void);
// end of exchange
shuffle.close();
```

```
// Mapper
writer = new CoscoWriter(
  shuffleId: String,
  mapper: long);

writer.collect(
  partition: int, row: byte[]);
// ...
writer.collect(
  partition: int, row: byte[]);

writer.close();
```

```
// Reducer
reader = new CoscoReader(
  shuffleId: String,
  mappers: long[],
  partition: int);

while (reader.next()) {
  // using row
  row = reader.row();
}

reader.close();
```

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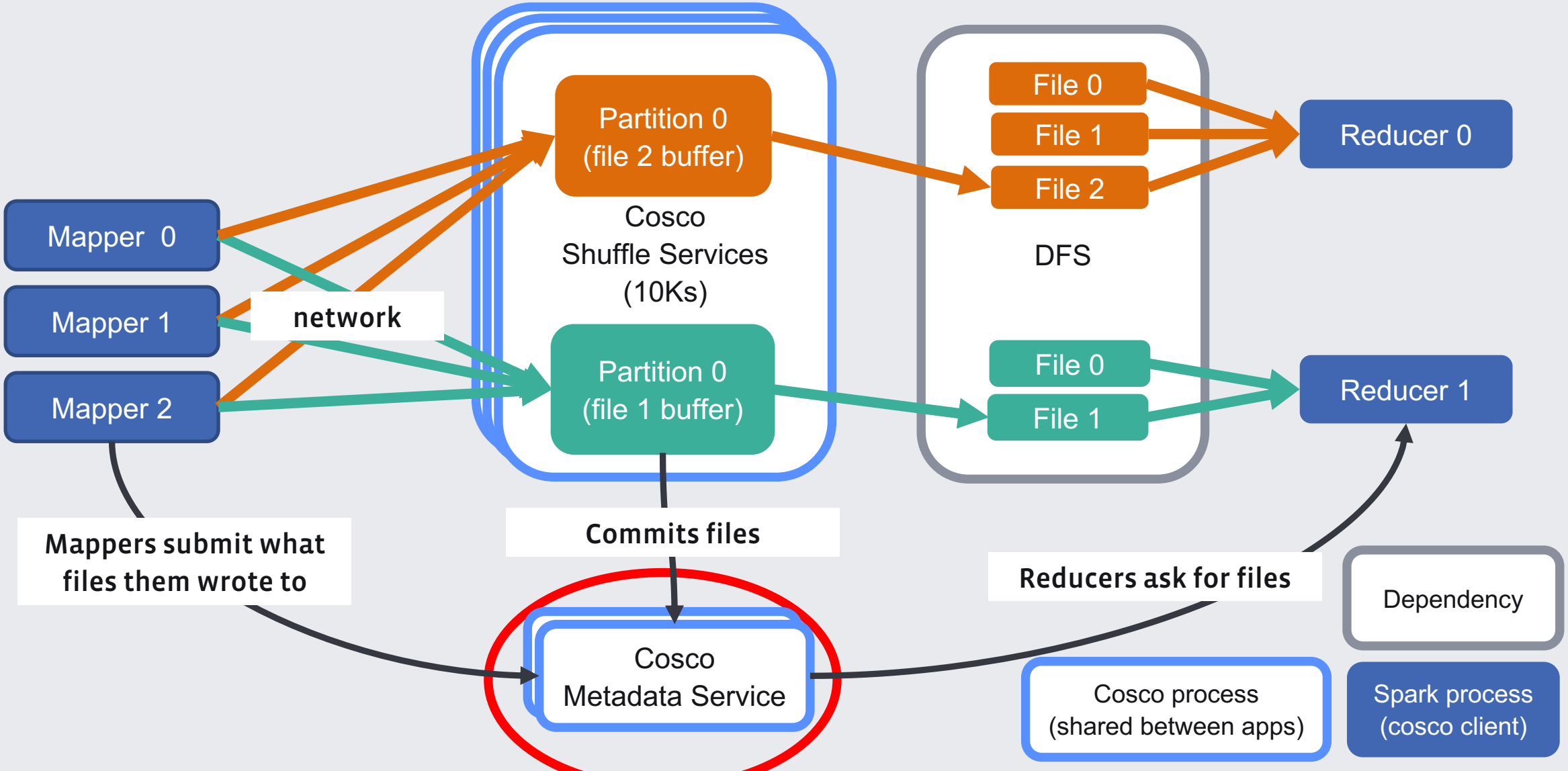
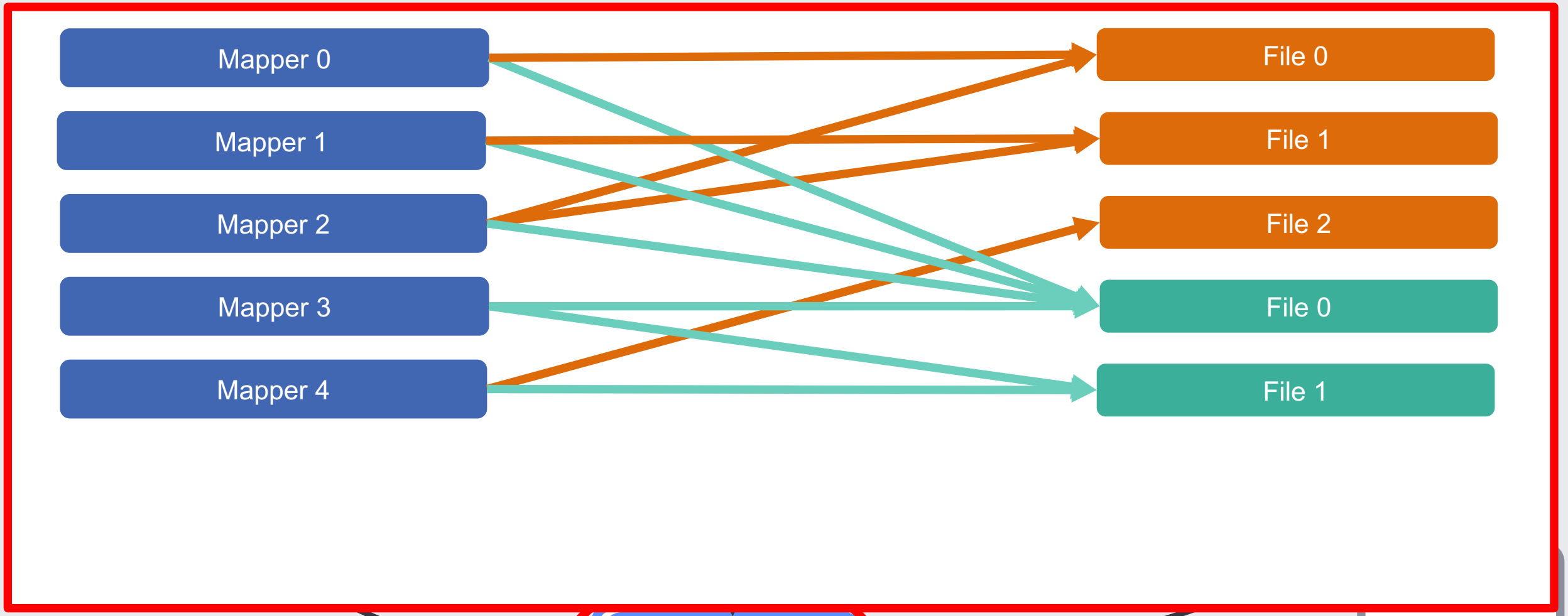

Partition 0
(file 2 buffer)
Cosco
Shuffle Services
(10Ks)
Partition 0
(file 1 buffer)
File 0
File 1
File 2
DFS
File 0
File 1
Reducer 0
Reducer 1
Mapper 0
Mapper 1
Mapper 2
network
Mappers submit what files them wrote to
Commits files
Reducers ask for files
Cosco
