Riffle: Optimized Shuffle Service for Large-Scale Data Analytics

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facebook

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Batch analytics systems are widely used

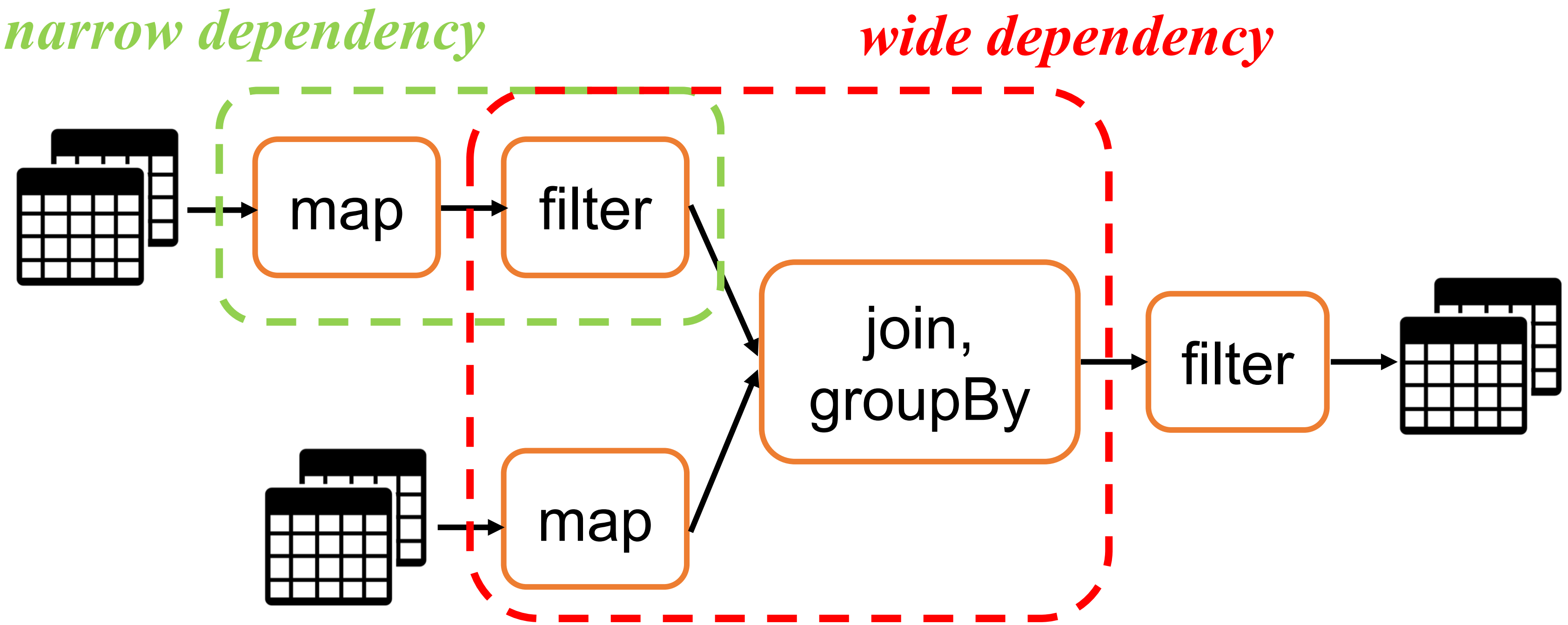
- Large-scale SQL queries
- Custom batch jobs
- Pre-/Post-processing for ML

At facebook

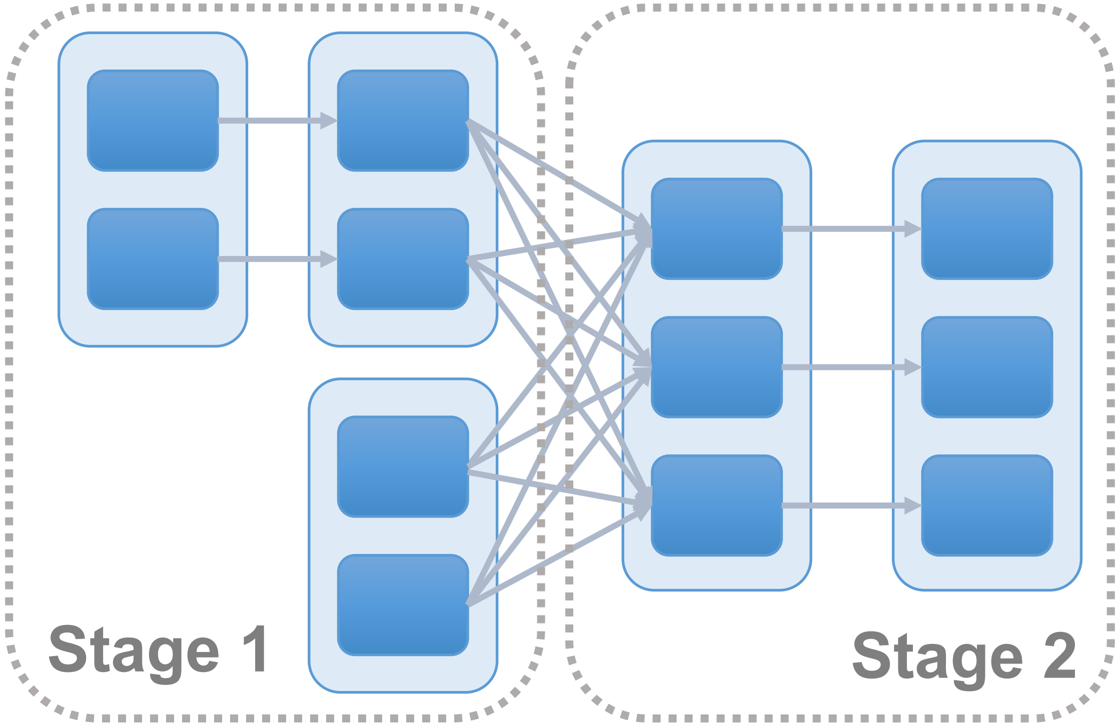
10s of PB new data is generated every day for batch processing

