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Advanced partitioning techniques for massively distributed computation

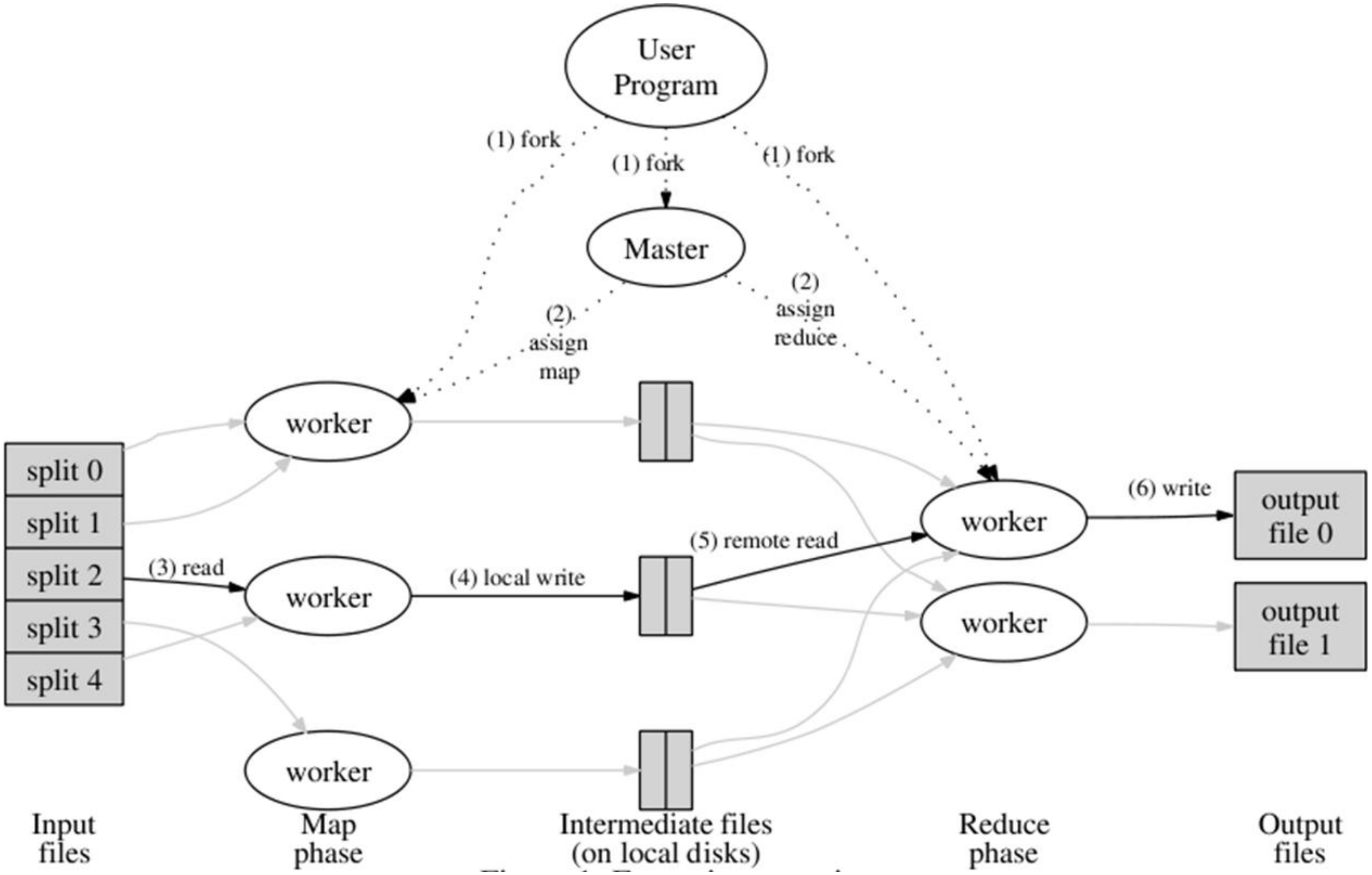
Outline

- Background
  - MapReduce Model
  - SCOPE Language and Cosmos system
- Advanced partitioning techniques
  - Partial Partitioning
    - Hash-Based Partitioning
    - Range-Based Partitioning
  - Indexed-based Partitioning
- Critiques and Discussion