Metadata Service
Dependency
Cosco process
(shared between apps)
Spark process
(cosco client)

Metadata



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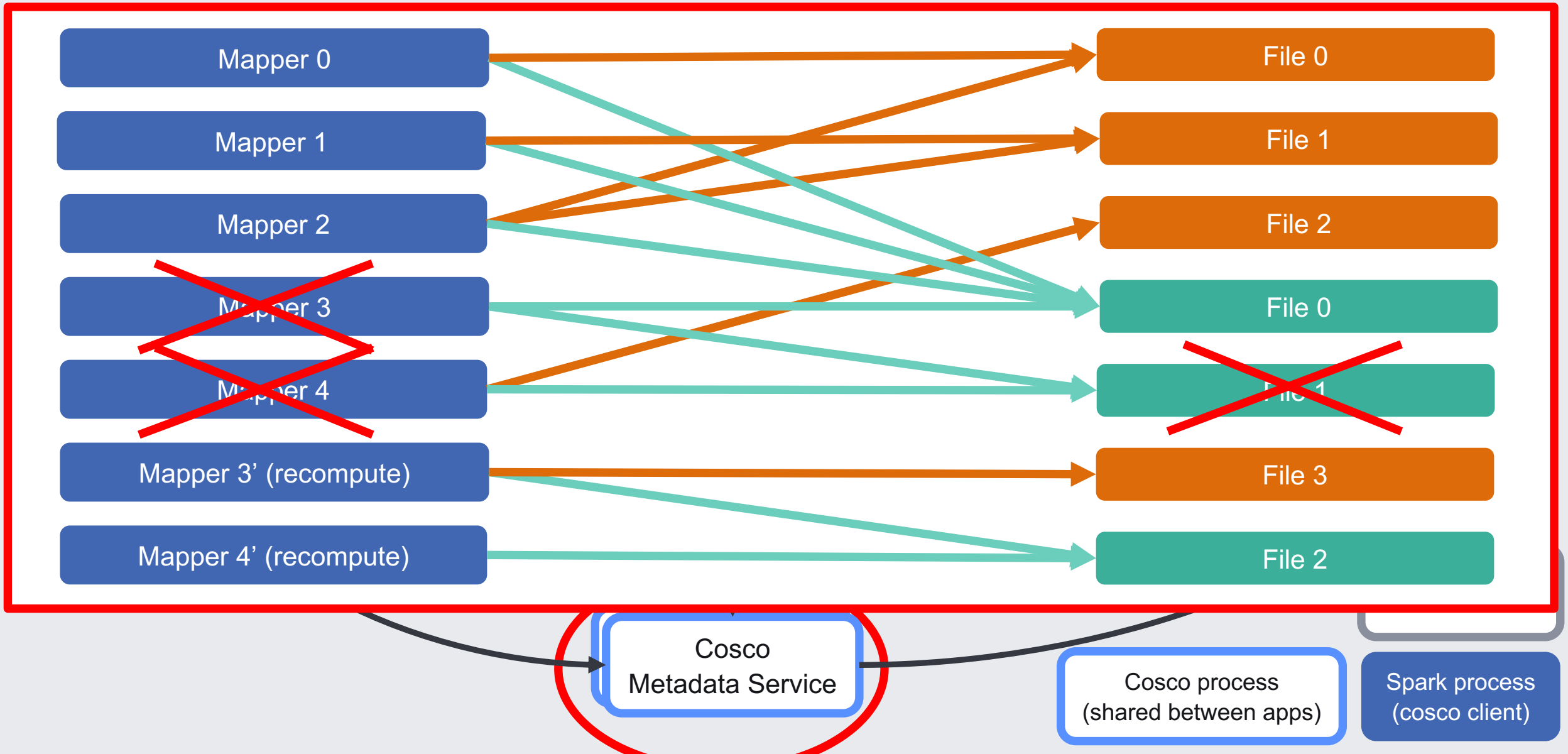
Mapper 0
Mapper 1
Mapper 2
Mapper 3
Mapper 4
Mapper 3' (recompute)
Mapper 4' (recompute)
File 0
File 1
File 2
File 0
File 1
File 3
File 2
Cosco
Metadata Service
Cosco process
(shared between apps)
Spark process
(cosco client)