100s of TB data is added to be processed by a single job

Batch analytics jobs: logical graph

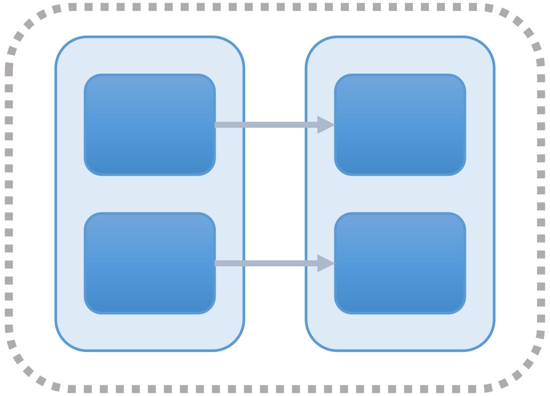


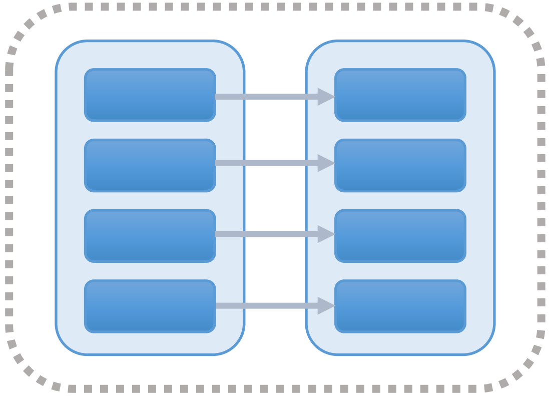
Batch analytics jobs: DAG execution plan



- Shuffle: all-to-all communication between stages
- >10x larger than available memory, strong fault tolerance requirements
  → on-disk shuffle files

The case for tiny tasks





- Benefits of slicing jobs into small tasks
  - Improve parallelism [Tinytasks HotOS 13] [Subsampling IC2E 14] [Monotask SOSP 17]
  - Improve load balancing [Sparrow SOSP 13]
  - Reduce straggler effect [Dolly NSDI 13] [SparkPerf NSDI 15]

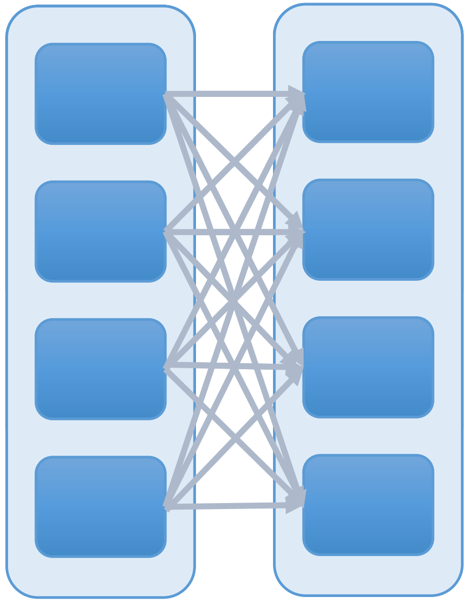
The case against tiny tasks

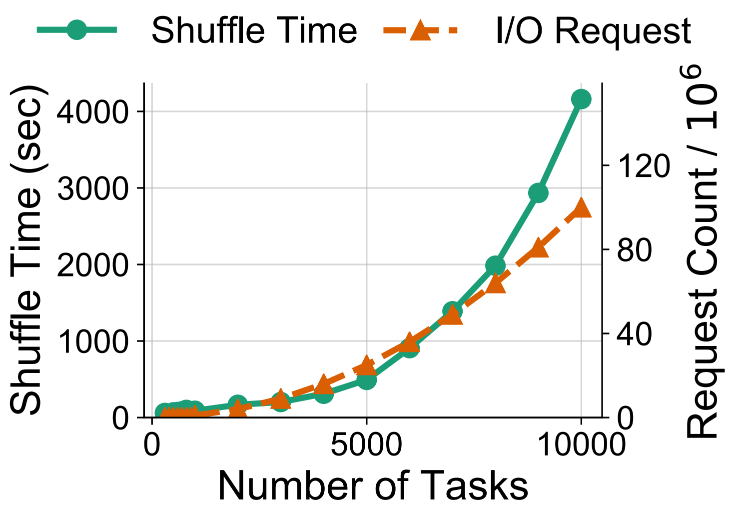
> *Although we were able to run the Spark job with such a high number of tasks, we found that there is significant performance degradation when the number of tasks is too high.*

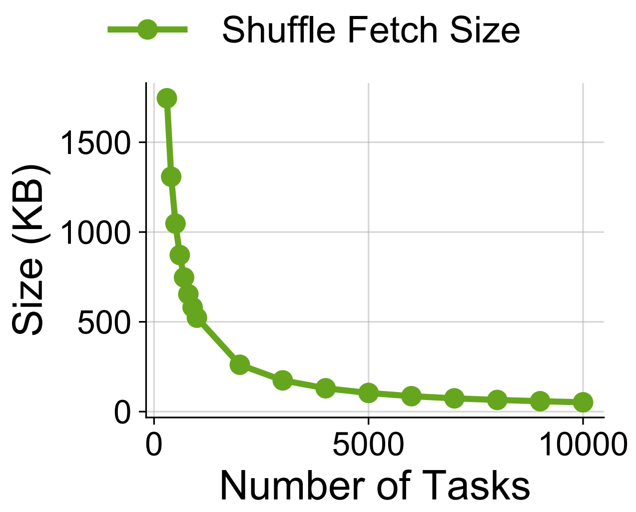
- Engineering experience often argues against running too many tasks
  - Medium scale → very large scale (10x larger than memory space)
  - Single-stage jobs → multi-stage jobs (> 50%)

[*] Apache Spark @Scale: A 60 TB+ Production Use Case. https://tinyurl.com/yadx29gl