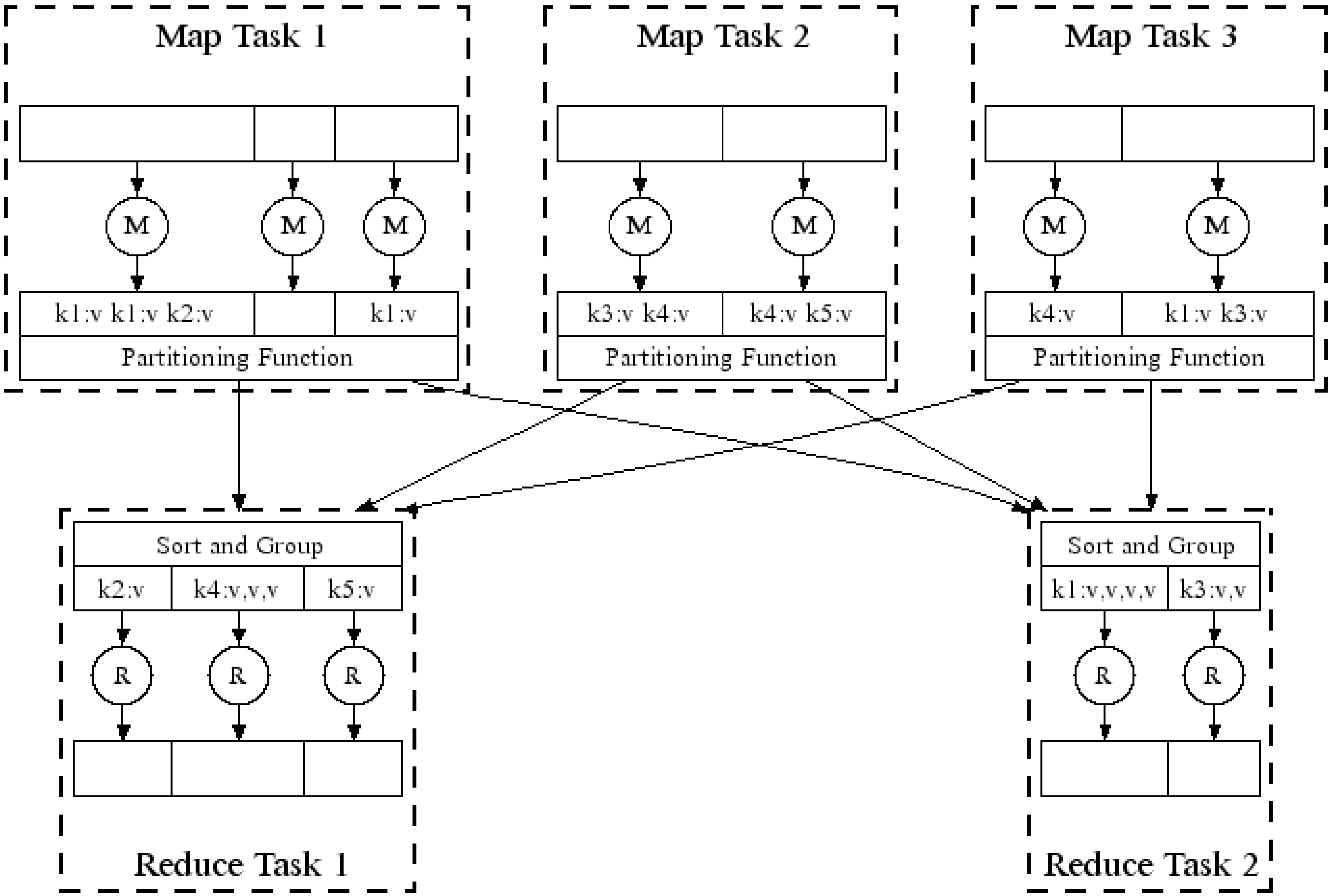
Background

- MapReduce Model
- SCOPE Language and Cosmos system

MapReduce Model



MapReduce Model

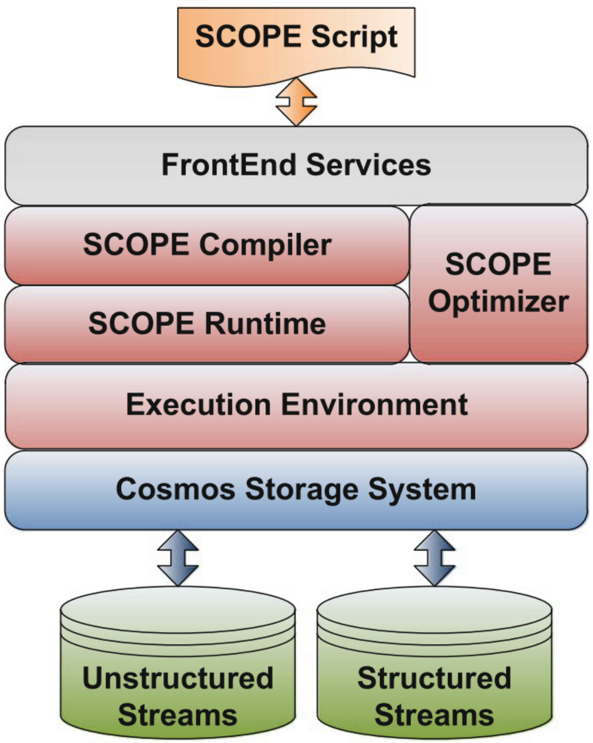


Limitations of MapReduce

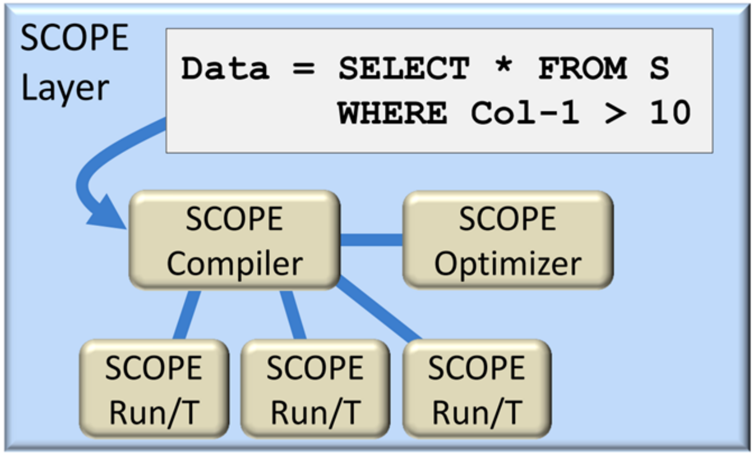
- Expertise are required to translate the application logic to MapReduce model in order to achieve parallelism.
- Code can be hard to debug and almost impossible to be reused.
- Complex application can become cumbersome to implement.
- Optimization of MapReduce jobs could be difficult.

SCOPE (Structured Computation Optimized for Parallel Execution) Language and Cosmos System

```
select R.c, S.d, count(*)
from R, S
where R.a = S.a and R.b = S.b and p1(R) and p2(S)
group by R.c, S.d
```




```
R1 = SELECT A+C AS ac, B.Trim() AS B1
     FROM R
     WHERE StringOccurs(C, "xyz") > 2