```
// Driver
shuffle = new CoscoExchange(
  shuffleId: String,
  partitions: int,
  recomputeWritersCallback: (mappers: long[], reason: String) -> void);
// end of exchange
shuffle.close();
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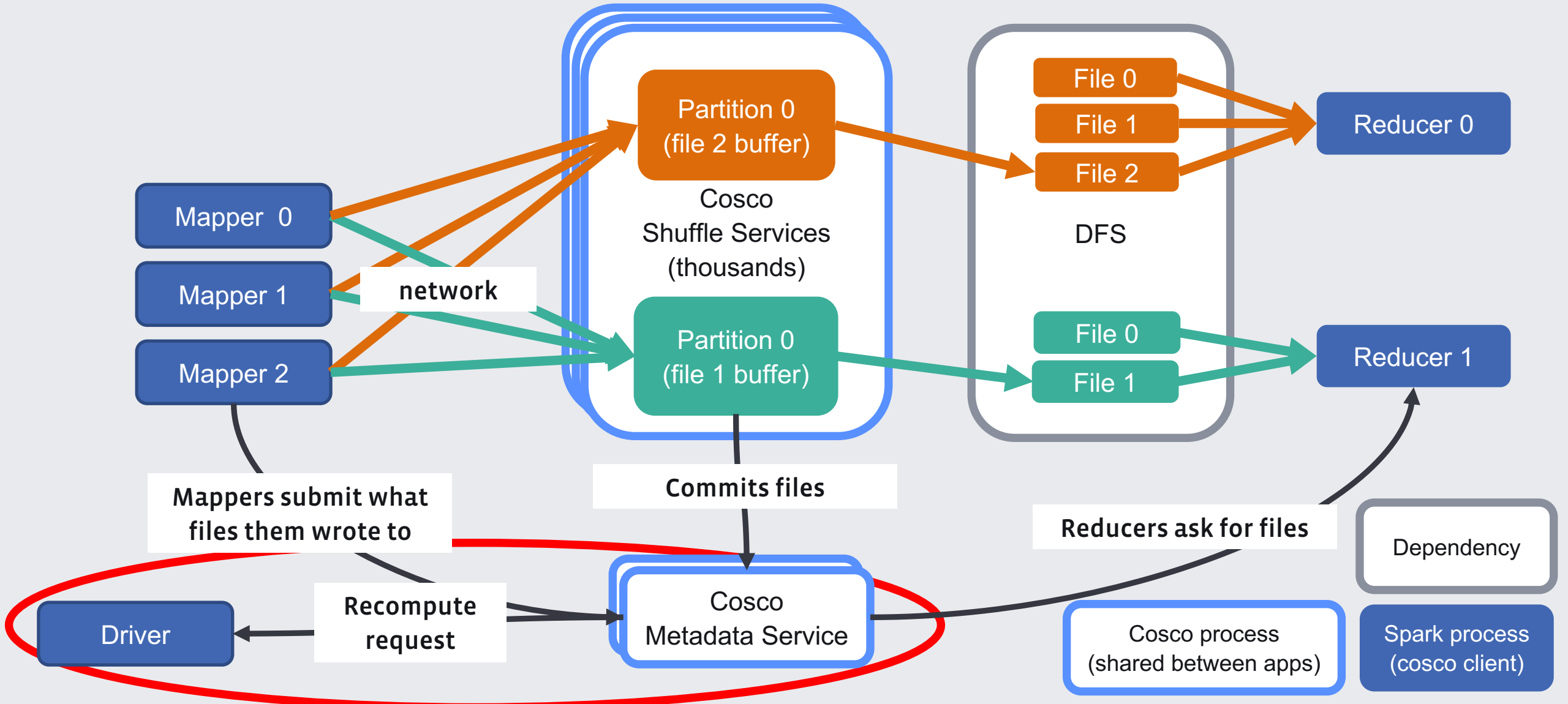
Partition 0
(file 2 buffer)
Cosco
Shuffle Services
(thousands)
Partition 0
(file 1 buffer)
File 0
File 1
File 2
DFS
File 0
File 1
Reducer 0
Reducer 1
Mapper 0
Mapper 1
Mapper 2
network
Mappers submit what files them wrote to
Commits files
Reducers ask for files
Recompute request
Driver
Cosco
Metadata Service
Dependency
Cosco process
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Spark process