Shuffle I/O grows *quadratically* with data

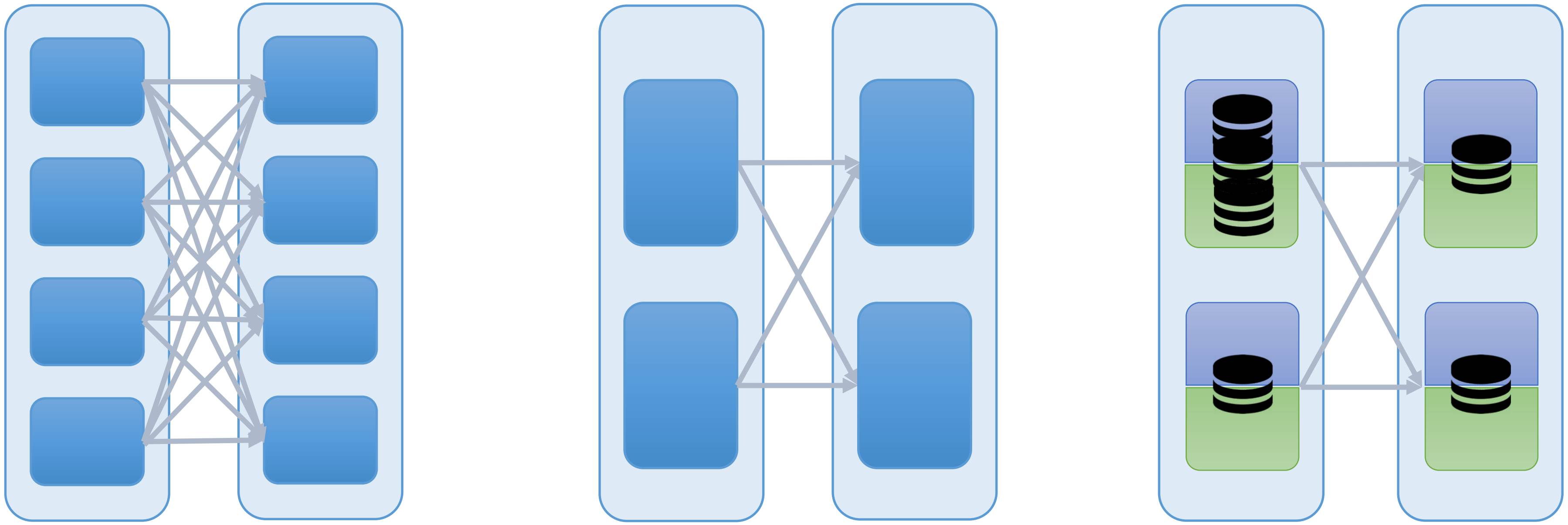






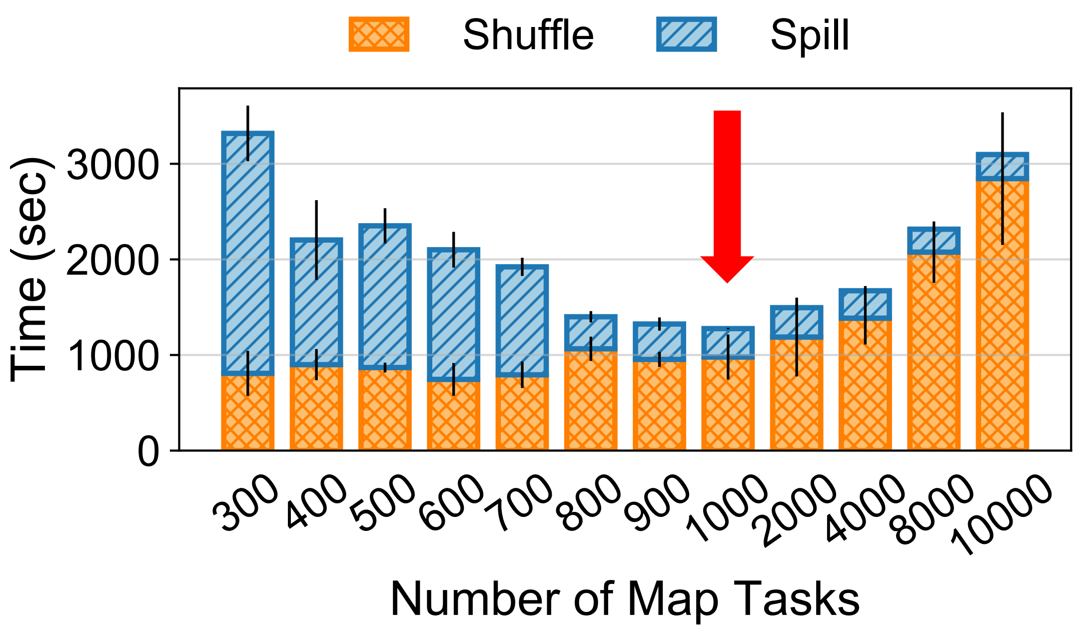
- Large amount of fragmented I/O requests
  - Adversarial workload for hard drives!