#CS
public static
int StringOccurs(string str, string ptrn)
{
   int cnt=0; int pos=-1;
   while (pos+1 < str.Length) {
     pos = str.IndexOf(ptrn, pos+1) ;
     if (pos < 0) break;
     cnt++;
   }
   return cnt;
}
#ENDCS
```

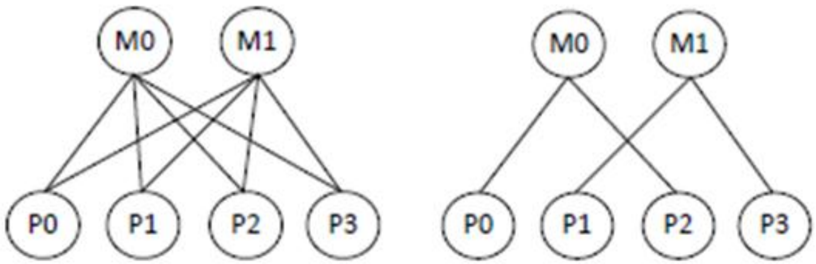


Advanced partitioning techniques

- Partial Partitioning
  - Hash-Based Partitioning
  - Range-Based Partitioning
- Indexed-based Partitioning

Partial Partitioning

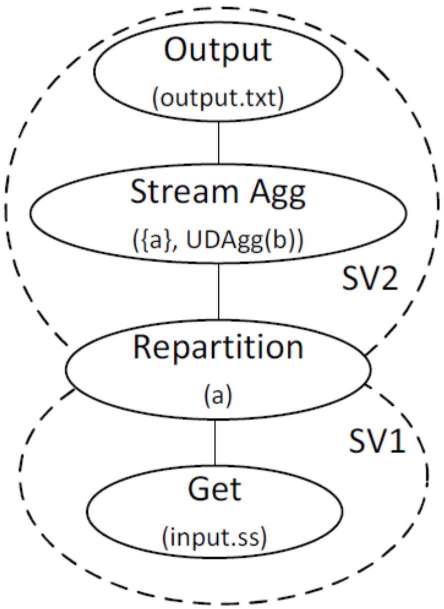
- Even after query optimization, certain repartitions are still inevitable.
- However by carefully define the partition scheme, we could use partial repartitioning to replace full repartitioning.
- Partial partitioning could greatly reduce I/O, communication and memory burden while relieve the scheduler and decrease response time

