AN ADAPTIVE EXECUTION ENGINE FOR APACHE SPARK SQL

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Agenda

- Challenges in Spark SQL* High Performance
- Adaptive Execution Background
- Adaptive Execution Architecture
- Benchmark Result

*Other names and brands may be claimed as the property of others.

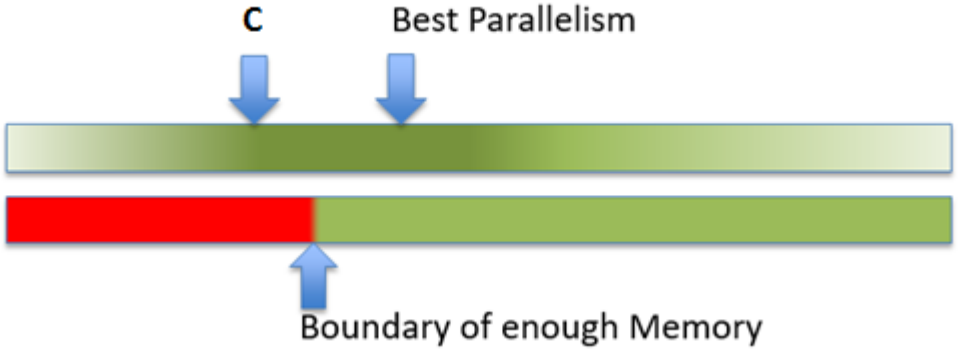
Challenges in Tuning Shuffle Partition Number

- Partition Num **P** = spark.sql.shuffle.partition (200 by default)
- Total Core Num **C** = Executor Num * Executor Core Num
- Each Reduce Stage runs the tasks in (P / C) rounds

Shuffle Partition Challenge 1

- Partition Num Too Small：Spill, OOM
- Partition Num Too Large：Scheduling overhead. More IO requests. Too many small output files
- Tuning method: Increase partition number starting from C, 2C, … until performance begin to drop

  Impractical for each query in production.

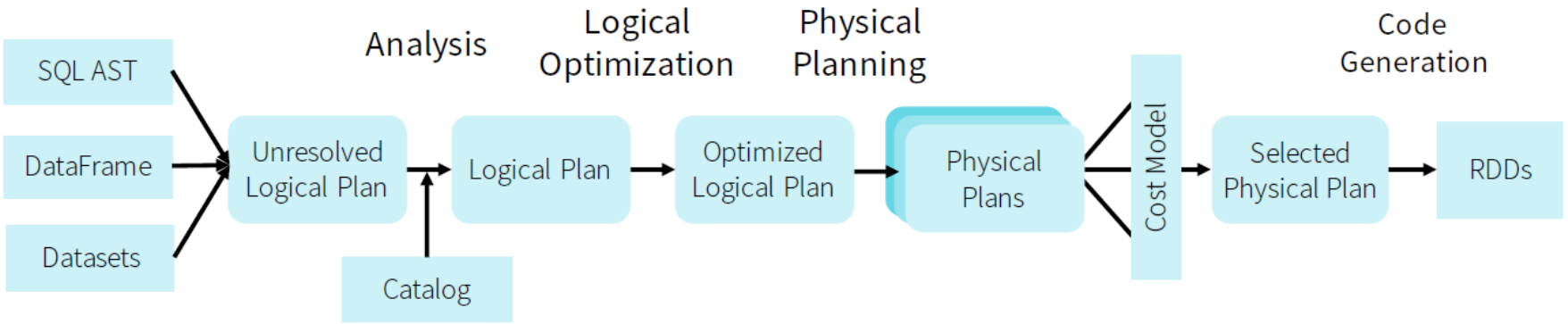


Shuffle Partition Challenge 2

- The same Shuffle Partition number doesn't fit for all Stages
- Shuffle data size usually decreases during the execution of the SQL query

Question: Can we set the shuffle partition number for each stage automatically?

Spark SQL* Execution Plan



- The execution plan is fixed after planning phase.

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Image from: https://databricks.com/blog/2015/03/24/spark-sql-graduates-from-alpha-in-spark-1-3.html

Spark SQL* Join Selection

```
SELECT xxx

FROM A

JOIN B

ON A.Key1 = B.Key2
```