Strawman: tune number of tasks in a job

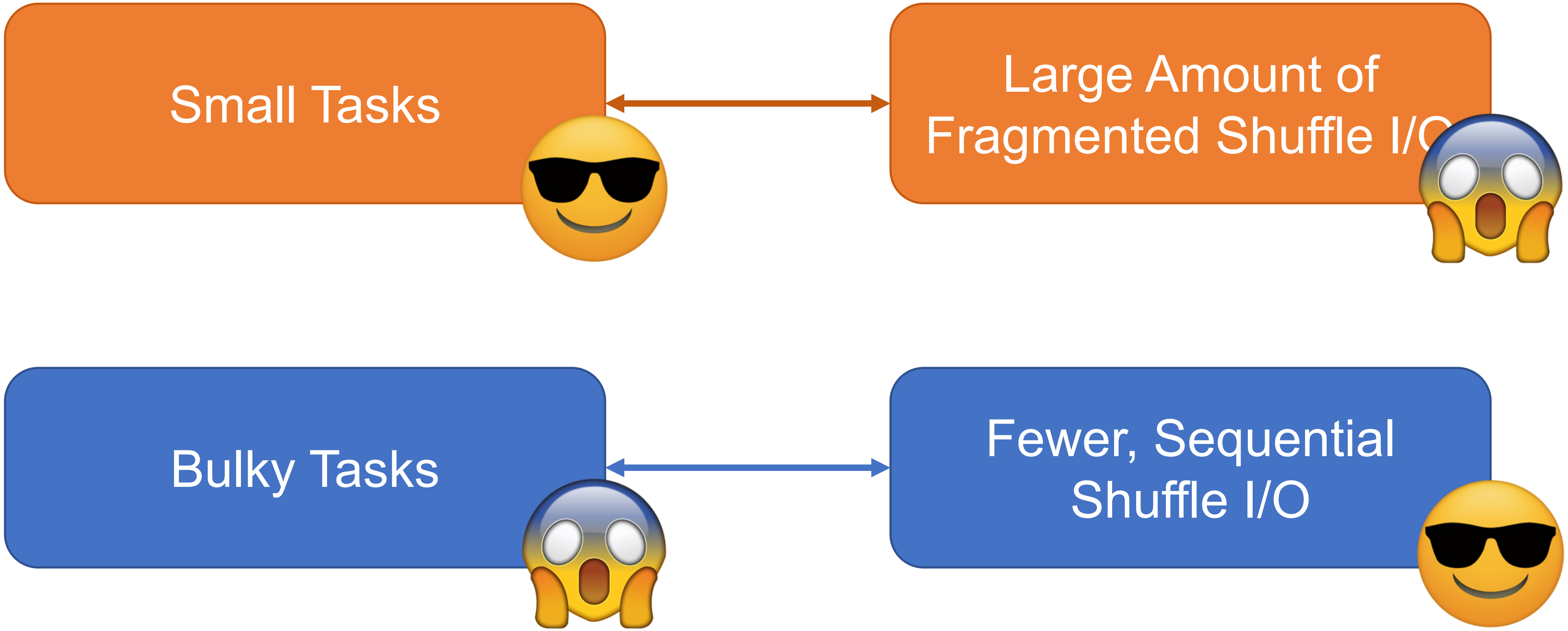


- Tasks spill intermediate data to disk if data splits exceed memory capacity
- Larger task execution reduces shuffle I/O, but increases spill I/O

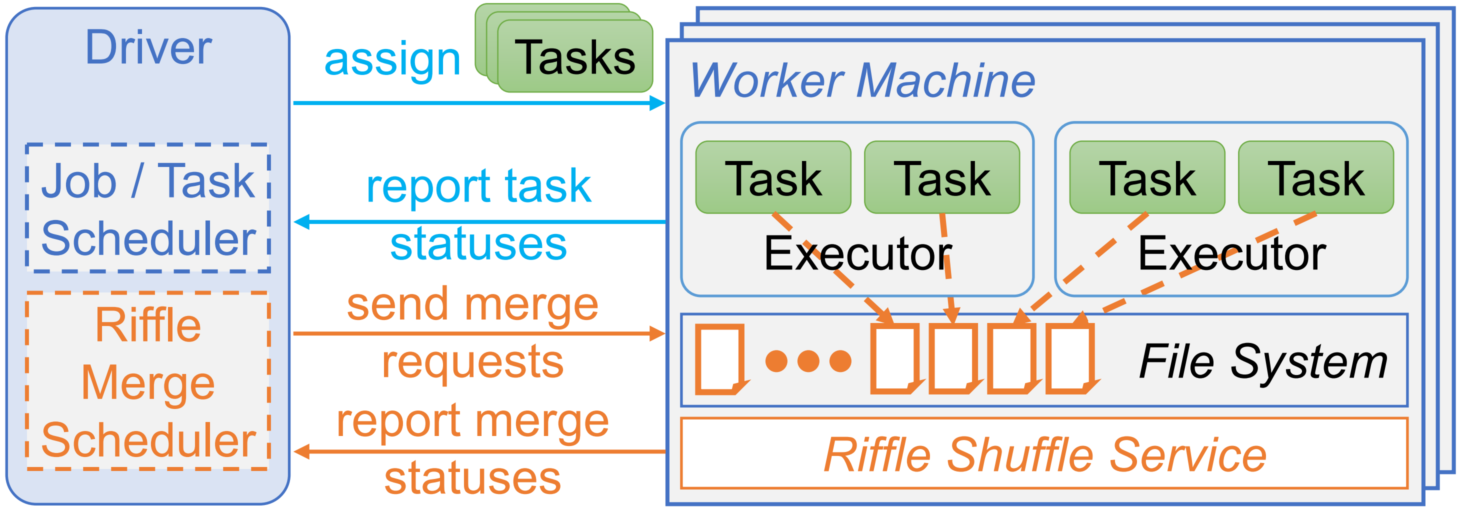
Strawman: tune number of tasks in a job



- Need to retune when input data volume changes for each individual job
- Bulky tasks can be detrimental [Dolly NSDI 13] [SparkPerf NSDI 15] [Monotask SOSP 17]
  - straggler problems, imbalanced workload, garbage collection overhead


Small Tasks
Large Amount of Fragmented Shuffle I/O
Bulky Tasks
Fewer, Sequential Shuffle I/O