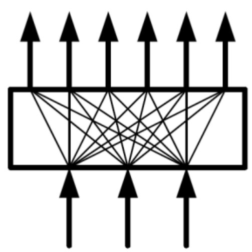


Hash-Based Partial Partitioning

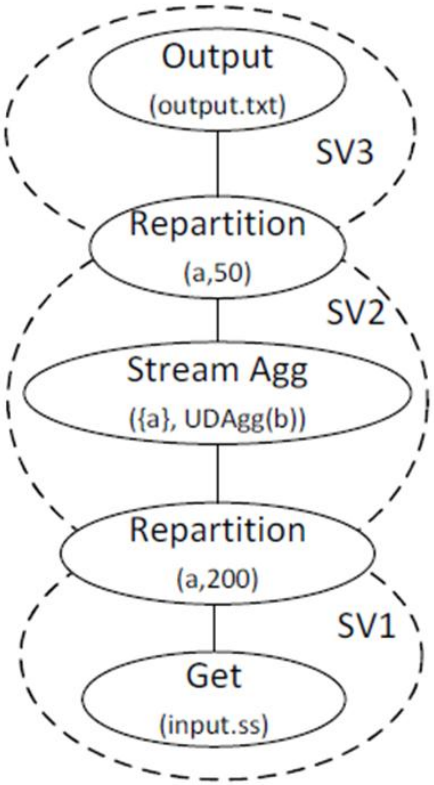
```
SELECT a, UDAgg(b) AS aggB
FROM SSTREAM "input.ss"
GROUP BY a;

OUTPUT TO SSTREAM "output.ss"
       [HASH | RANGE] CLUSTERED BY a;
```

If the input has already been hash partitioned by a, a great deal of resources would be saved



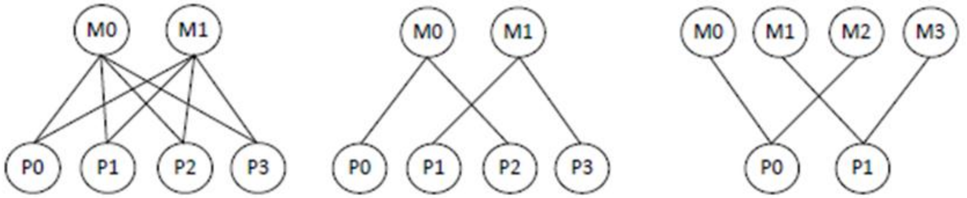


Full Repartitioning



Hash-Based Partial Partitioning

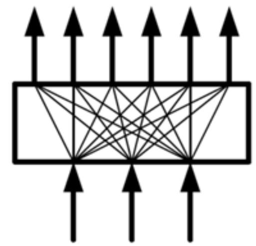
Example 1 *Suppose that* $pi = 4$ *and* $po = 2$ *(i.e., we want to partition 2-ways an input that is already 4-way partitioned). Every row in* P_0 *satisfies* $h(C) \equiv 0 \mod 4$*, where* h *is the hash function and* C *are the partitioning columns. Figure 5(a) shows the default partitioning strategy which connects every input vertex with every output vertex. In this case, we know that* $h(C) \equiv 0 \mod 2$ *as well, and therefore* P_0 *would never generate a row satisfying* $h(C) \equiv 1 \mod 2$*. Thus,* M_1 *does not need to read the* empty *local partition produced by* P_0*. In general,* M_0 *only reads from* P_0 *and* P_2*, and* M_1 *from* P_1 *and* P_3*. Figure 5(b) shows the refined merge graph. A similar strategy can be applied when* $pi = 2$ *and* $po = 4$*. Figure 5(c) shows the refined partitioning graph.*



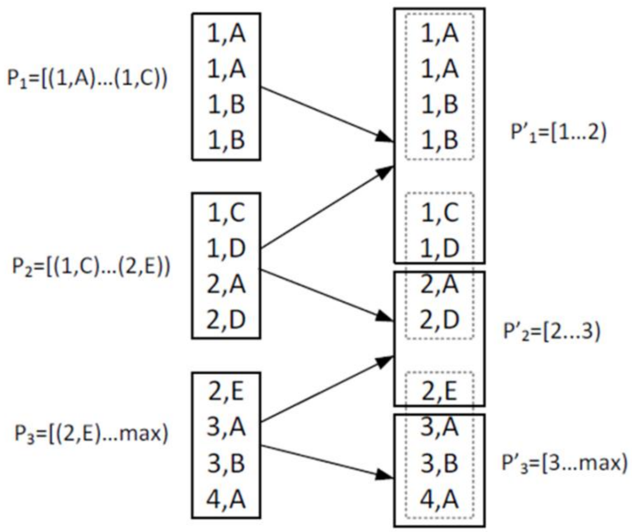
(a) Full Partitioning (b) Partial Merge (c) Partial Partitioning

Range-Based Partial Partitioning

- Range-Based Partial Partitioning could be used when input and output partition scheme share common prefix.
- Determine the partition boundary is important because it is crucial to reduce latency.