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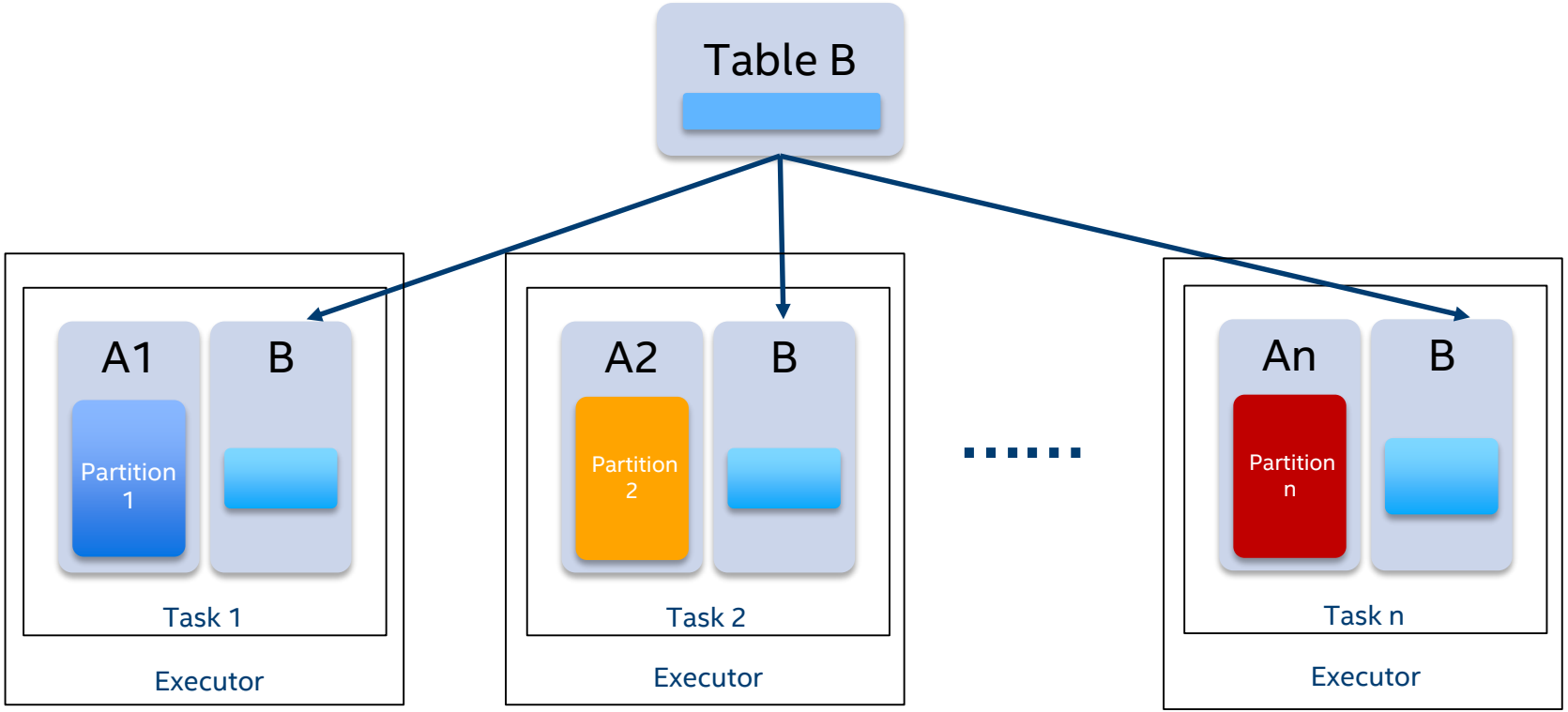
Broadcast Hash Join

