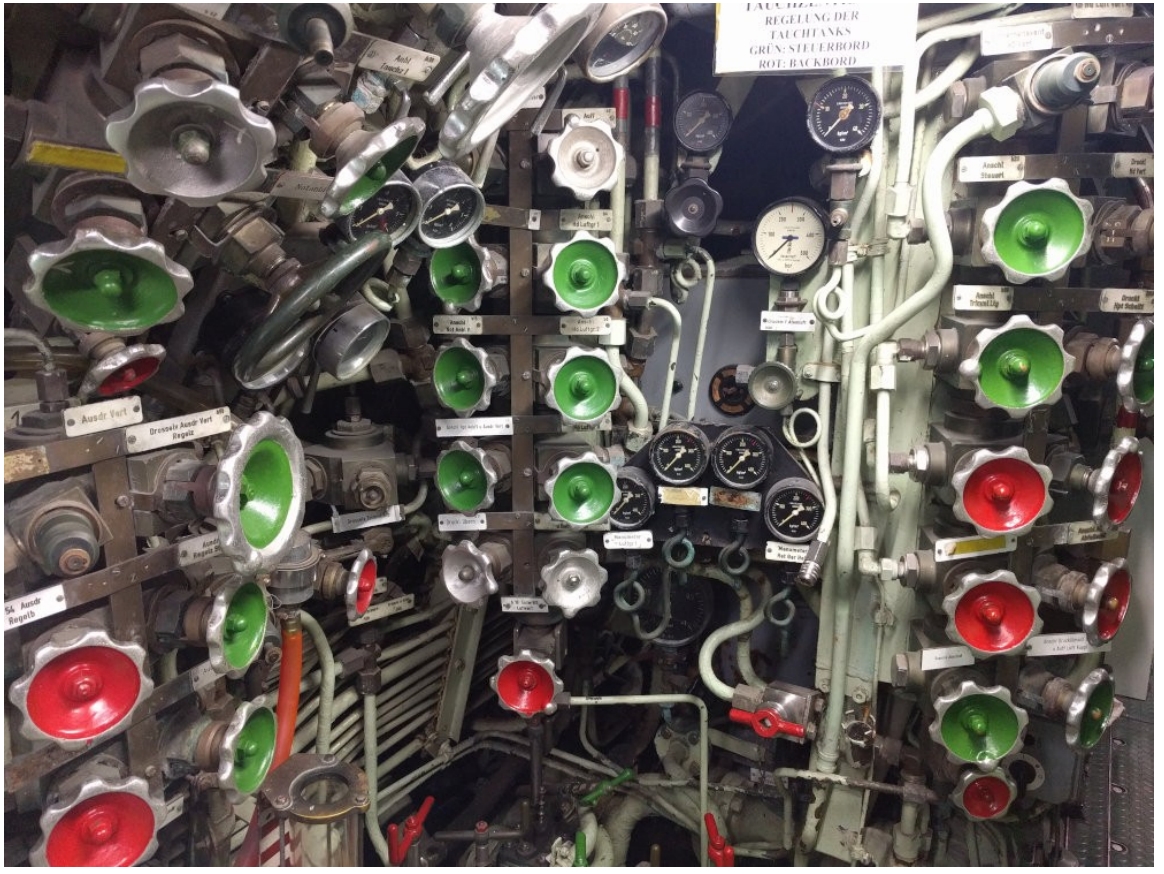
How Optimizer Works



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Query execution

- *Parsing*
- *Preparing*
- **Optimizing**
- *Executing*

How make optimizations visible

- `EXPALIN EXTENDED …; SHOW WARNINGS;`
  - Very old, shows only results of the optimisation
- `EXPLAIN/ANALYZE FORMAT=JSON …;`
  - 10.1, more info
- `set optimizer_trace=1; …;`

  `select * from information_schema.optimizer_trace;`
  - 10.4 explains decisions taking process

Pre-Optimizer changes (parsing)

- `Exp IN (single_val) → Exp = single_val`
- `Exp IN NOT (single_val) → Exp <> single_val`
- `WHERE col → WHERE col <> 0`
- `WHERE NOT col → WHERE col = 0`

Optimization steps

- Query transformations (non-cost-based, identical, open ways for other optimizations)
- Join optimization - preliminary phase (info collection)
- Join optimization (greedy search)
- Join optimization - plan refinement
- Other kinds of plan refinement

Query transformations:

- Derived/view merge
- IN predicate → IN subquery
- EXISTS → IN (opens EXISTS → IN or Materialization)
- MIN/MAX subquery
- Semi-join
- IN materialization
- outer → inner joins
- Condition optimization

Query transformations: Derived/view merge

```
select * from
  (select * from t1 where a>1)
  as tt;
```