Full Repartitioning



Range-Based Partial Partitioning

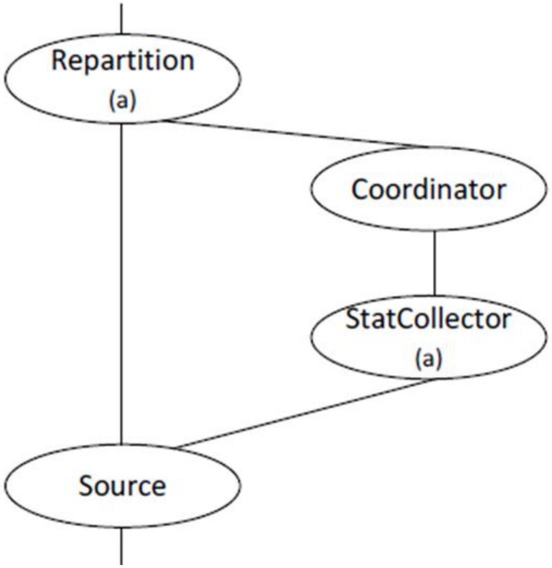
Algorithm 1: PartitionBoundaries(C, T, B)

```
Input:  Columns C, Partition size T, Buckets B
Output:  Partition boundaries P
/* Assume that C and B.cols share common prefix CP
   and for each 1 < i <|B|:  B[i-1].hi = B[i].lo     */
/* Output is partitioned by CP, which implies C,
   and each partition size is around T               */
CB = ∪_i [Π_CP B[i].lo, Π_CP B[i].hi) // project B on CP
idx = 0;
while idx < |CB| do
    actLo = CB[idx].Lo;
    actSize = CB[idx].Size;
    idx++;
    while actLo = CB[idx].Lo OR
          CB[idx].size / 2 < T - actSize do
        actSize += CB[idx].size;
        idx++;
    end
    P = P ∪ [actLo, CB[idx-1].hi);
end
return P;
```

Range-Based Partial Partitioning

- Boundary decision could not only be made at compile time but also running time.
- Although extra cost is needed, it could avoid skewed partition in certain cases which would lead to high latency

The StatCollector intercept the input and compute a histogram on the partitioning columns . Then the Coordinator compute a overall histogram and decide the overall partition boundaries.

