# The effect of collisions on the performance of reduction filters.

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## Introduction

The optimization of general queries in a distributed database management system is an important research topic. The problem is to select the best sequence of database operations that will process the query and minimize costs. Approaches include algorithms which are join-based [1, 2], semijoin-based [3, 4, 5, 6, 7, 8, 9, 10], or a combination of both [11]. Many algorithms concentrate on special types of queries [5, 12, 13, 14, 15, 6]. Some algorithms have been developed which improve on strategies produced by other heuristics [16, 17]. However, it has been shown [18, 19] that finding an optimal solution for a given general query is NP-hard so most algorithms aim to produce an efficient but (perhaps) suboptimal evaluation strategy. A new approach is to use hash-semijoins, which employ reduction filters (also known as Bloom filters), to reduce costs. Bloom filters are first described in [20], and have mostly been used to improve the relational join operation [21, 22, 23, 24, 25]. Bloom filters have been applied to other relational operations [26, 27, 28] and file processing operations [29]. Mullin [30, 31] employs Bloom filters to improve the semijoin operation. His method is limited to the case where there are only

two sites involved in the query and it has not been expanded to cater for general queries. Tseng and Chen [32] present a new relational operator called a hash-semijoin. They propose a method which will transform a sequence of semijoins, produced by any existing semijoin-based algorithm, into a more cost effective sequence by replacing some of the semijoins by hash-semijoins. But their approach has not been experimentally evaluated.

## The algorithm

In our recent work [33, 34] we use reduction filters. Each filter is an array of bits that functions as a very compact representation of the values of a join attribute in a relation. A hash function is used to set bits in the filter. It is then used to identify tuples (in other relations) which cannot belong to the result. The relations can be reduced significantly in size, data transfers can be reduced and costs minimized.

Our algorithm, which is based on reduction filters, can process general queries consisting of an arbitrary number of relations and join attributes. Each query is represented by a graph and an adjacency list. Each relation is usually only processed once — to minimize data transfers. However, if a filter changes during use then certain relations must be processed again — a queue is used to record this information. The algorithm consists of two phases: during phase one the adjacency list is used to determine the order in which the filters are constructed

and used.

*Phase one:*

1. Select the relation with lowest in-degree for processing.
2. Scan adjacency list to see which filters must be constructed. If a filter is already available then concurrently use it to reduce the relation and produce all required filters.
3. If a filter has changed the use the following " filter rule": if a filter for a relation changes then add that relation to the queue only if it has already been processed; it is not already on the queue; and it is not the most recently processed relation.
4. Use adjacency list to "remove edges" from query graph — that is, reduce the in-degree of each relation in the list by 1.
5. Mark relation as processed.

Repeat all steps until each relation has been processed once.

*Phase two:*

1. Remove relation from queue.
2. Reduce relation using all appropriate filters.
3. If a filter changes then use the "filter rule".

Repeat all steps until the queue is empty.

This work has one serious limitation — we used a "perfect" hash function which means that collisions are not possible. Experiments showed that our algorithm could reduce data transfers very substantially [33]. However, in a database collisions in the reduction filter[1] are a reality and a problem. Such collisions mean that the hash-semijoin cannot achieve the same

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[1] A collision occurs when two attribute values hash to the same address in the filter.

amount of reduction as a traditional semijoin would. In this paper we investigate the effect that collisions have on the performance of our algorithm.

## The experiments

We have an experimental framework consisting of a collection of software to generate random queries with certain characteristics. Software is also used to generate the relations needed to execute each query. We assume a distributed relational database management system connected via a point to point network. There is no fragmentation nor replication. We consider only select-project-join (SPJ) queries, each consisting of a number of relations located at different sites which must be joined and the result made available at the query site. To evaluate, we compare our method not against another algorithm but against the effects of a "full reducer" — an algorithm which reduces the relations to just those tuples which can be part of the final result. We believe that this method is more objective and gives a better assessment of the performance of the algorithm.

We designed a set of experiments to test the performance with different collision rates; specifically 0% through 9% and then 10% through 60% collisions. (Our framework allows us to specify and guarantee a certain percentage of collisions in the filter. For full details see [35]). At each collision rate we generated and executed 600 random queries, where each relation has between 200 and 600 tuples; the active domains had between 150 and 250 values; the selectivity of each attribute was set between 0.5 and 0.95; and each relation had approximately 75% of the joining attributes. For convenience the queries are grouped by type, where type 3–2 means that the query has

three relations and two join-attributes. The result tables are presented below:

| Type | 0% | 1% | 2% | 3% | 4% |
|------|-----|-----|-----|-----|-----|
| 3-2 | 83.54 | 83.48 | 84.60 | 84.93 | 84.69 |
| 3-3 | 95.34 | 97.38 | 93.95 | 92.48 | 95.15 |
| 3-4 | 99.26 | 100 | 100 | 99.81 | 99.60 |
| 4-2 | 91.51 | 92.37 | 94.92 | 95.69 | 94.88 |
| 4-3 | 99.05 | 99.09 | 98.66 | 97.21 | 98.29 |
| 4-4 | 100 | 100 | 100 | 99.87 | 100 |
| 5-2 | 99.55 | 96.72 | 97.59 | 98.55 | 96.91 |
| 5-3 | 100 | 100 | 99.85 | 99.82 | 99.96 |
| 5-4 | 100 | 100 | 100 | 100 | 100 |
| 6-2 | 98.55 | 98.92 | 98.74 | 98.98 | 99.03 |
| 6-3 | 100 | 100 | 99.97 | 99.99 | 100 |
| 6-4 | 100 | 100 | 100 | 100 | 100 |
| Avg | 97.23 | 99.33 | 97.36 | 97.27 | 97.38 |

Table 1 Average reduction: 0% – 4%

| Type | 5% | 6% | 7% | 8% | 9% |
|------|-----|-----|-----|-----|-----|
| 3-2 | 83.87 | 84.19 | 81.94 | 81.59 | 83.36 |
| 3-3 | 93.95 | 95.56 | 93.07 | 96.15 | 92.95 |
| 3-4 | 100 | 100 | 100 | 99.51 | 100 |
| 4-2 | 94.97 | 93.03 | 90.57 | 91.85 | 91.68 |
| 4-3 | 98.89 | 97.96 | 99.36 | 98.52 | 99.21 |
| 4-4 | 100 | 99.72 | 99.77 | 100 | 100 |
| 5-2 | 97.87 | 96.40 | 96.75 | 97.68 | 96.86 |
| 5-3 | 99.99 | 99.84 | 98.70 | 98.65 | 99.98 |
| 5-4 | 100 | 100 | 100 | 100 | 100 |
| 6-2 | 99.67 | 99.11 | 99.12 | 98.30 | 98.11 |
| 6-3 | 100 | 99.76 | 99.74 | 100 | 99.93 |
| 6-4 | 100 | 100 | 100 | 100 | 100 |
| Avg | 97.43 | 97.13 | 96.59 | 96.85 | 96.84 |

Table 2 Average reduction: 5% – 9%

| Type | 10% | 20% | 30% | 40% | 50% | 60% |
|------|-----|-----|-----|-----|-----|-----|
| 3-2 | 85.26 | 80.11 | 75.21 | 73.31 | 72.74 | 69.56 |
| 3-3 | 95.75 | 93.15 | 87.27 | 90.53 | 86.10 | 88.58 |
| 3-4 | 99.55 | 99.02 | 98.95 | 97.92 | 98.58 | 97.11 |
| 4-2 | 93.54 | 92.13 | 89.29 | 86.25 | 87.43 | 81.23 |
| 4-3 | 97.45 | 97.83 | 96.41 | 98.34 | 94.53 | 96.62 |
| 4-4 | 100 | 100 | 100 | 100 | 99.63 | 98.31 |
| 5-2 | 96.01 | 96.39 | 95.39 | 92.22 | 91.21 | 89.37 |
| 5-3 | 99.64 | 98.38 | 98.98 | 96.56 | 98.72 | 98.10 |
| 5-4 | 100 | 100 | 100 | 100 | 100 | 99.77 |
| 6-2 | 99.28 | 97.88 | 96.53 | 98.55 | 97.41 | 95.81 |
| 6-3 | 100 | 100 | 99.58 | 99.13 | 99.59 | 99.44 |
| 6-4 | 100 | 100 | 100 | 100 | 100 | 100 |
| Avg | 97.21 | 96.24 | 94.80 | 94.40 | 93.83 | 92.82 |

Table 3 Average reduction: 10% – 60%

## Conclusions

The results show that when the collision rate is between 0% and 10% then we can achieve, on average, a 97% reduction in the relations, and in approximately 83% of all queries the relations were fully reduced[2]. It would appear that the query type has more of an influence on the reduction rate than the percentage of collisions. This is not an unexpected result since, as the number of joining attributes increases we use more filters on a relation and this reduces the impact of the collisions.

When we looked at collision rates in the range 10% to 60% we found that we could still achieve 95% reduction on average, and approximately 68% of all queries were fully reduced.

The conclusions of this paper are very significant. To our knowledge no one has ever examined the effect of collisions on the performance of a hash-semijoin based algorithm.

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[2] The relations had been reduced to just those tuples which can participate in the final join.

Our main conclusion is that the collisions, even at 60%, do not significantly affect performance.

A full discussion of the results will be presented at conference time.

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