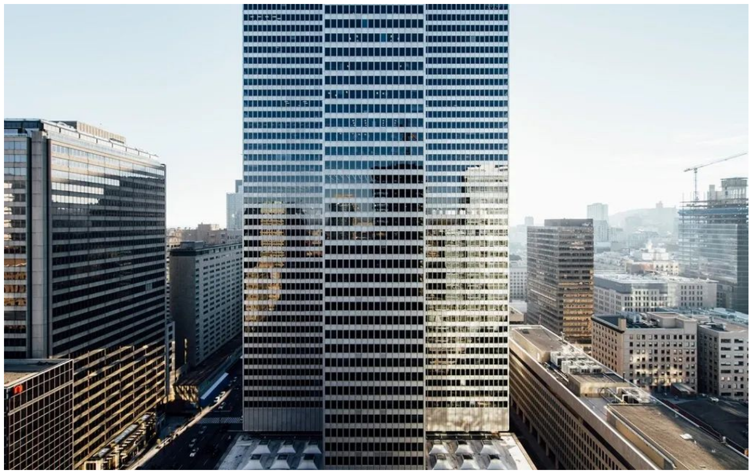
MySQL 8.0 Server层最新架构详解

Original 道客 阿里开发者 2021-07-25 17:15

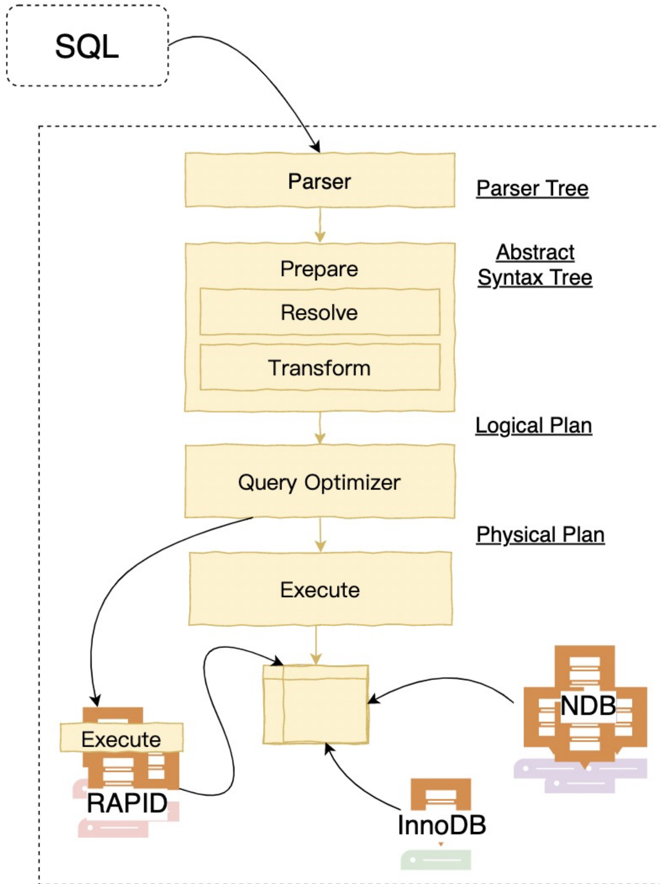
收录于合集

#mysql 5 #数据存储与数据库 16



一 背景和架构

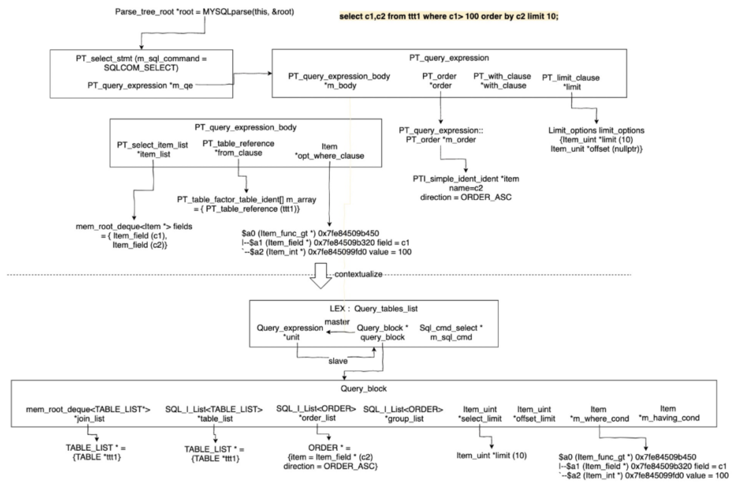
本文基于MySQL 8.0.25源码进行分析和总结。这里MySQL Server层指的是MySQL的优化器、执行器部分。我们对MySQL的理解还建立在5.6和5.7版本的理解之上，更多的是对比PostgreSQL或者传统数据库。然而从MySQL 8.0开始，持续每三个月的迭代和重构工作，使得MySQL Server层的整体架构有了质的飞越。下面来看下MySQL最新的架构。



我们可以看到最新的MySQL的分层架构和其他数据库并没有太大的区别，另外值得一提的是从图中可以看出MySQL现在更多的加强InnoDB、NDB集群和RAPID(HeatWave clusters)内存集群架构的演进。下面我们就看下具体细节，我们这次不随着官方的Feature实现和重构顺序进行理解，本文更偏向于从优化器、执行器的流程角度来演进。

二 MySQL 解析器Parser

首先从Parser开始，官方MySQL 8.0使用Bison进行了重写，生成Parser Tree，同时Parser Tree会contextualize生成MySQL抽象语法树（Abstract Syntax Tree）。

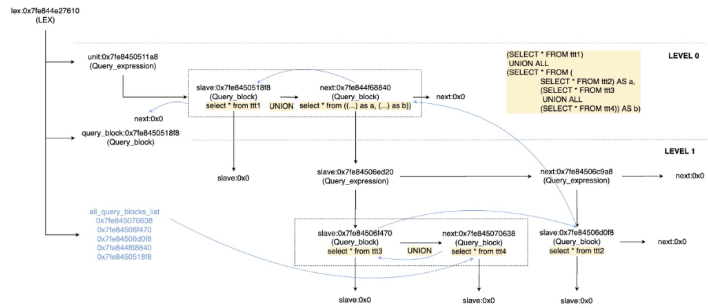


MySQL抽象语法树和其他数据库有些不同，是由比较让人拗口的SELECT_LEX_UNIT/SELECT_LEX类交替构成的，然而这两个结构在最新的版本中已经重命名成标准的SELECT_LEX -> Query_block和SELECT_LEX_UNIT -> Query_expression。Query_block是代表查询块，而Query_expression是包含多个查询块的查询表达式，包括UNION AND/OR的查询块（如SELECT * FROM t1 union SELECT * FROM t2）或者有多Level的ORDER BY/LIMIT (如SELECT * FROM t1 ORDER BY a LIMIT 10) ORDER BY b LIMIT 5。

例如，来看一个复杂的嵌套查询：