Riffle: optimized shuffle service



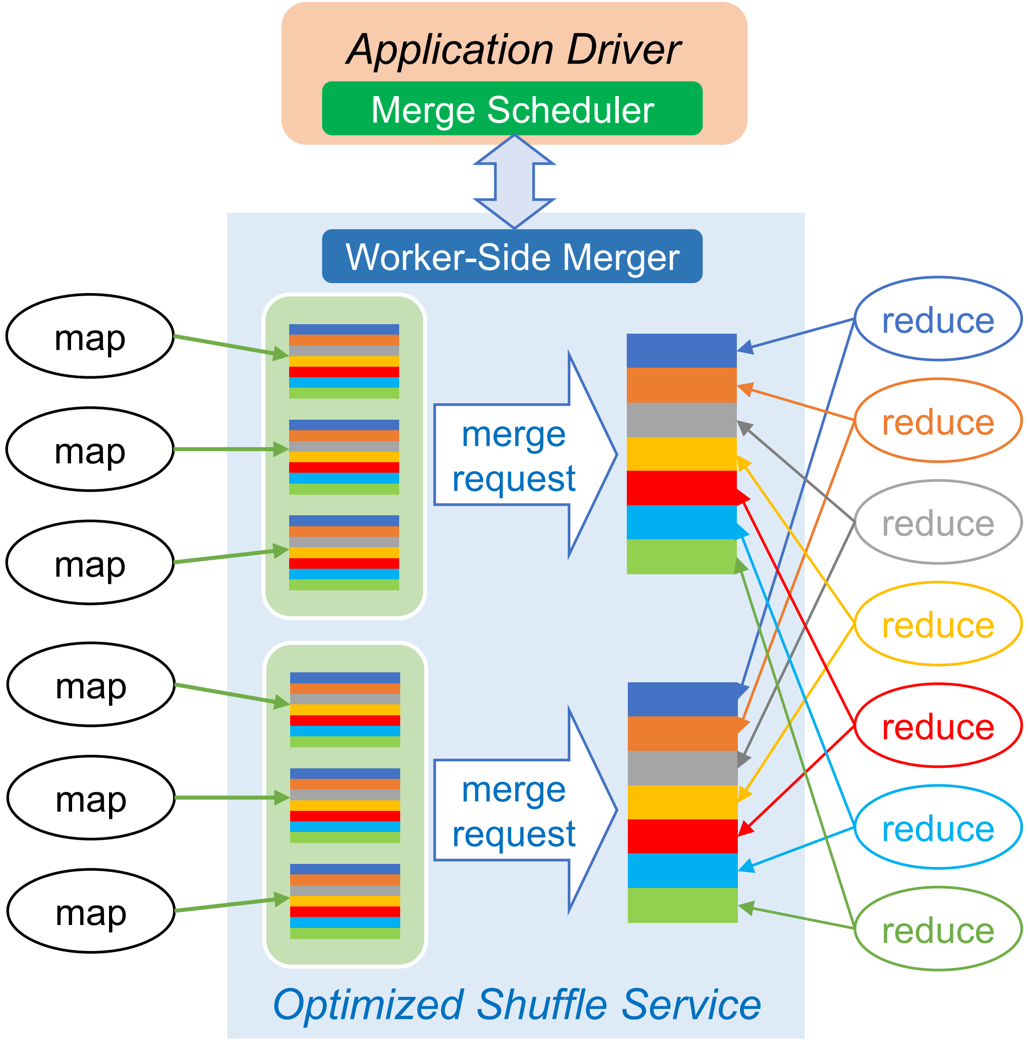
- Riffle shuffle service: a long running instance on each physical node
- Riffle scheduler: keeps track of shuffle files and issues merge requests

Riffle: optimized shuffle service

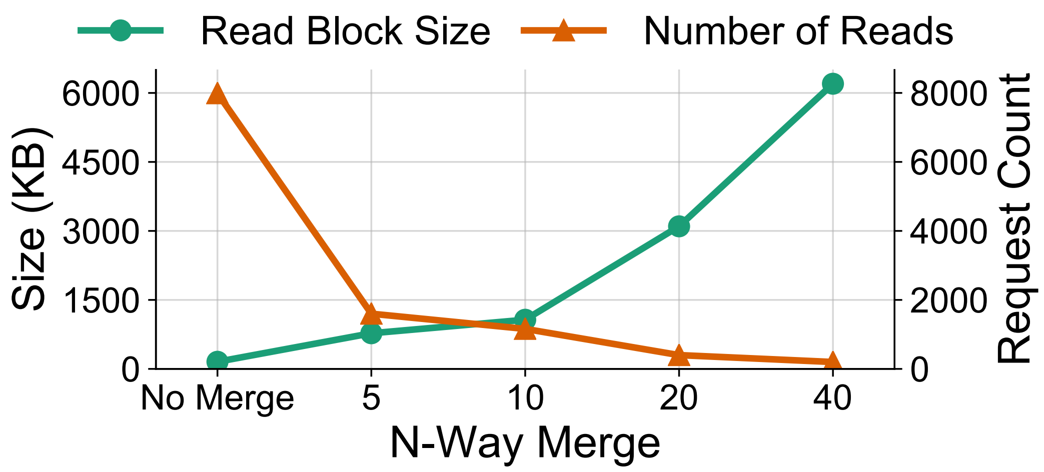
- When receiving a merge request

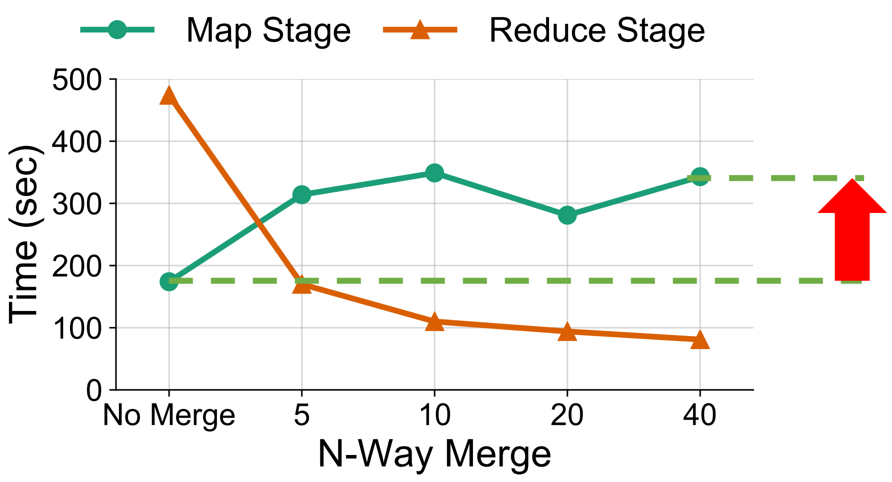
1. Combines small shuffle files into larger ones
2. Keeps original file layout