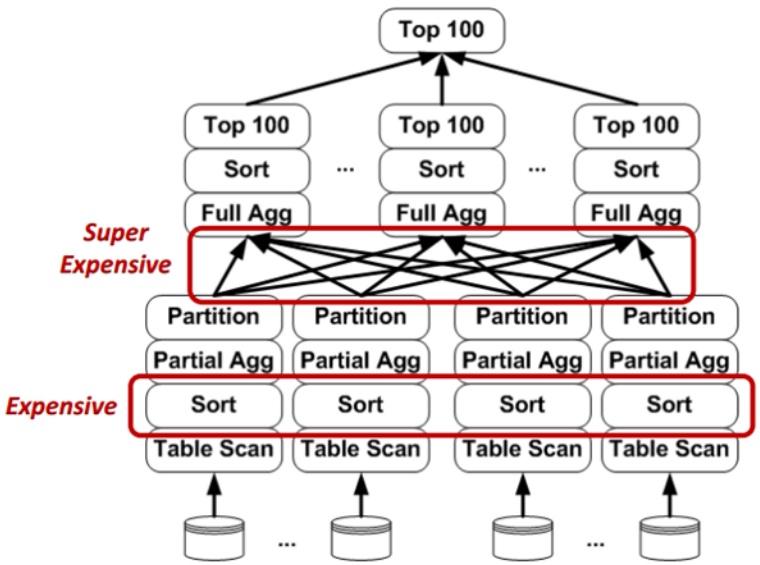


Integrating the Techniques into SCOPE Optimizer

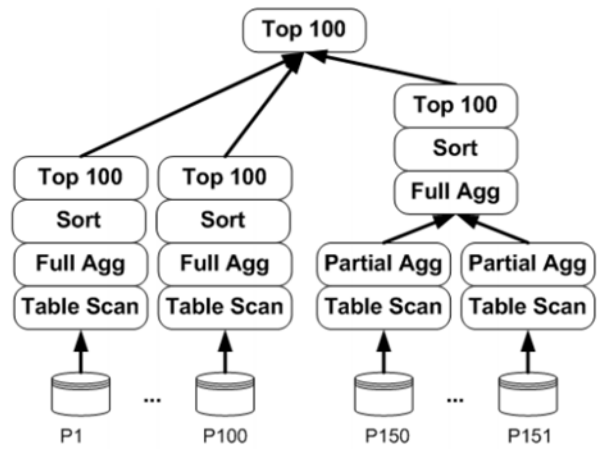
- Optimizer would eliminate certain repartition when certain functional dependency is detected between input partition scheme and potential output partition scheme.
- Optimizer chooses to repartition data based on requirements of subsequent operators.
- Optimizer would consider partial repartition if certain structural properties are detected. Compromise may also occur.

SCOPE Optimizer and Structured Streams

```sql
SELECT GetDomain(URL) AS Domain,
       SUM((MyNewScoreFunction(A, B, …)) AS TotalScore
FROM Web-Table
GROUP BY Domain;

SELECT TOP 100 Domain ORDER BY TotalScore;
```



Unstructured Datasets



Structured Datasets (Sstream)
(partitioned by URL, sorted by URL)

Much more efficient w/o shuffling data

Opportunities for optimizing N-ary operators

- Pushing partition scheme from one input to others: when inputs are partitioned in compatible way this method might be better.
- Heuristic Range partition: Obtaining a overall histogram buckets and generate boundary based on the overall statistics.
- Broadcast optimization: Based common prefix, partition the smaller input and for each partition of large inputs, send all partitions of smaller input to it.

Experimental Results

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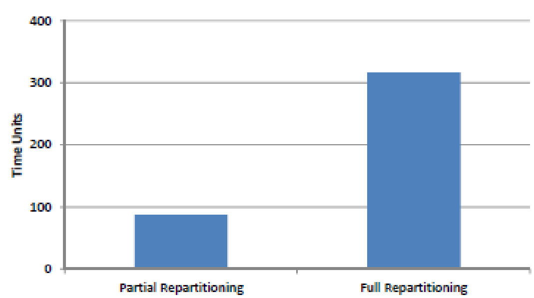
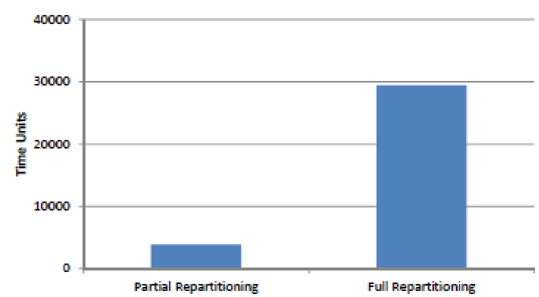
```
SELECT domain, host, Agg(col1), ..., Agg(coln)
FROM SSTREAM "WebPages.ss"
GROUP BY domain, host
```

Domain	Host	Top-level-directory	URL-suffix	Data
com.microsoft	www	download/	en/default.aspx?WT.mc_id=MSCOM_HP_US_Nav_Downloads	...
com.microsoft	windows	products/	home	...
com.bing	www	videos/	browse?FORM=Z9LH6	...
...	...	...	...	...

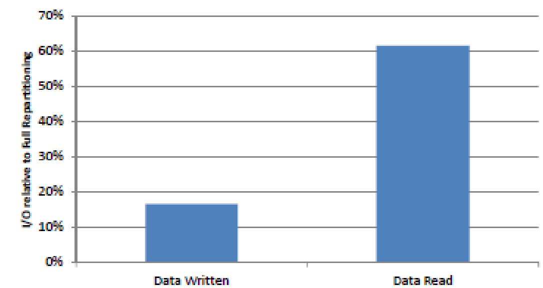
Table 1: Sample Information for a Web-pages Structured Stream