```
 (SELECT *
   FROM ttt1)
UNION ALL
  (SELECT *
   FROM
     (SELECT *
      FROM ttt2) AS a,
     (SELECT *
      FROM ttt3
      UNION ALL SELECT *
      FROM ttt4) AS b)
```

在MySQL中就可以用下面方式表达：



经过解析和转换后的语法树仍然建立在Query_block和Query_expression的框架下，只不过有些LEVEL的query block被消除或者合并了，这里不再详细展开。

三 MySQL prepare/rewrite阶段

接下来我们要经过resolve和transformation过程Query_expression::prepare->Query_block::prepare，这个过程包括（按功能分而非完全按照执行顺序）：

1 Setup and Fix

- setup_tables：Set up table leaves in the query block based on list of tables.
- resolve_placeholder_tables/merge_derived/setup_table_function/setup_materialized_derived：Resolve derived table, view or table function references in query block.
- setup_natural_join_row_types：Compute and store the row types of the top-most NATURAL/USING joins.
- setup_wild：Expand all '*' in list of expressions with the matching column references.
- setup_base_ref_items：Set query_block's base_ref_items.
- setup_fields：Check that all given fields exists and fill struct with current data.
- setup_conds：Resolve WHERE condition and join conditions.
- setup_group：Resolve and set up the GROUP BY list.