- Reducers fetch fewer, large blocks instead of many, small blocks



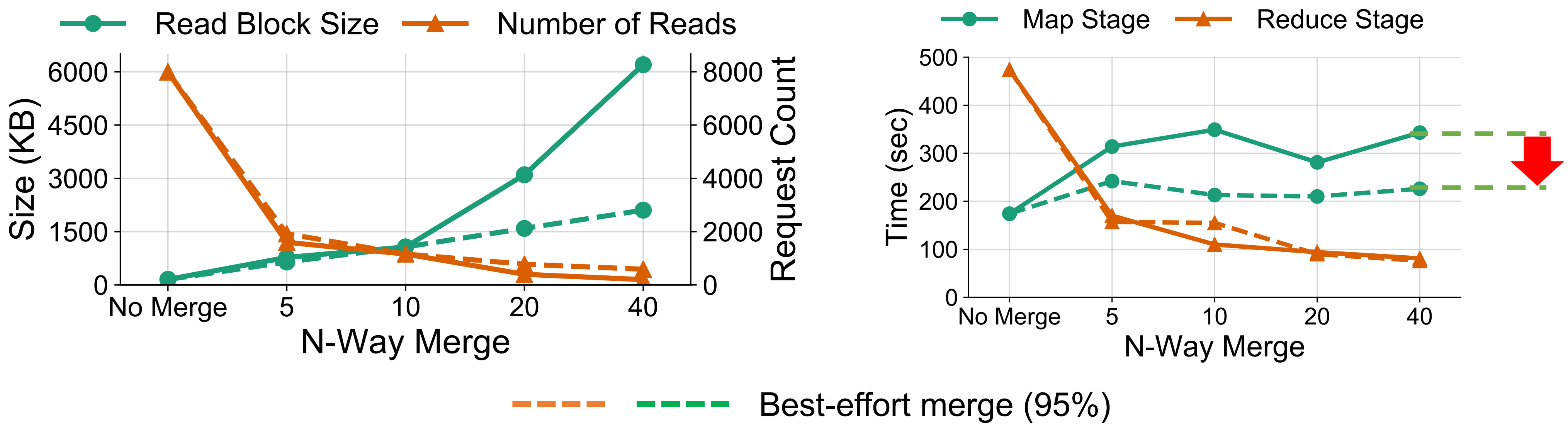
Results with merge operations on synthetic workload





- Riffle reduces number of fetch requests by 10x
- Reduce stage -393s, map stage +169s → job completes 35% faster

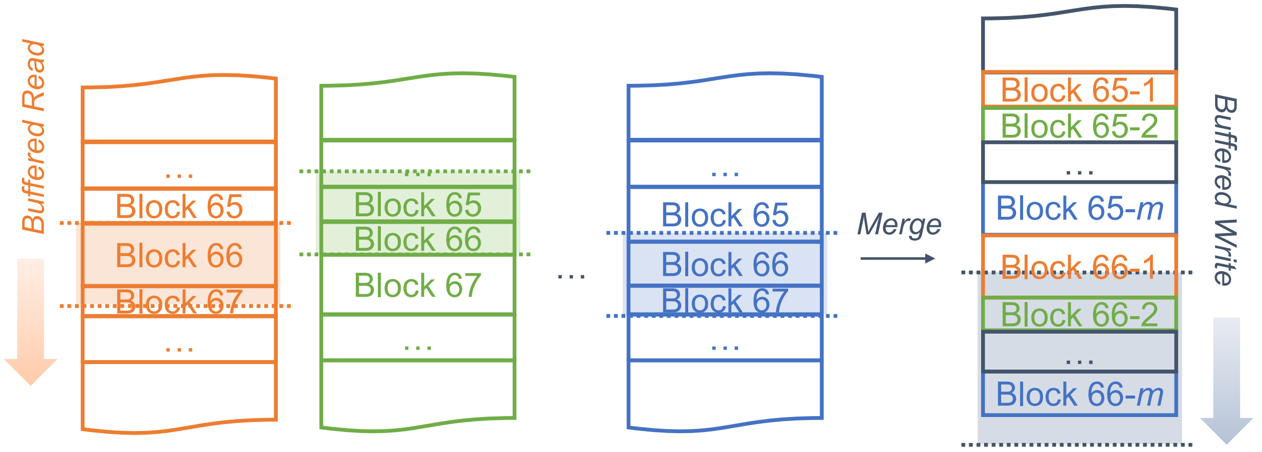
Best-effort merge: mixing merged and unmerged files

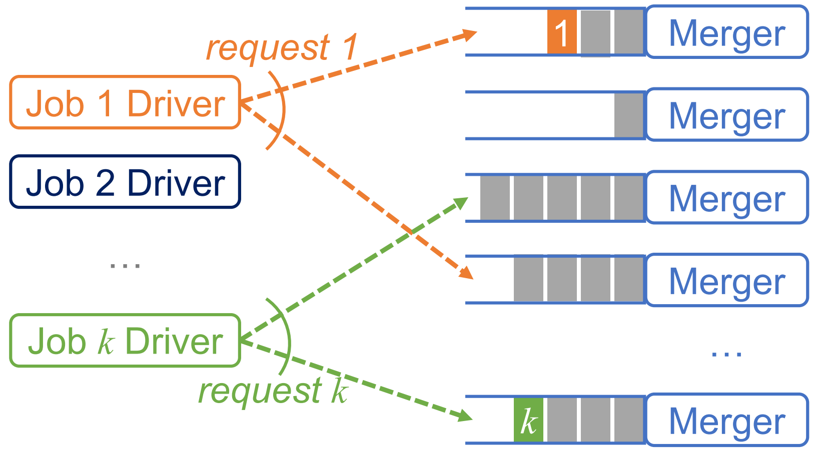


- Reduce stage -393s, map stage +52s → job completes 53% faster
  - Riffle finishes job with only ~50% of cluster resources!

Additional enhancements

- Handling merge operation failures
- Efficient memory management
- Balance merge requests in clusters