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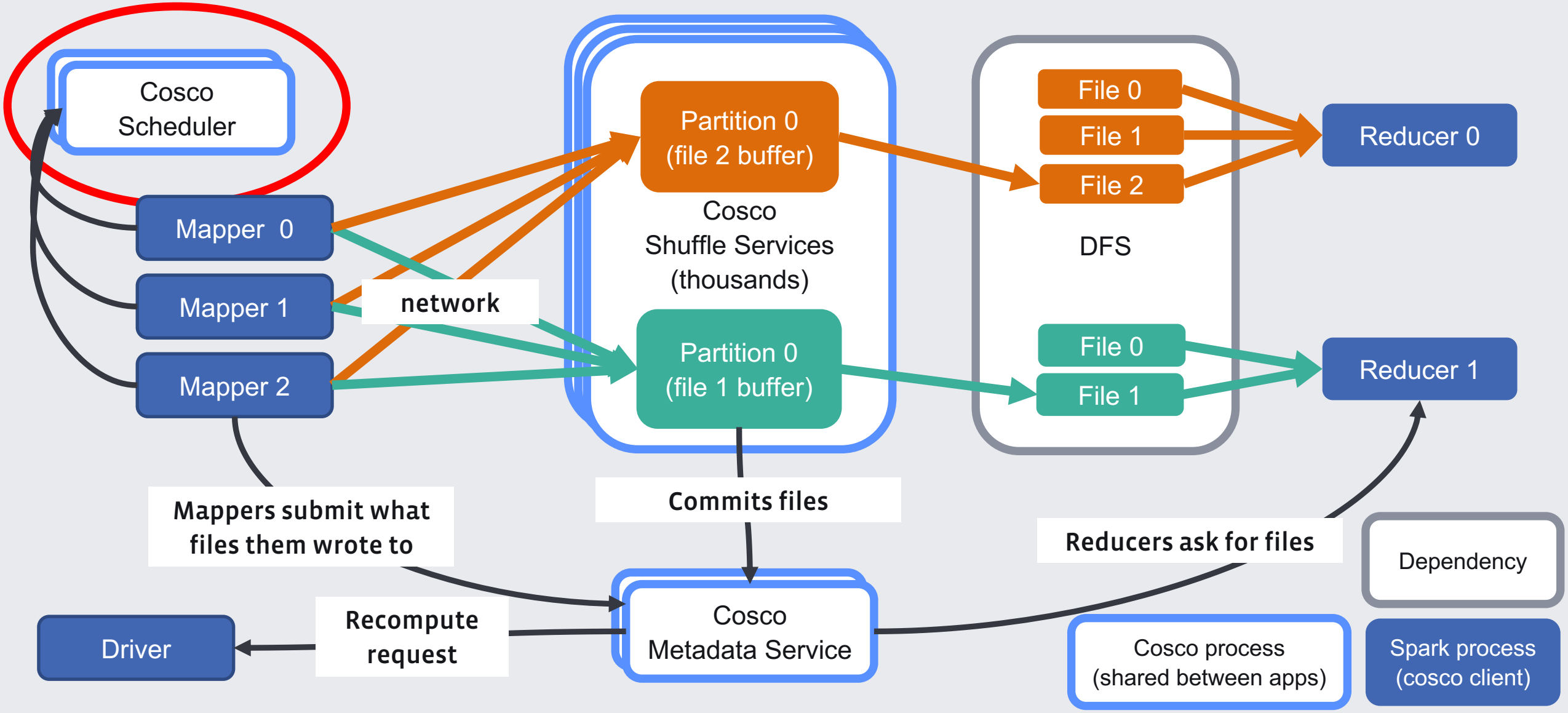
Scheduler


Cosco
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network
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(file 2 buffer)
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Shuffle Services
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Limits

- Cosco doesn’t support large rows (<4MiB)
- Capacity: shuffle services memory, number of write-ahead buffers

Future work

- “Unlimited” shuffle exchange:
  - millions of splits/partitions
  - 10s of PiBs
- Streaming

Questions?

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