- m_having_cond->fix_fields：Setup the HAVING clause.

- resolve_rollup：Resolve items in SELECT list and ORDER BY list for rollup processing.

- resolve_rollup_item：Resolve an item (and its tree) for rollup processing by replacing items matching grouped expressions with Item_rollup_group_items and updating properties (m_nullable, PROP_ROLLUP_FIELD). Also check any GROUPING function for incorrect column.

- setup_order：Set up the ORDER BY clause.

- resolve_limits：Resolve OFFSET and LIMIT clauses.

- Window::setup_windows1 ： Set up windows after setup_order() and before setup_order_final().

- setup_order_final： Do final setup of ORDER BY clause, after the query block is fully resolved.

- setup_ftfuncs：Setup full-text functions after resolving HAVING.

- resolve_rollup_wfs : Replace group by field references inside window functions with references in the presence of ROLLUP.

2 Transformation

- remove_redundant_subquery_clause : Permanently remove redundant parts from the query if 1) This is a subquery 2) Not normalizing a view. Removal should take place when a query involving a view is optimized, not when the view is created.

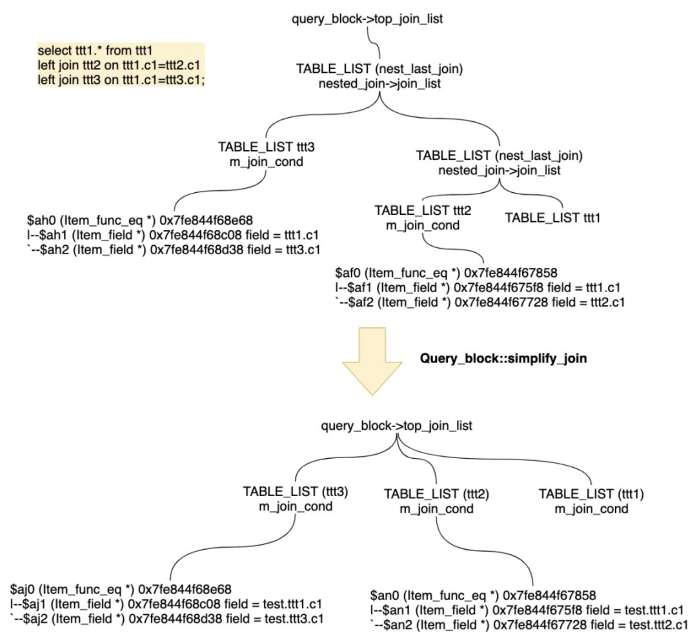
- remove_base_options： Remove SELECT_DISTINCT options from a query block if can skip distinct.

- resolve_subquery : Resolve predicate involving subquery, perform early unconditional subquery transformations.

- Convert subquery predicate into semi-join, or
- Mark the subquery for execution using materialization, or
- Perform IN->EXISTS transformation, or
- Perform more/less ALL/ANY -> MIN/MAX rewrite
- Substitute trivial scalar-context subquery with its value

- transform_scalar_subqueries_to_join_with_derived： Transform eligible scalar subqueries to derived tables.
- flatten_subqueries ： Convert semi-join subquery predicates into semi-join join nests. Convert candidate subquery predicates into semi-join join nests. This transformation is performed once in query lifetime and is irreversible.
- apply_local_transforms :
    - delete_unused_merged_columns : If query block contains one or more merged derived tables/views, walk through lists of columns in select lists and remove unused columns.
    - simplify_joins： Convert all outer joins to inner joins if possible
    - prune_partitions： Perform partition pruning for a given table and condition.
- push_conditions_to_derived_tables： Pushing conditions down to derived tables must be done after validity checks of grouped queries done by apply_local_transforms();
- Window::eliminate_unused_objects： Eliminate unused window definitions, redundant sorts etc.