If it can not be merged then cause will be mentioned

```
"join_preparation": {
  "select_id": 1,
  "steps": [
    {
      "derived": {
        "table": "tt",
        "select_id": 2,
        "algorithm": "merged"
      }
    },
```

Query transformations: IN predicate → IN subquery

```
set @@in_predicate_conversion_threshold= 2;
select * from t1 where a in (1,2);

explain extended
select * from t1 where a in (1,2);
id  select_type  table   type possible_keys   key key_len  ref  rows filtered Extra

…

Warnings:
Note 1003 /* select#1 */ select `test`.`t1`.`a` AS `a`,`test`.`t1`.`b` AS `b` from
`test`.`t1` semi join ((values (1),(2)) `tvc_0`) where 1
```

Semi-join is a result of conversion to IN-Subquery

Query transformations: EXISTS → IN

```
EXPLAIN EXTENDED
SELECT Name FROM Country
           WHERE (EXISTS (select 1 from City where City.Population > 100000 and
                          Code = Country) OR
                  Name LIKE 'L%') AND
                 Surfacearea > 1000000;
+--+------------+-------+----+------------------+----+-------+----+----+---------+-----------+
|Id|select_type |table  |type|possible_keys     |key |key_len|ref |rows|filtered |Extra      |
|1 |PRIMARY     |Country|ALL |Name,SurfaceArea  |NULL|NULL   |NULL|239 |29.71    |Using where|
|2 |MATERIALIZED|City   |ALL |Population,Country|NULL|NULL   |NULL|4079|87.45    |Using where|
+--+------------+-------+----+------------------+----+-------+----+----+---------+-----------+
Warnings:
Note 1276 Field or reference 'world.Country.Code' of SELECT #2 was resolved in SELECT #1
Note 1003 /* select#1 */ select `world`.`Country`.`Name` AS `Name` from `world`.`Country` where
(<expr_cache><`world`.`Country`.`Code`>(<in_optimizer>(`world`.`Country`.`Code`,`world`.`Countr
y`.`Code` in ( <materialize> (/* select#2 */ select `world`.`City`.`Country` from
`world`.`City` where `world`.`City`.`population` > 100000 ),
<primary_index_lookup>(`world`.`Country`.`Code` in <temporary table> on distinct_key where
`world`.`Country`.`Code` = `<subquery2>`.`Country`)))) or `world`.`Country`.`Name` like 'L%')
and `world`.`Country`.`SurfaceArea` > 1000000
```

Query transformations: MIN/MAX Subquery

```
explain extended

SELECT a FROM t1 WHERE b < ANY ( SELECT b FROM t1 GROUP BY b );

id  select_type table   type    possible_keys   key key_len ref rows
filtered    Extra

...

Warnings:

Note    1003    /* select#1 */ select `test`.`t1`.`a` AS `a` from
`test`.`t1` where <nop>(<in_optimizer>(`test`.`t1`.`b`,(/* select#2 */
select max(`test`.`t1`.`b`) from `test`.`t1`) > <cache>(`test`.`t1`.`b`)))
```

Query transformations: semi-join & IN materialization

```
select * from t1
  where a in (select pk from t2);
```

```
"steps": [
 {
   "transformation": {
     "select_id": 2,
     "from": "IN (SELECT)",
     "to": "materialization",
     "sjm_scan_allowed": true,
     "possible": true
   }
 },
 {
   "transformation": {
     "select_id": 2,
     "from": "IN (SELECT)",
     "to": "semijoin",
     "chosen": true
   }
 },
```

Query transformations: outer → inner joins

```
explain extended
SELECT * FROM t1 LEFT JOIN t2 ON t2.a=t1.a WHERE t2.b < 5;
id select_type  table  type   possible_keys key key_len   ref
rows   filtered  Extra
...
Warnings:
Note   1003   select `test`.`t1`.`a` AS `a`,`test`.`t1`.`b`
AS `b`,`test`.`t2`.`a` AS `a`,`test`.`t2`.`b` AS `b` from
`test`.`t1` join `test`.`t2` where `test`.`t2`.`a` =
`test`.`t1`.`a` and `test`.`t2`.`b` < 5
```

“t2.b < 5“ is null rejecting

Query transformations: Condition optimization

- Multiple-equality part #1: Equality list building
- Constant propagation
- Trivial condition detection

Query transformations: Condition optimization

```
create table t1
  (a int primary key, b int);
select * from t1 where t1.a=0;
```

```
          {
            "rows_estimation": [
              {
                "table": "t1",
                "rows": 1,
                "cost": 1,
                "table_type": "const"
              }
            ]
          },
```

```
explain extended
select * from t1 where t1.a=0;
...
Warnings:
Note 1003 select 0 AS `a`,0 AS `b` from `test`.`t1` where 1
```

```
"condition_processing": {
  "condition": "WHERE",
  "original_condition": "t1.a = 0",
  "steps": [
    {
      "transformation": "equality_propagation",
      "resulting_condition": "multiple equal(0, t1.a)"
    },
    {
      "transformation": "constant_propagation",
      "resulting_condition": "multiple equal(0, t1.a)"
    },
    {
      "transformation": "trivial_condition_removal",
      "resulting_condition": "multiple equal(0, t1.a)"
    }
  ]
```