(a) Latency



(b) Total Work



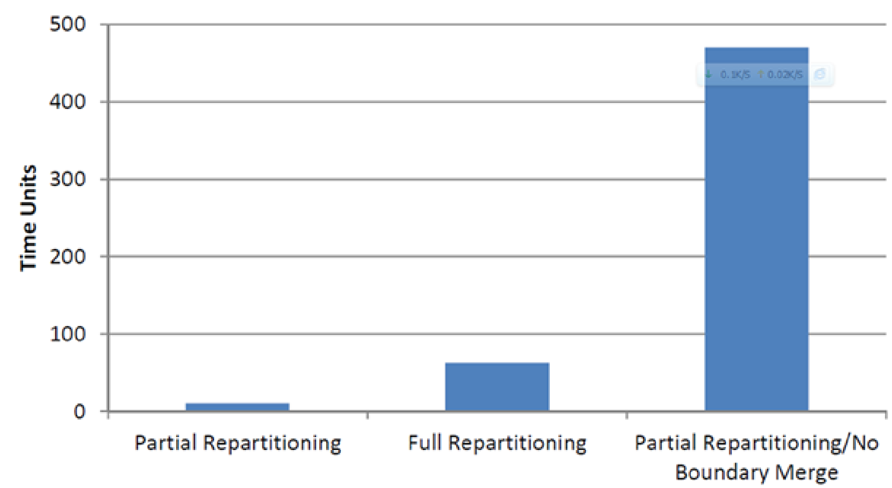
(c) Data Write and Data Read

Experiment Results

- The data is ranged-partitioned and sorted by {domain, host, top-level-directory}

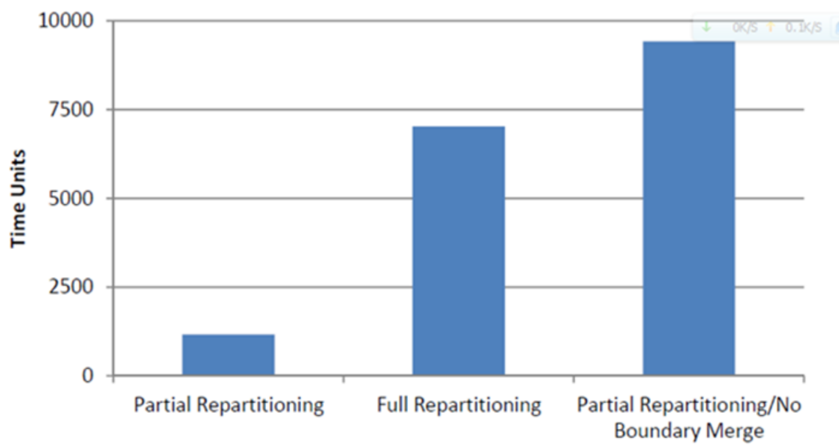
```sql
SELECT domain, host, Agg(col1), ..., Agg(coln)
FROM (
    SELECT * FROM T1 UNION ALL
    SELECT * FROM T2 UNION ALL
    SELECT * FROM T3 UNION ALL
    SELECT * FROM T4
     )
GROUP BY domain, host
```

- T1,T2,T3,T4,come from different period of time and different domain.

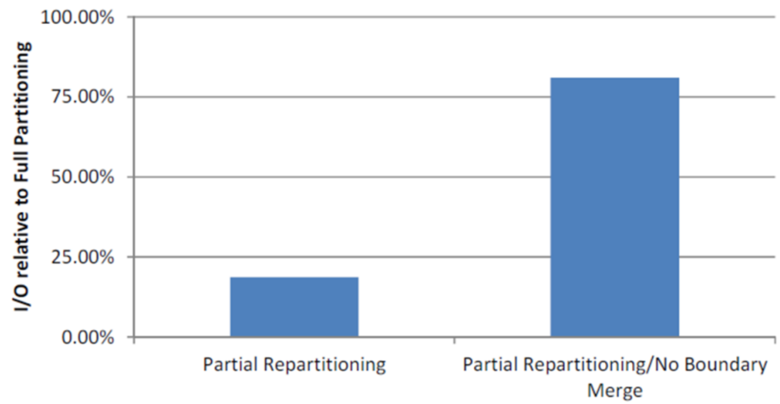


(a) Latency

Experimental Results



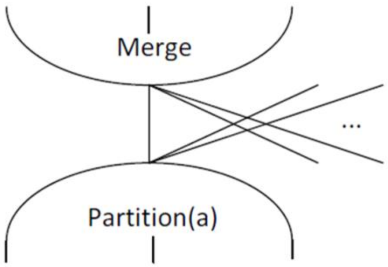
(b) Total Work



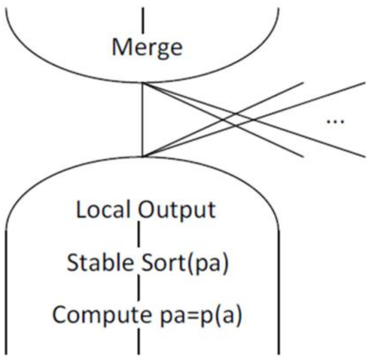
(c) Total Data I/O

Indexed-based Partitioning

- In the situation of terabytes of data, even the local repartition would be quite expensive
- We could compute a value pa(index number) utilize a stable sort to virtually "partition" the input data.