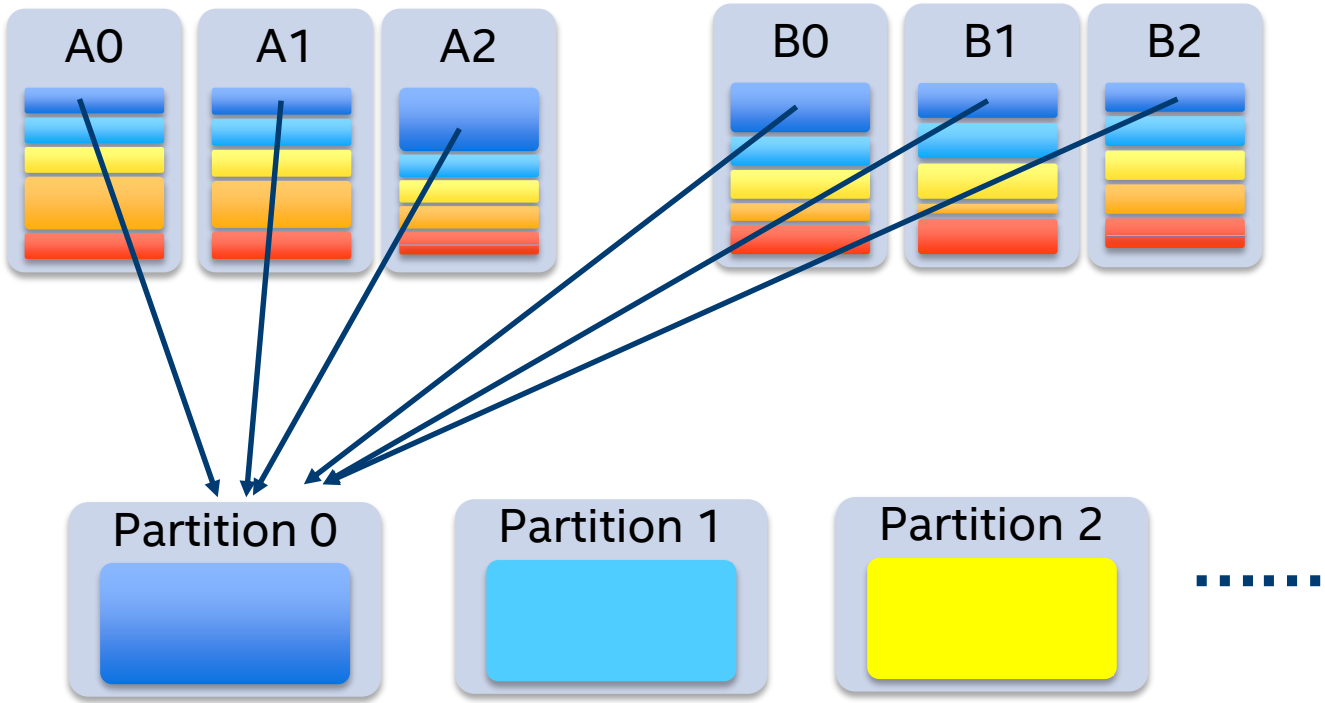


Shuffle Hash Join / Sort Merge Join

MAP

SHUFFLE

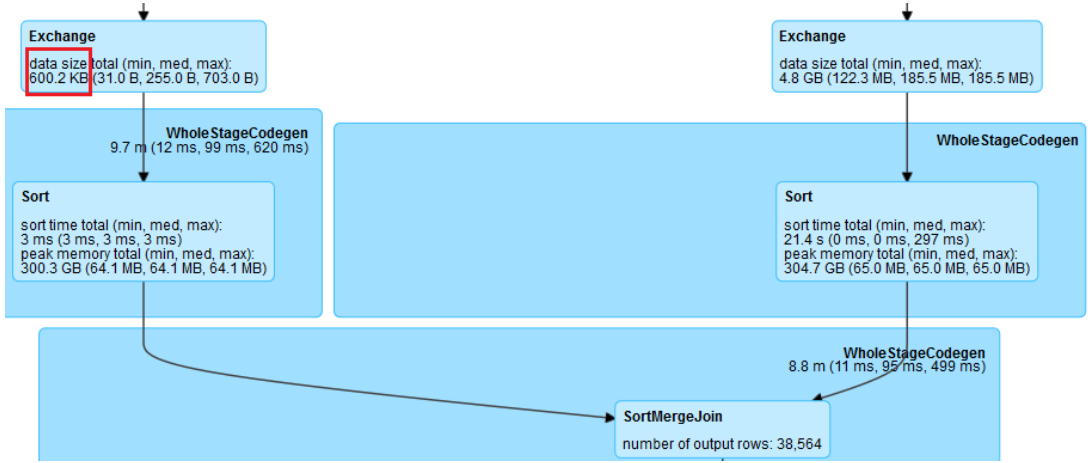
REDUCE



Spark SQL* Join Selection

- spark.sql.autoBroadcastJoinThreshold is 10 MB by default

- For complex queries, a Join may takes intermediate results as inputs. At planning phase, Spark SQL* doesn't know the exact size and plans it to SortMergeJoin.



Question: Can we optimize the execution plan at runtime based on the runtime statistics ?

Data Skew in Join

- Data in some partitions are extremely larger than other partitions.
- Data skew is a common source of slowness for Shuffle Joins.

Summary Metrics for 5600 Completed Tasks

Metric	Min	25th percentile	Median	75th percentile	Max
Duration	15 ms	2 s	3 s	5 s	4.0 min
Scheduler Delay	0 ms	2 ms	2 ms	3 ms	1 s
Task Deserialization Time	3 ms	5 ms	6 ms	7 ms	0.4 s
GC Time	0 ms	0 ms	0.2 s	0.3 s	35 s
Result Serialization Time	0 ms	0 ms	0 ms	0 ms	3 ms
Getting Result Time	0 ms	0 ms	0 ms	0 ms	0 ms
Peak Execution Memory	0.0 B	0.0 B	0.0 B	0.0 B	0.0 B
Shuffle Read Blocked Time	0 ms	44 ms	0.2 s	0.6 s	31 s
Shuffle Read Size / Records	0.0 B / 0	3.5 MB / 374415	4.9 MB / 747052	6.9 MB / 1783859	172.8 MB / 283732661
Shuffle Remote Reads	0.0 B	3.4 MB	4.7 MB	6.6 MB	166.6 MB
Shuffle Write Size / Records	0.0 B / 0	109.0 B / 3	132.0 B / 4	158.0 B / 6	262.0 B / 13
Shuffle spill (memory)	0.0 B	0.0 B	0.0 B	0.0 B	13.3 GB
Shuffle spill (disk)	0.0 B	0.0 B	0.0 B	0.0 B	68.2 MB

Ways to Handle Skewed Join nowadays

- Increase shuffle partition number
- Increase BroadcastJoin threashold to change Shuffle Join to Broadcast Join
- Add prefix to the skewed keys
- ……

Question 3: These involve many manual efforts and are limitted. Can we handle skewed join at runtime automatically?