这里，节省篇幅，我们只举例关注下和top_join_list相关的simple_joins这个函数的作用，对于Query_block中嵌套join的简化过程。



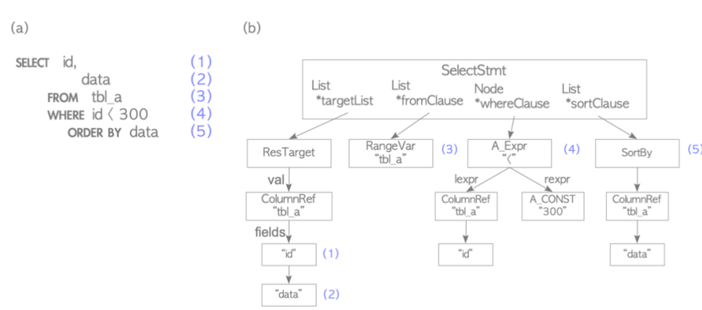
3 对比PostgreSQL

为了更清晰的理解标准数据库的做法，我们这里引用了PostgreSQL的这三个过程：

Parser

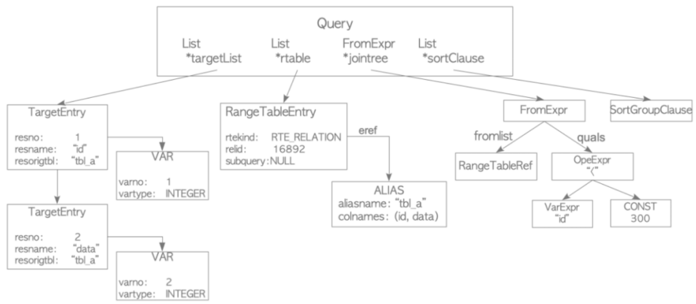
下图首先Parser把SQL语句生成parse tree。

```
testdb=# SELECT id, data FROM tbl_a WHERE id < 300 ORDER BY data;
```



Analyzer/Analyser

下图展示了PostgreSQL的analyzer/analyser如何将parse tree通过语义分析后生成query tree。



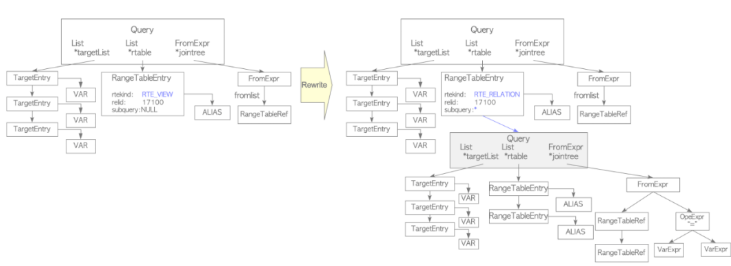
Rewriter

Rewriter会根据规则系统中的规则把query tree进行转换改写。

```
sampledb=# CREATE VIEW employees_list
sampledb-#       AS SELECT e.id, e.name, d.name AS department
sampledb-#             FROM employees AS e, departments AS d WHERE e.depart
```

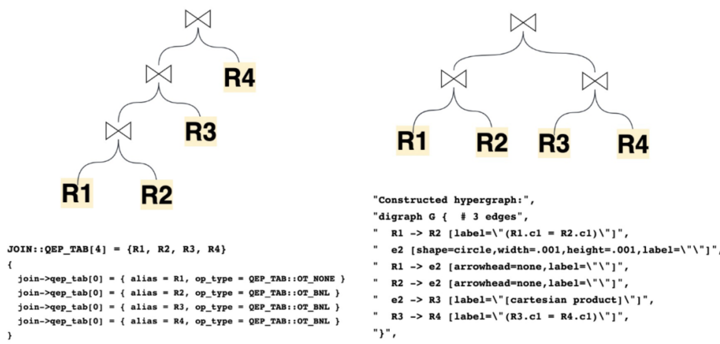
下图的例子就是一个包含view的query tree如何展开成新的query tree。

```
sampledb=# SELECT * FROM employees_list;
```