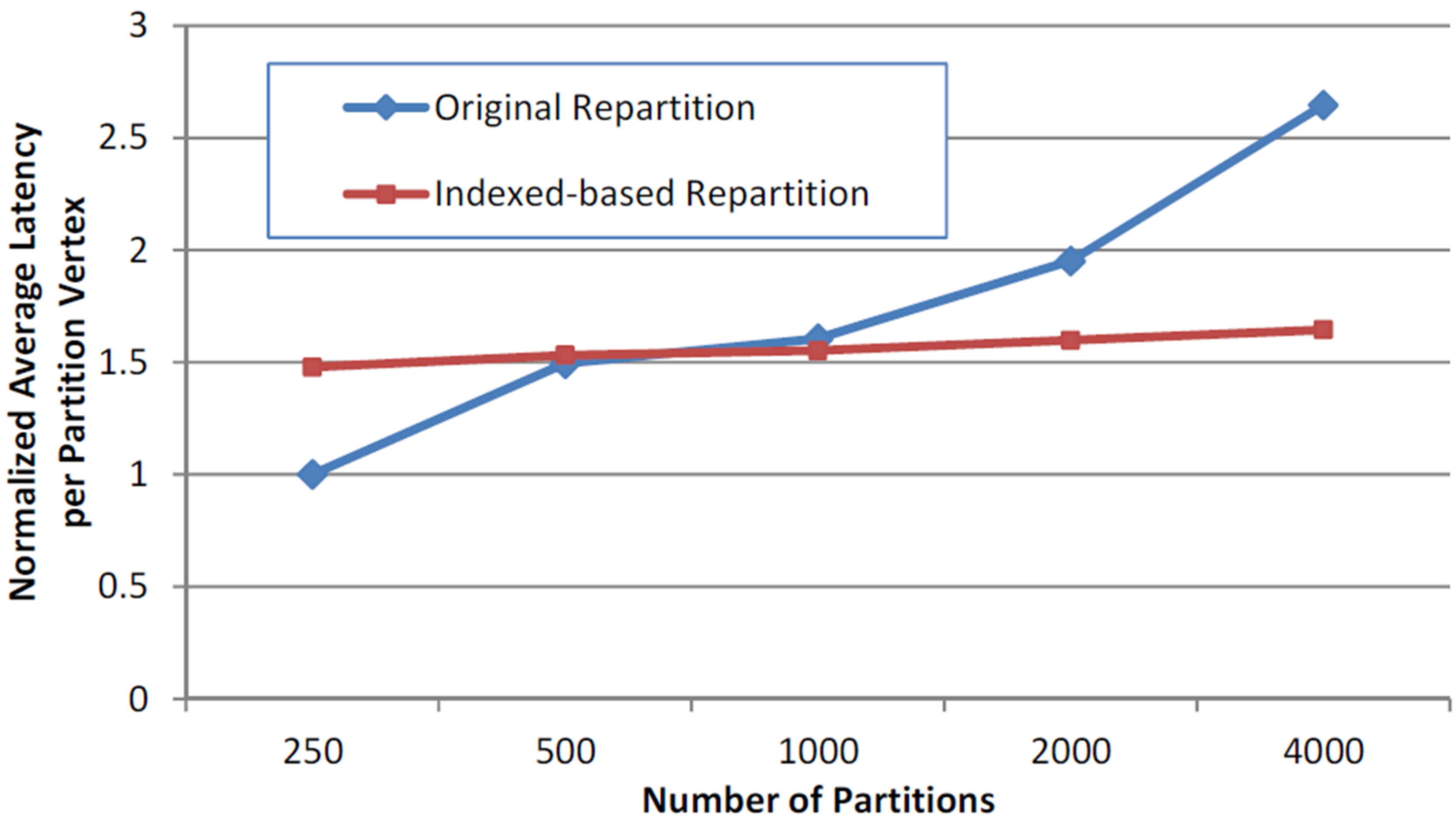


(a) Traditional partitioning.



(b) Indexed partitioning.

Experimental Results



Critiques and Discussion

Critique and discussion

- The paper did not provide detailed example and description for optimization opportunities for the N-ary operator.
- Due to commercial reason, the paper only provides relative measurements for the experiment results.
- Network environment for the experiments is not mentioned.

Critique and discussion

- No example and experimental results were given for expensive N-ary operation like join.

- All of these advanced partitioning techniques and even the whole optimizer rely heavily on structural properties of the input stream.

Q&A