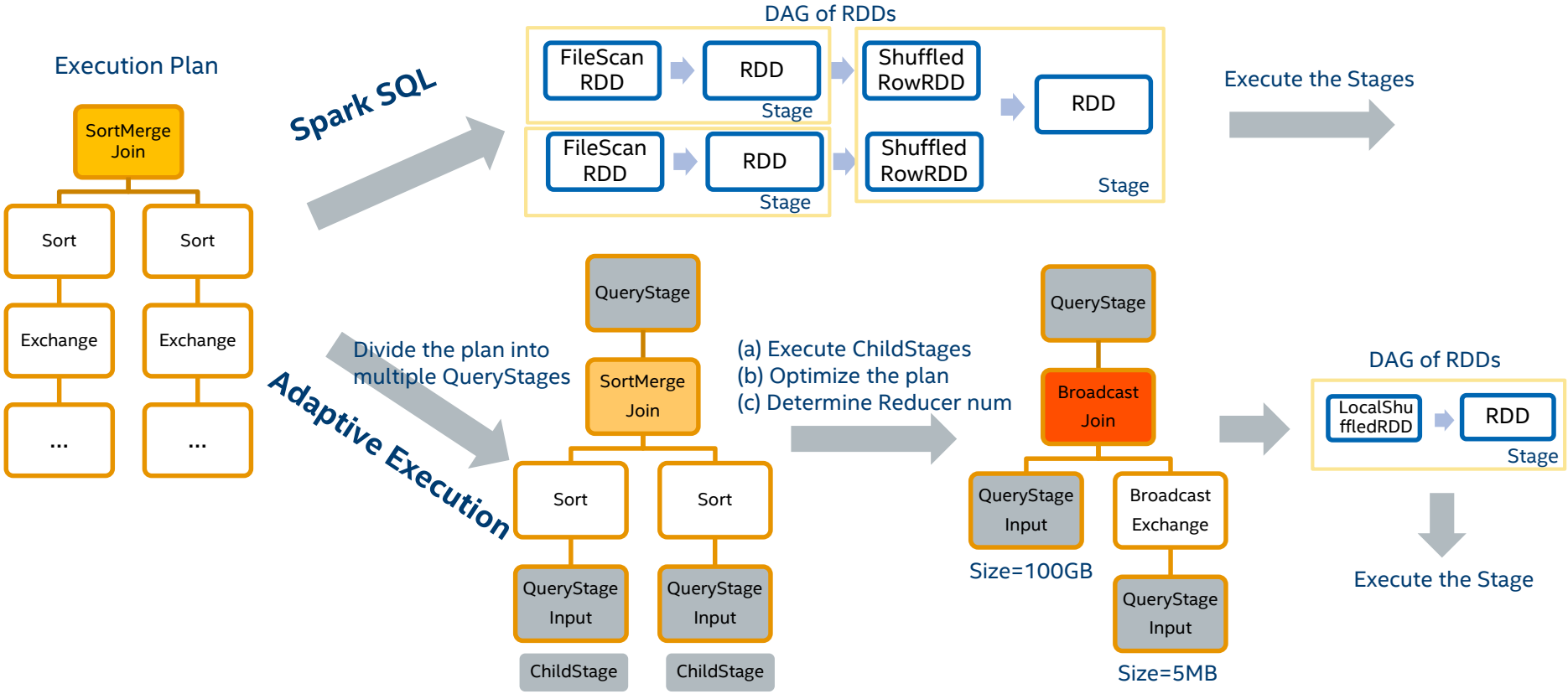
Adaptive Execution Background

- SPARK-9850: Adaptive execution in Spark*
- SPARK-9851: Support submitting map stages individually in DAGScheduler
- SPARK-9858: Introduce an ExchangeCoordinator to estimate the number of post-shuffle partitions.

A New Adaptive Execution Engine in Spark SQL*

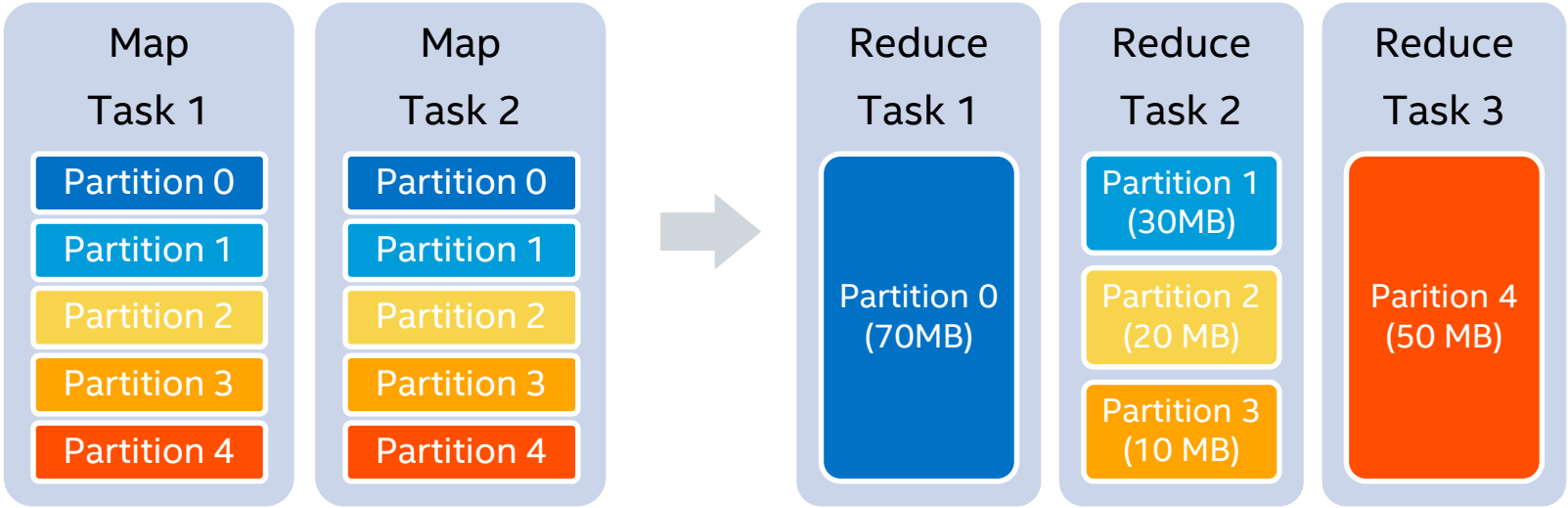
*Other names and brands may be claimed as the property of others.