四 MySQL Optimize和Planning阶段

接下来我们进入了逻辑计划生成物理计划的过程，本文还是注重于结构的解析，而不去介绍生成的细节，MySQL过去在8.0.22之前，主要依赖的结构就是JOIN和QEP_TAB。JOIN是与之对应的每个Query_block，而QEP_TAB对应的每个Query_block涉及到的具体“表”的顺序、方法和执行计划。然而在8.0.22之后，新的基于Hypergraph的优化器算法成功的抛弃了QEP_TAB结构来表达左深树的执行计划，而直接使用HyperNode/HyperEdge的图来表示执行计划。



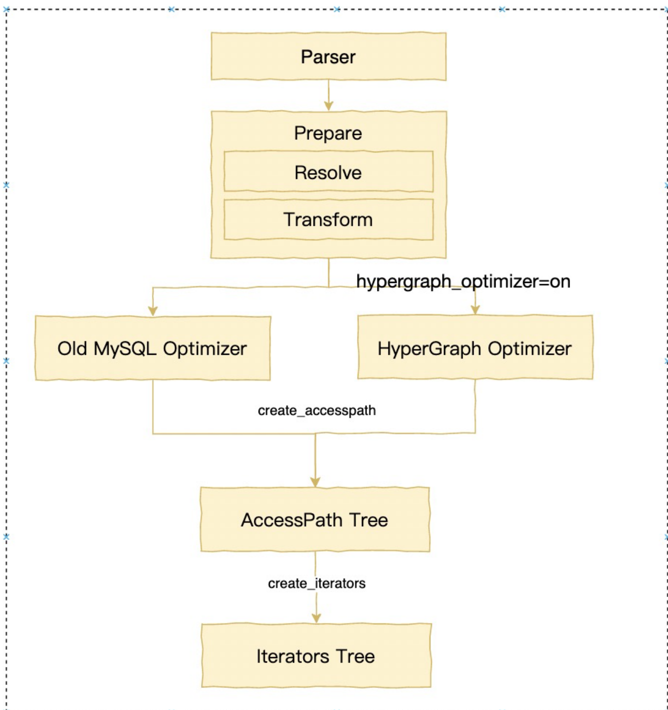
举例可以看到数据结构表达的left deep tree和超图结构表达的bushy tree对应的不同计划展现：

```
| -> Inner hash join (no condition)  (cost=1.40 rows=1)
    -> Table scan on R4  (cost=0.35 rows=1)
    -> Hash
        -> Inner hash join (no condition)  (cost=1.05 rows=1)
            -> Table scan on R3  (cost=0.35 rows=1)
            -> Hash
                -> Inner hash join (no condition)  (cost=0.70 rows=1)
                    -> Table scan on R2  (cost=0.35 rows=1)
                    -> Hash
                        -> Table scan on R1  (cost=0.35 rows=1)

| -> Nested loop inner join  (cost=0.55..0.55 rows=0)
    -> Nested loop inner join  (cost=0.50..0.50 rows=0)
        -> Table scan on R4  (cost=0.25..0.25 rows=1)
        -> Filter: (R4.c1 = R3.c1)  (cost=0.35..0.35 rows=0)
            -> Table scan on R3  (cost=0.25..0.25 rows=1)
    -> Nested loop inner join  (cost=0.50..0.50 rows=0)
        -> Table scan on R2  (cost=0.25..0.25 rows=1)
```

```
            -> Filter: (R2.c1 = R1.c1)  (cost=0.35..0.35 rows=0)
                -> Table scan on R1  (cost=0.25..0.25 rows=1)
```