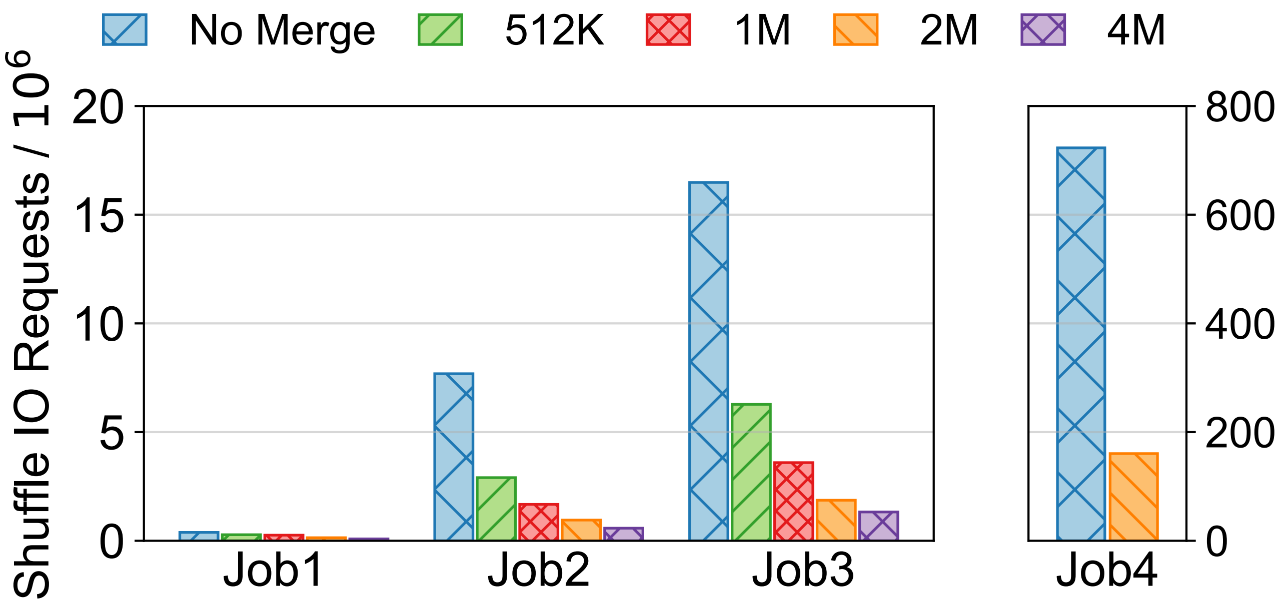
Experiment setup

- Testbed: Spark on a 100-node cluster
  - 56 CPU cores, 256GB RAM, 10Gbps Ethernet links
  - Each node runs 14 executors, each with 4 cores, 14GB RAM

- Workload: 4 representative production jobs at Facebook

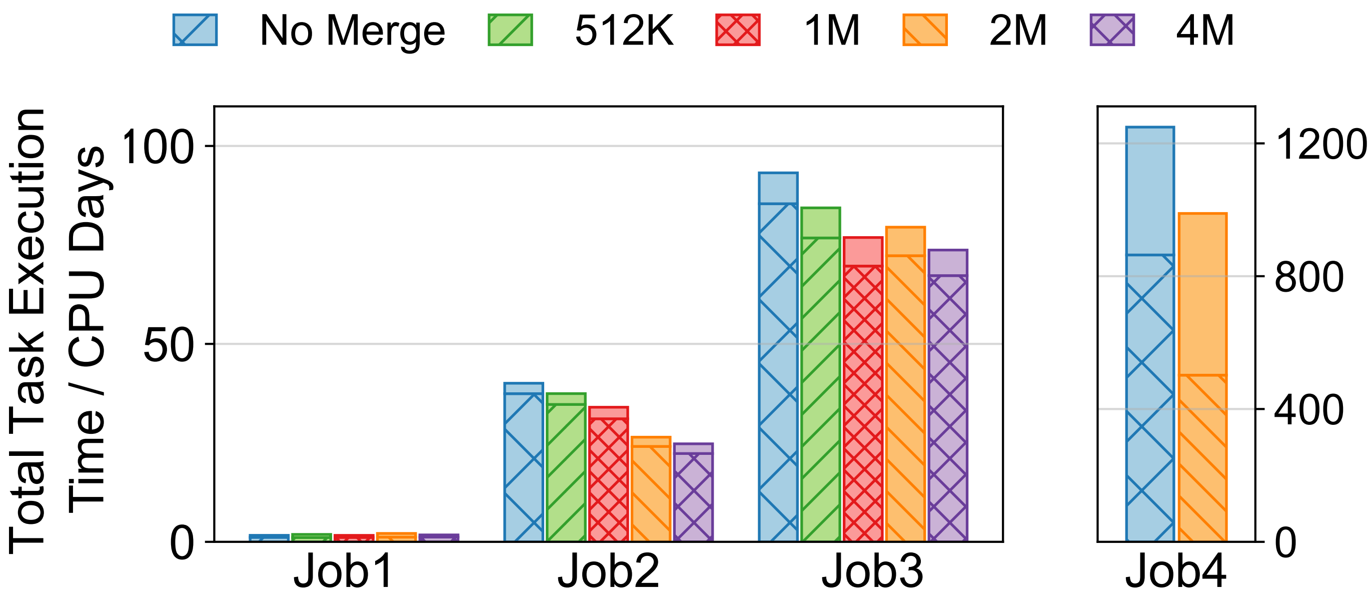
	Data	Map	Reduce	Block
1	167.6 GB	915	200	983 K
2	1.15 TB	7,040	1,438	120 K
3	2.7 TB	8,064	2,500	147 K
4	267 TB	36,145	20,011	360 K

Reduction in shuffle I/O requests



- Riffle reduces # of I/O requests by 5--10x for medium / large scale jobs

Savings in end-to-end job completion time

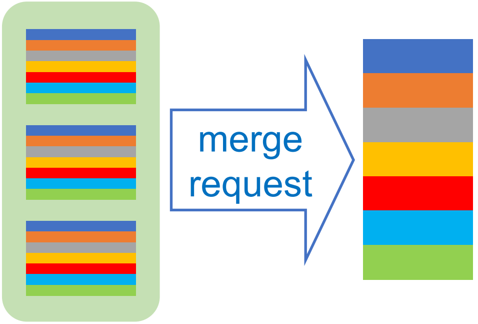


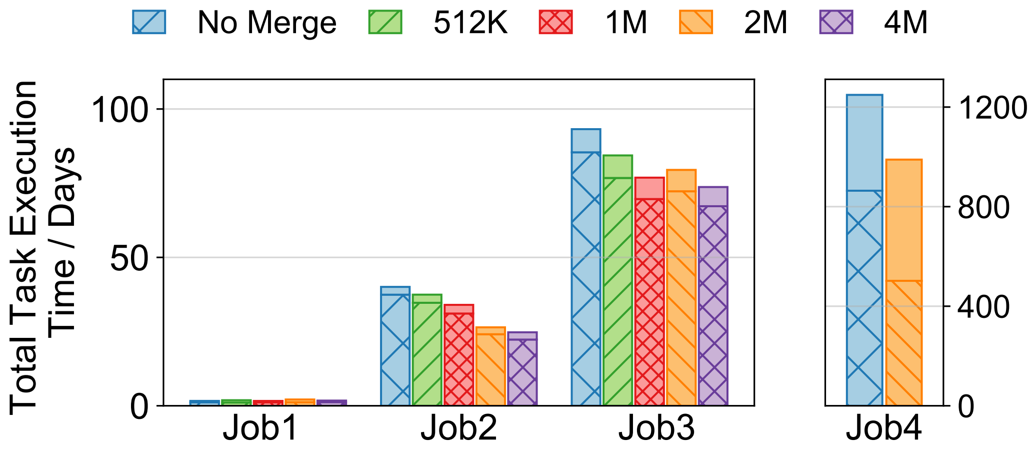
- Map stage time is almost not affected (with best-effort merge)
- Reduces job completion time by 20--40% for medium / large jobs

Conclusion

- Shuffle I/O becomes scaling bottleneck for multi-stage jobs

- Efficiently schedule merge operations, mitigate merge stragglers





- Riffle is deployed for Facebook's production jobs processing PBs of data

Thanks!