Adaptive Execution Architecture



Auto Setting the Number of Reducers

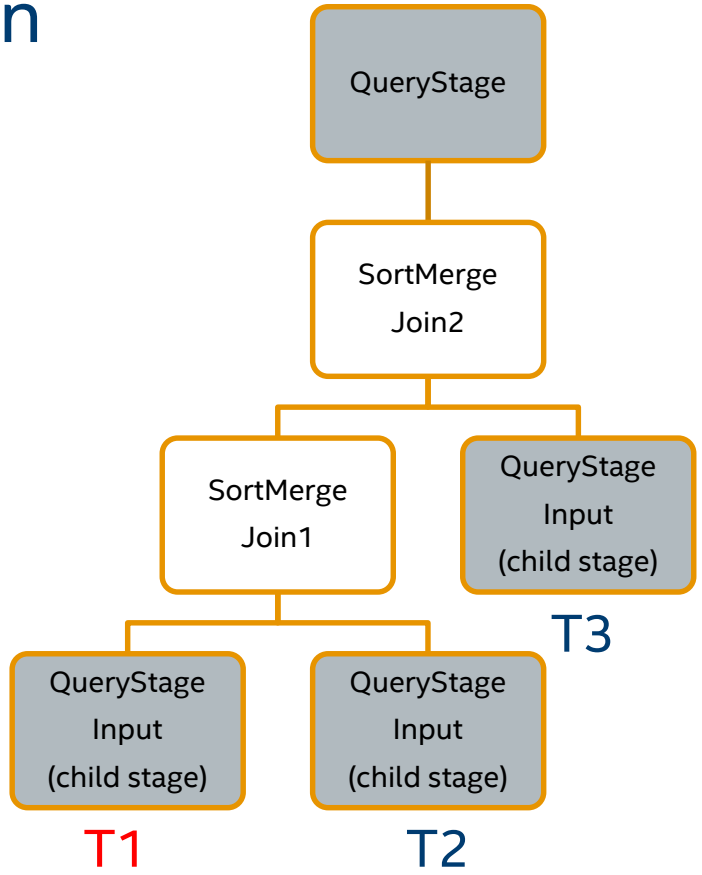
- 5 initial reducer partitions with size
  [70 MB, 30 MB, 20 MB, 10 MB, 50 MB]
- Set target size per reducer = 64 MB. At runtime, we use 3 actual reducers.
- Also support setting target row count per reducer.



Shuffle Join => Broadcast Join Example 1

- T1 < broadcast threshold
- T2 and T3 > broadcast threshold

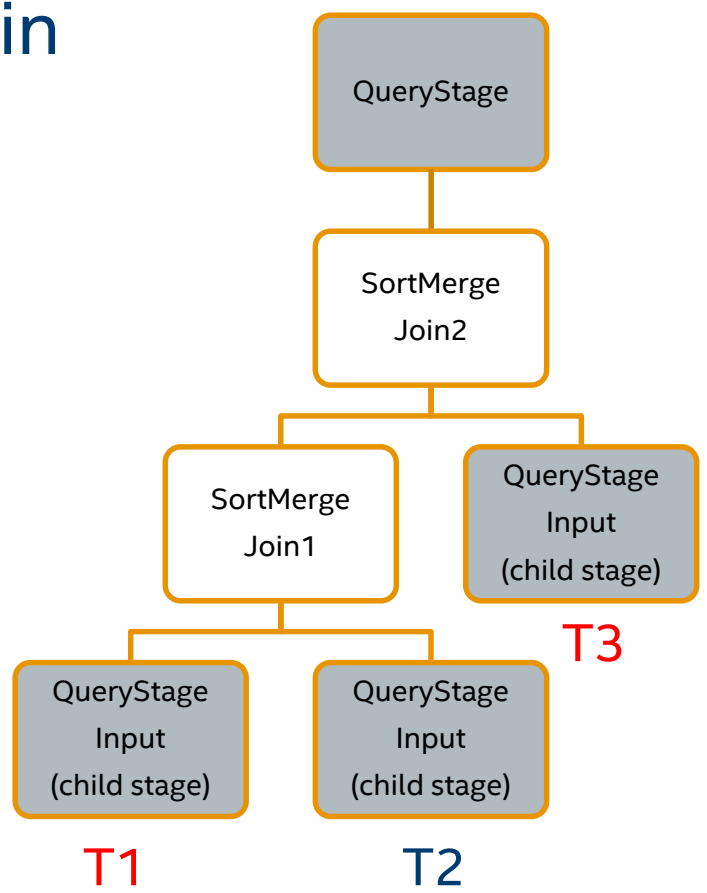
- In this case, both Join1 and Join2 are not changed to broadcast join