MySQL8.0.2x为了更好的兼容两种优化器，引入了新的类AccessPath，可以认为这是MySQL为了解耦执行器和不同优化器抽象出来的Plan Tree。



1 老优化器的入口

老优化器仍然走JOIN::optimize来把query block转换成query execution plan (QEP)。

这个阶段仍然做一些逻辑的重写工作，这个阶段的转换可以理解为基于cost-based优化前做准备，详细步骤如下：

- Logical transformations
  - optimize_derived : Optimize the query expression representing a derived table/view.
  - optimize_cond : Equality/constant propagation.

- prune_table_partitions : Partition pruning.

- optimize_aggregated_query : COUNT(*), MIN(), MAX() constant substitution in case of implicit grouping.

- substitute_gc : ORDER BY optimization, substitute all expressions in the WHERE condition and ORDER/GROUP lists that match generated columns (GC) expressions with GC fields, if any.

* Perform cost-based optimization of table order and access path selection.

  - JOIN::make_join_plan() : Set up join order and initial access paths.

* Post-join order optimization

  - substitute_for_best_equal_field : Create optimal table conditions from the where clause and the join conditions.

  - make_join_query_block : Inject outer-join guarding conditions.

  - Adjust data access methods after determining table condition (several times).

  - optimize_distinct_group_order : Optimize ORDER BY/DISTINCT.

  - optimize_fts_query : Perform FULLTEXT search before all regular searches.

  - remove_eq_conds : Removes const and eq items. Returns the new item, or nullptr if no condition.

  - replace_index_subquery/create_access_paths_for_index_subquery : See if this subquery can be evaluated with subselect_indexsubquery_engine.

  - setup_join_buffering : Check whether join cache could be used.

- Code generation
    - alloc_qep(tables) : Create QEP_TAB array.
    - test_skip_sort : Try to optimize away sorting/distinct.
    - make_join_readinfo : Plan refinement stage: do various setup things for the executor.
    - make_tmp_tables_info : Setup temporary table usage for grouping and/or sorting.
    - push_to_engines : Push (parts of) the query execution down to the storage engines if they can provide faster execution of the query, or part of it.
    - create_access_paths : generated ACCESS_PATH.

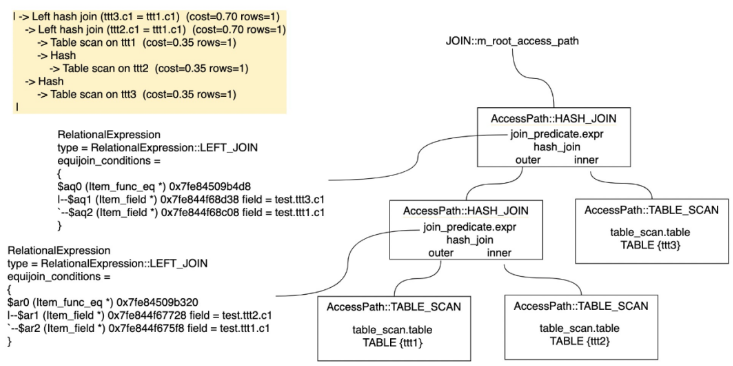
2 新优化器的入口

新优化器默认不打开，必须通过set optimizer_switch="hypergraph_optimizer=on"; 来打开。主要通过FindBestQueryPlan函数来实现，逻辑如下：

- 先判断是否属于新优化器可以支持的Query语法（CheckSupportedQuery），不支持的直接返回错误ER_HYPERGRAPH_NOT_SUPPORTED_YET。
- 转化top_join_list变成JoinHypergraph结构。由于Hypergraph是比较独立的算法层面的实现，JoinHypergraph结构用来更好的把数据库的结构包装到Hypergraph的edges和nodes的概念上的。
- 通过EnumerateAllConnectedPartitions实现论文中的DPhyp算法。
- CostingReceiver类包含了过去JOIN planning的主要逻辑，包括根据cost选择相应的访问路径，根据DPhyp生成的子计划进行评估，保留cost最小的子计划。