Optimization steps

- Query transformations (non-cost-based identical, open way for other optimizations)
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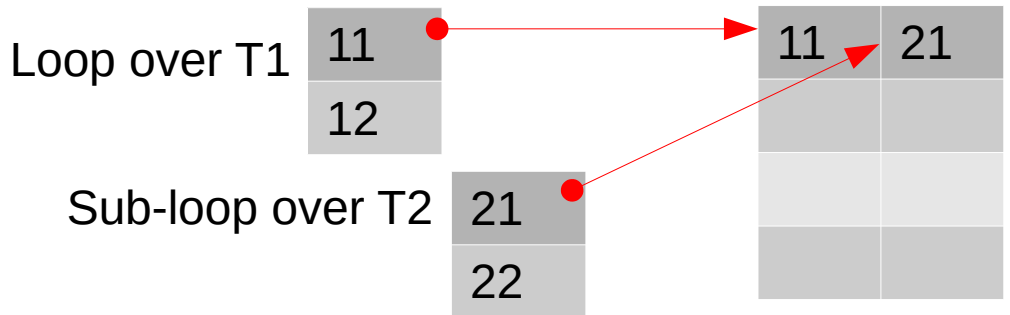
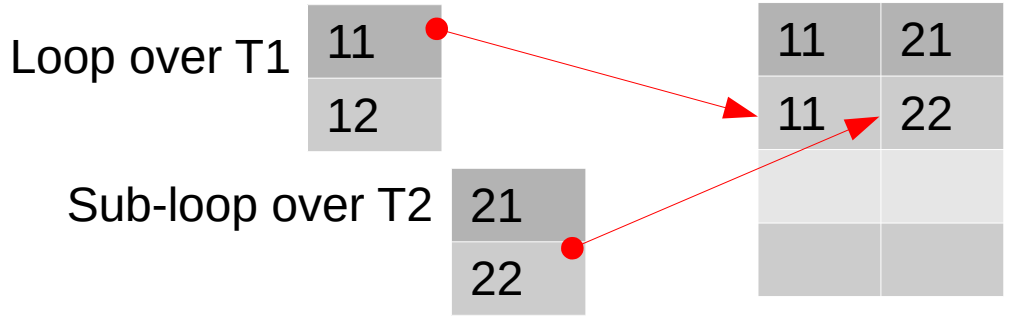
JOIN

MariaDB uses Nested loops



JOIN

MariaDB uses Nested loops



JOIN

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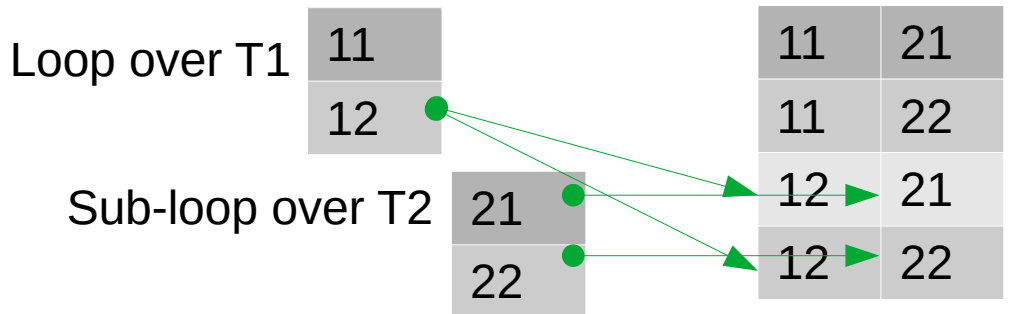

JOIN

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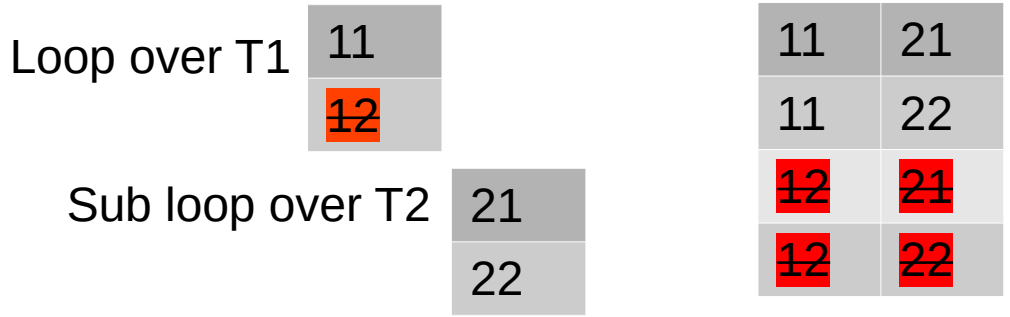

Each filtered row upper level multiply gain on lower level, so then more we filter on upper level then better.