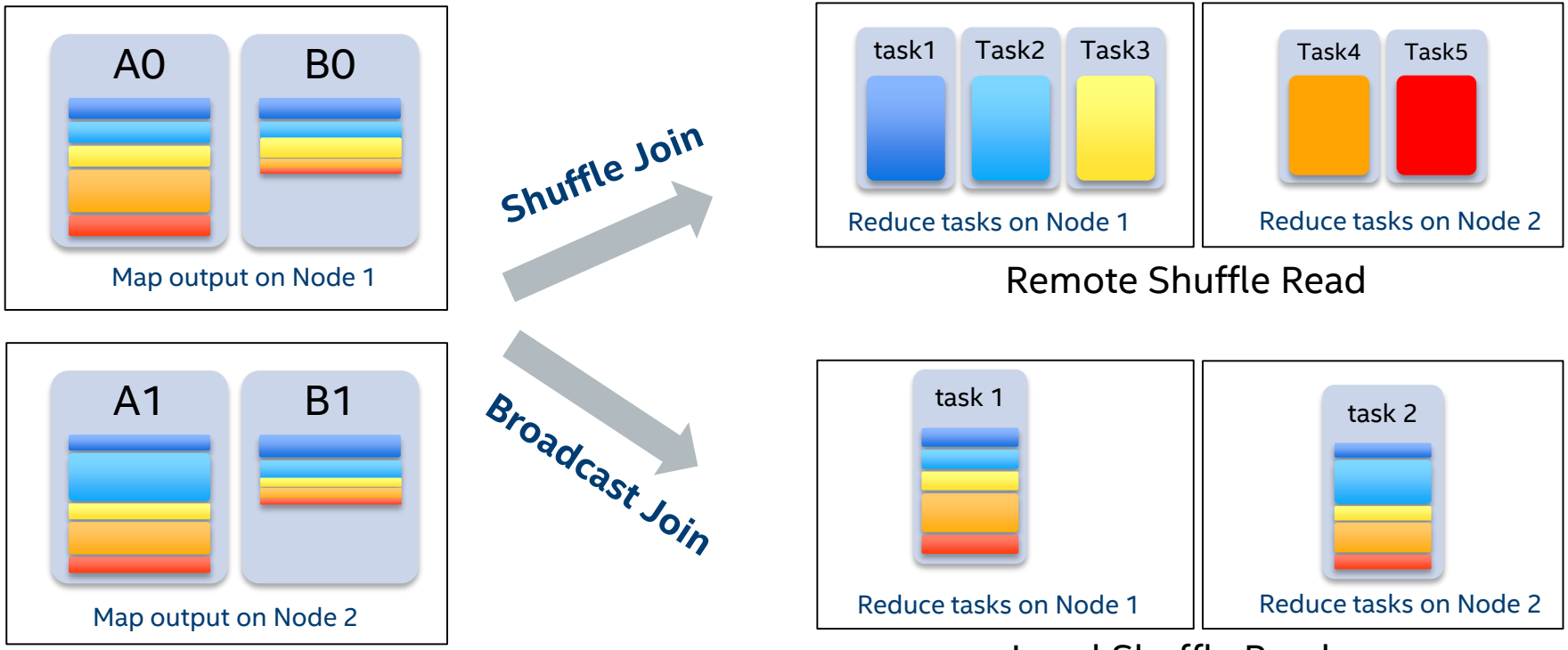
Shuffle Join => Broadcast Join Example 2