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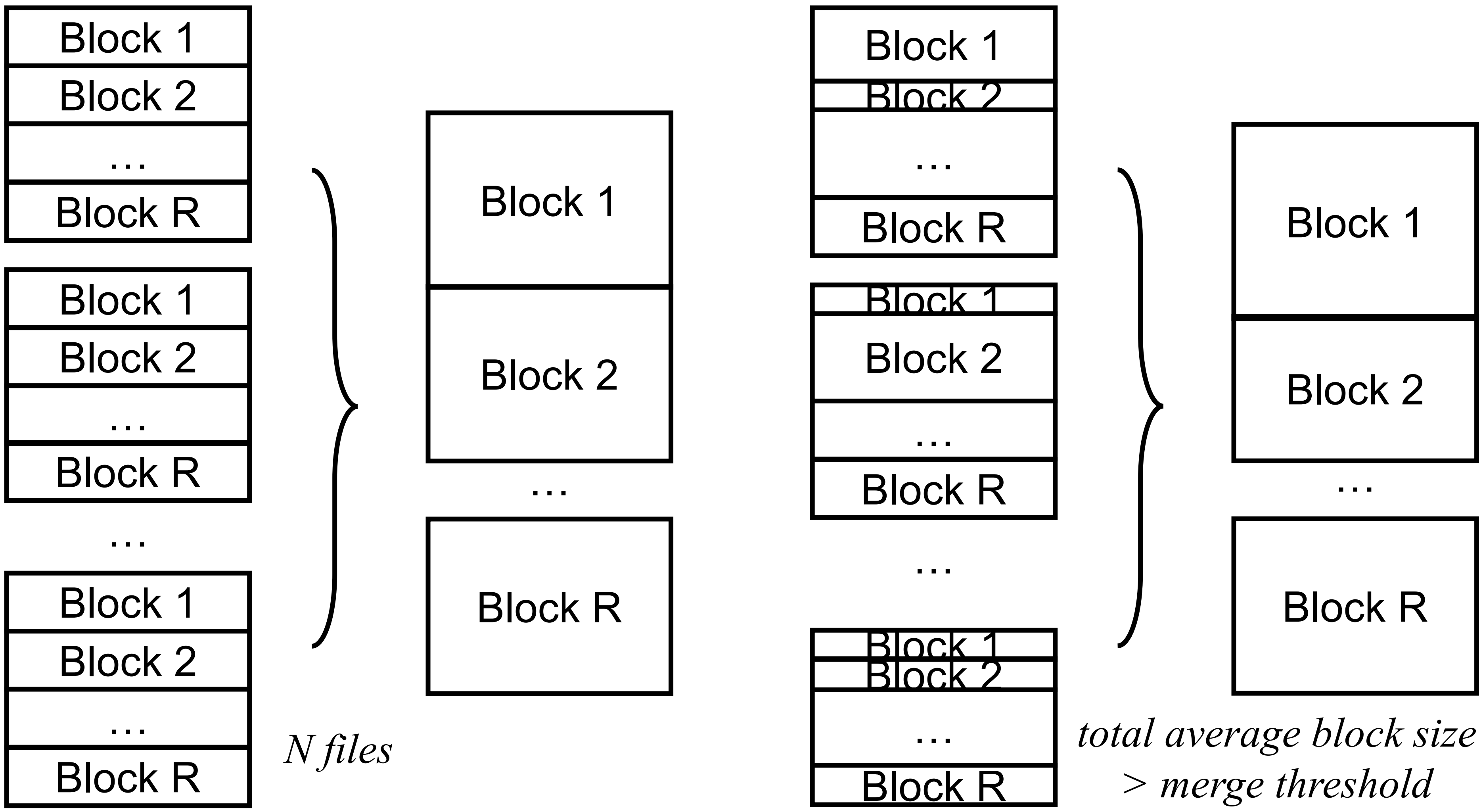
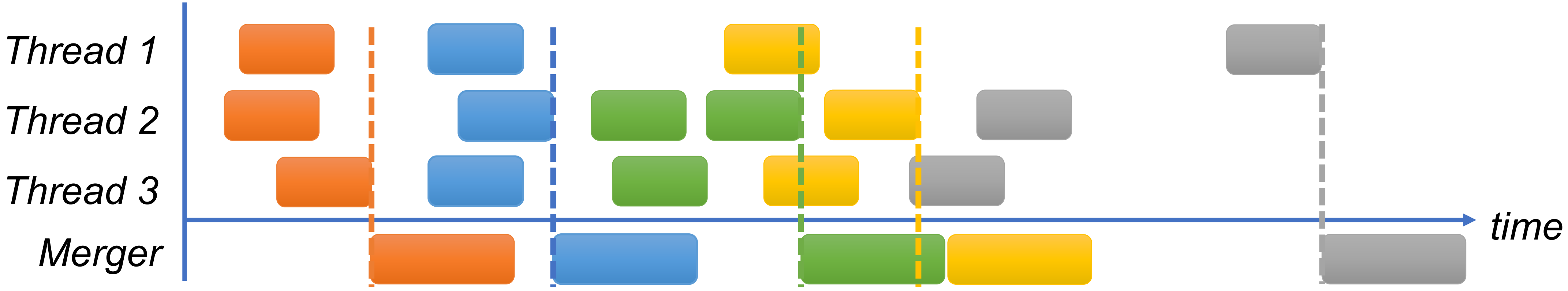
Riffle merge policies



Best-effort merge

- Observation: slowdown in map stage is mostly due to stragglers



- Best-effort merge: mixing merged and unmerged shuffle files
  - When number of finished merge requests is larger than a user specified percentage threshold, stop waiting for more merge results