- 得到root_path后，接下来处理group/agg/having/sort/limit的。对于Group by操作，目前Hypergraph使用sorting first + streaming aggregation的方式。

举例看下Plan（AccessPath）和SQL的关系：



最后生成Iterator执行器框架需要的Iterator执行载体，AccessPath和Iterator是一对一的关系（Access paths are a query planning structure that correspond 1:1 to iterators）。

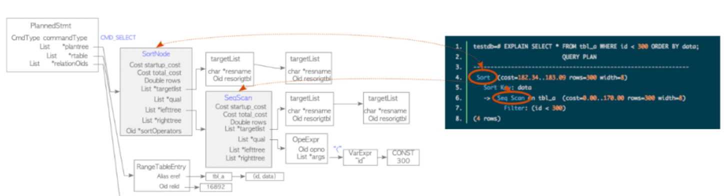
```
Query_expression::m_root_iterator = CreateIteratorFromAccessPath(......)

unique_ptr_destroy_only<RowIterator> CreateIteratorFromAccessPath(
     THD *thd, AccessPath *path, JOIN *join, bool eligible_for_batch_mode
......
   switch (path->type) {
     case AccessPath::TABLE_SCAN: {
       const auto &param = path->table_scan();
       iterator = NewIterator<TableScanIterator>(
           thd, param.table, path->num_output_rows, examined_rows);
       break;
     }
     case AccessPath::INDEX_SCAN: {
       const auto &param = path->index_scan();
       if (param.reverse) {
         iterator = NewIterator<IndexScanIterator<true>>(
             thd, param.table, param.idx, param.use_order, path->num_out
```

```
                examined_rows);
          } else {
            iterator = NewIterator<IndexScanIterator<false>>(
                thd, param.table, param.idx, param.use_order, path->num_outp
                examined_rows);
          }
          break;
        }
        case AccessPath::REF: {
......
}
```

3 对比PostgreSQL

```
testdb=# EXPLAIN SELECT * FROM tbl_a WHERE id < 300 ORDER BY data;
                          QUERY PLAN
---------------------------------------------------------------
 Sort  (cost=182.34..183.09 rows=300 width=8)
   Sort Key: data
   ->  Seq Scan on tbl_a  (cost=0.00..170.00 rows=300 width=8)
         Filter: (id < 300)
(4 rows)
```



五 总结

本文主要focus在MySQL最新版本官方的源码上，重点分析了官方的重构在多阶段和各阶段结构上的变化和联系，更多的是为了让大家了解一个全新的MySQL的发展。

关于我们

PolarDB 是阿里巴巴自主研发的云原生分布式关系型数据库，于2020年进入Gartner全球数据库Leader象限，并获得了2020年中国电子学会颁发的科技进步一等奖。PolarDB 基于云原生分布式数据库架构，提供大规模在线事务处理能力，兼具对复杂查询的并行处理能力，在云原生分布式数据库领域整体达到了国际领先水平，并且得到了广泛的市场认可。在阿里巴巴集团内部的最佳实践中，PolarDB还全面支撑了2020年天猫双十一，并刷新了数据库处理峰值记录，高达1.4亿TPS。欢迎有志之士加入我们，简历请投递到daoke.wangc@alibaba-inc.com，期待与您共同打造世界一流的下一代云原生分布式关系型数据库。

数据库技术图谱

数据库技术图谱由阿里云数据库专家团出品，含7个知识点，17个课程 ，6个体验场景，9个公开课，带你从基础到进阶玩转常见数据库，同时深入实战，学习阿里云使用各数据库的最佳实践！

点击“阅读原文”，开始学习吧~

收录于合集 #mysql 5

上一篇 · MySQL 深潜 - 一文详解 MySQL Data Dictionary

Read more