- T1 and T3 < broadcast threshold
- T2 > broadcast threshold

- In this case, both Join1 and Join2 are changed to broadcast join



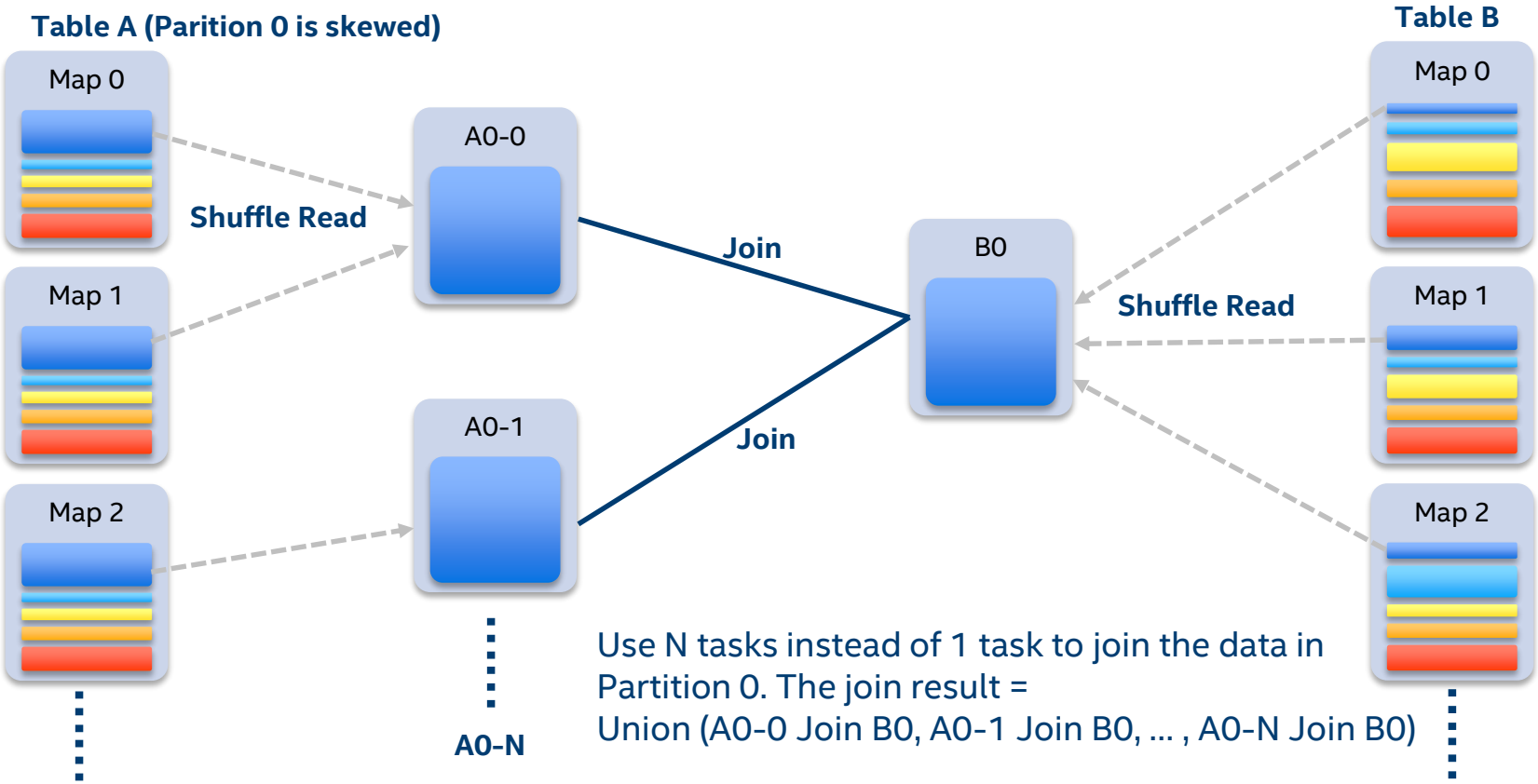
Remote Shuffle Read => Local Shuffle Read



Skewed Partition Detection at Runtime

- After executing child stages, we calculate the data size and row count of each partition from MapStaus.
- A partition is skewed if its data size or row count is N times larger than the median, and also larger than a pre-defined threshold.

Handling Skewed Join



Use N tasks instead of 1 task to join the data in Partition 0. The join result =
Union (A0-0 Join B0, A0-1 Join B0, ... , A0-N Join B0)

Benchmark Result

Cluster Setup

Hardware		BDW
Slave	Node#	**98**
	CPU	Intel（R） Xeon（R） CPU E5-2699 v4 @ 2.20GHz (88 cores)
	Memory	256 GB
	Disk	7× 400 GB SSD
	Network	10 Gigabit Ethernet
Master	CPU	Intel(R) Xeon(R) CPU E5-2699 v4 @ 2.20GHz (88 cores)
	Memory	256 GB
	Disk	7× 400 GB SSD
	Network	10 Gigabit Ethernet

Software	
OS	CentOS* Linux release 6.9
Kernel	2.6.32-573.22.1.el6.x86_64
Spark*	Spark* master (2.3) / Spark* master (2.3) with adaptive execution patch
Hadoop*/HDFS*	hadoop-2.7.3
JDK	1.8.0_40 (Oracle* Corporation)

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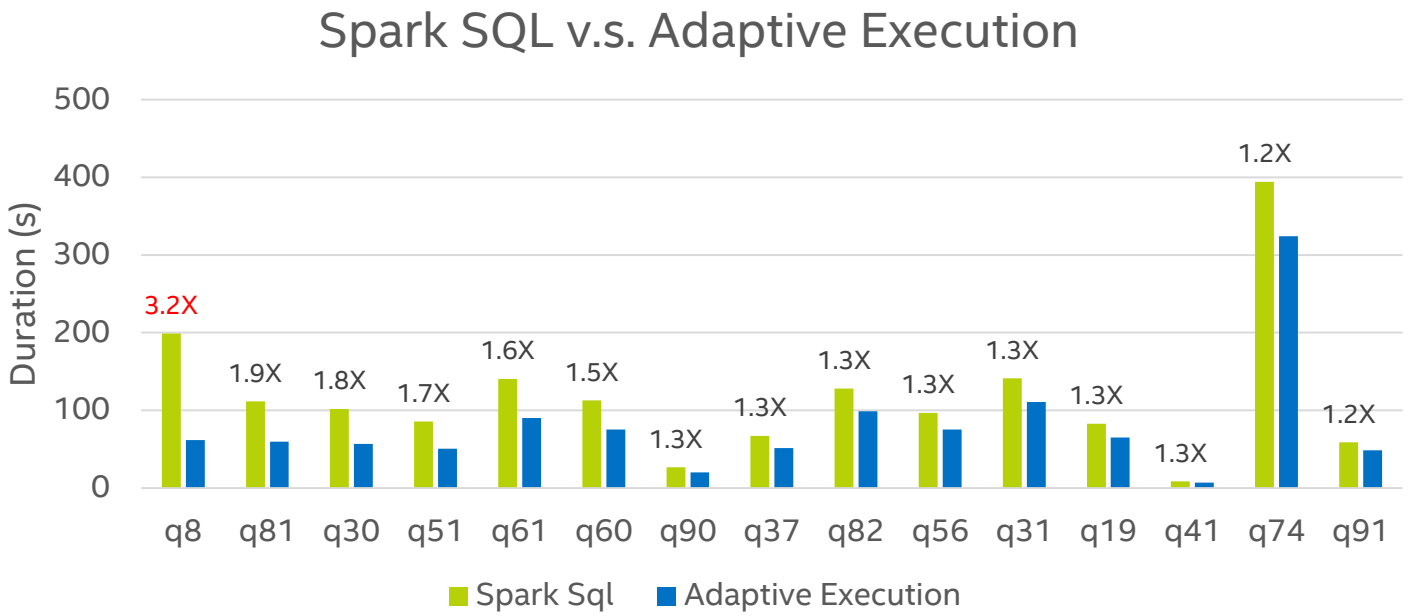
For more complete information about performance and benchmark results, visit www.intel.com/benchmarks

TPC-DS* 100TB Benchmark



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Auto Setting the Shuffle Partition Number

- Less scheduler overhead and task startup time.
- Less disk IO requests.
- Less data are written to disk because more data are aggregatd.

Partition Number 10976 (q30)

WITH customer_total_return AS (SELECT wr_returning_customer_sk AS ctr_customer_sk, ca… run at AccessController.java:0 +details	2017/10/17 11:31:01	18 s	10976/10976			6.9 GB	
WITH customer_total_return AS (SELECT wr_returning_customer_sk AS ctr_customer_sk, ca… run at AccessController.java:0 +details	2017/10/17 11:30:52	10 s	10976/10976			17.0 GB	6.8 GB

Partition Number changed to 1084 and 1079 at runtime. (q30)

WITH customer_total_return AS (SELECT wr_returning_customer_sk AS ctr_customer_sk, ca… run at AccessController.java:0 +details	2017/10/18 04:17:22	4 s	1079/1079			5.3 GB	
WITH customer_total_return AS (SELECT wr_returning_customer_sk AS ctr_customer_sk, ca… run at Executors.java:511 +details	2017/10/18 04:17:14	7 s	1084/1084			17.7 GB	5.2 GB

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SortMergeJoin -> BroadcastJoin at Runtime

- Eliminate the data skew and straggler in SortMergeJoin
- Remote shuffle read -> local shuffle read.
- Random IO read -> Sequence IO read

SortMergeJoin (q8):

SELECT s_store_name, sum(ss_net_profit) FROM store_sales, date_dim, store, (SELECT ca… run at AccessController.java:0 +details	2017/10/18 18:13:29	2.5 min	10976/10976			52.0 GB	13.2 KB
SELECT s_store_name, sum(ss_net_profit) FROM store_sales, date_dim, store, (SELECT ca… run at AccessController.java:0 +details	2017/10/18 18:12:48	37 s	12121/12121	1183.1 GB			52.0 GB
SELECT s_store_name, sum(ss_net_profit) FROM store_sales, date_dim, store, (SELECT ca… run at AccessController.java:0 +details	2017/10/18 18:13:25	2 s	10976/10976			2.5 KB	2.5 KB

BroadcastJoin (q8 Adaptive Execution):

SELECT s_store_name, sum(ss_net_profit) FROM store_sales, date_dim, store, (SELECT ca… run at Executors.java:511 +details	2017/10/18 02:48:56	10 s	12121/12121			17.4 GB	284.3 KB
SELECT s_store_name, sum(ss_net_profit) FROM store_sales, date_dim, store, (SELECT ca… run at ThreadPoolExecutor.java:1142 +details	2017/10/18 02:48:56	71 ms	69/69			2.5 KB	

*For more complete information about performance and benchmark results, visit www.intel.com/benchmarks

Scheduling Difference

- Spark SQL* has to wait for the completion of all broadcasts before scheduling the stages. Adaptive Execution can start the stages earlier as long as its dependencies are completed.

Original Spark:

SELECT i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact, sum(ss_ext_sales_p... run at AccessController.java:0 +details	2017/10/09 21:43:01	34 s	10128/10128	259.7 GB
SELECT i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact, sum(ss_ext_sales_p... run at AccessController.java:0 +details	2017/10/09 21:43:01	3 s	280/280	496.9 MB
SELECT i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact, sum(ss_ext_sales_p... run at ThreadPoolExecutor.java:1142 +details	2017/10/09 21:42:11	0.3 s	10/10	3.9 MB
SELECT i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact, sum(ss_ext_sales_p... run at ThreadPoolExecutor.java:1142 +details	2017/10/09 21:42:11	4 s	280/280	181.5 MB

50 Seconds Gap

BroadcastExchange

data size (bytes): 1,008,785,152
time to collect (ms): 19,267
time to build (ms): 24,074
time to broadcast (ms): 6,003

Adaptive Execution:

SELECT i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact, sum(ss_ext_sales_p... run at Executors.java:511 +details	2017/10/10 15:18:10	55 s	10128/10128	259.7 GB
SELECT i_brand_id brand_id, i_brand brand, i_manufact_id, i_manufact, sum(ss_ext_sales_p... run at ThreadPoolExecutor.java:1142 +details	2017/10/10 15:18:08	4 s	280/280	181.5 MB

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