Push Model (others)

Pull Model:

```
class query_plan_node
 { ...
  virtual int get_next();
 ...}
```

Upper level call get_next()

Pull Model (MariaDB)

```
Loop 1 (do_subselect())
  Loop 2 (do_subselect())
    …
      Loop N (do_subselect())
        send_data()
```

Join optimization - preliminary phase

- Check conditions/tables for possible “ref” access
- Get information about each table
  - Range analysis: produces possible range access
  - Partition pruning finds used partitions
  - Condition selectivity estimation (Use the range analysis with histograms instead of indexes)

Join optimization - preliminary phase

```
create table t1 (a int primary key, ...
create table t2 (a int primary key, …

select * from t1,t2
  where
    t1.a=t2.a and
    t2.a>1 and t2.a < 5;
```

```
{
  "ref_optimizer_key_uses": [
    {
      "table": "t1",
      "field": "a",
      "equals": "t2.a",
      "null_rejecting": false
    },
    {
      "table": "t2",
      "field": "a",
      "equals": "t1.a",
      "null_rejecting": false
    }
  ]
},
```

Join optimization - preliminary phase

```
"rows_estimation": [
  {
    "table": "t1",
    "range_analysis": {
      "table_scan": {
        "rows": 3,
        "cost": 4.7066
      },
```

```
"potential_range_indexes": [
  {
    "index": "PRIMARY",
    "usable": true,
    "key_parts": ["a"]
  }
],
"setup_range_conditions": [],
"group_index_range": {
  "chosen": false,
  "cause": "not single_table"
},
```

```
"analyzing_range_alternatives": {
 "range_scan_alternatives": [
   {
     "index": "PRIMARY",
     "ranges": ["(1) < (a) <
                (5)"],
     "rowid_ordered": false,
     "using_mrr": false,
     "index_only": false,
     "rows": 1,
     "cost": 2.5021,
     "chosen": true
   }
 ],
```

```
"analyzing_roworder_intersect": {
     "cause": "too few roworder scans"
   },
```

Join optimization - preliminary phase

t1	t2

<pre>"chosen_range_access_summary": {
  "range_access_plan": {
  "type": "range_scan",
  "index": "PRIMARY",
  "rows": 1,
  "ranges": ["(1) < (a) < (5)"]
  },
  "rows_for_plan": 1,
  "cost_for_plan": 2.5021,
  "chosen": true</pre>
	<pre>"chosen_range_access_summary": {
	  "range_access_plan": {
	  "type": "range_scan",
	  "index": "PRIMARY",
	  "rows": 3,
	  "ranges": ["(1) < (a) < (5)"]
	  },
	  "rows_for_plan": 3,
	  "cost_for_plan": 5.0064,
	  "chosen": true</pre>

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- Query transformations (non-cost-based identical, open way for other optimizations)
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Join optimization (greedy search)

- Limited by depth greedy search (recursive search)
  - use best variant on each step
  - reject branch (pruning) if we see that there is better
  - If depth is bigger then number of tables we get exhaustive search
- Work with prefixes

Join optimization (greedy search)

```
"considered_execution_plans": [
  {
    "plan_prefix": [],
    "table": "t1",
...
    "rows_for_plan": 1,
    "cost_for_plan": 2.7021,
    "rest_of_plan": [
      {
        "plan_prefix": ["t1"],
        "table": "t2",
...
        "rows_for_plan": 1,
        "cost_for_plan": 3.9021,
        "estimated_join_cardinality": 1
      }
...
```

```
  {
    "plan_prefix": [],
    "table": "t2",
...
    "rows_for_plan": 3,
    "cost_for_plan": 5.6064,
    "pruned_by_cost": true
  }
```

```
{
  "best_join_order": ["t1", "t2"]
},
```

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- Query transformations (non-cost-based identical, open way for other optimizations)
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Join optimization - plan refinement

- Take apart WHERE/ON conditions and attach them to tables
  - Multiple-Equality Part #2: Take Item_equal(a,b,c) and generate pair like a=b, a=c.
  - Multiple-Equality Part #3: Equality Substitution.
- Index condition push down
- Join buffering
- ORDER BY … LIMIT Optimization

Take apart WHERE/ON conditions

```
  select * from t1,t2
    where t1.a=t2.a and t2.a>1 and
       t2.a < 5 and cos(t1.b) > 0 and sin(t2.b) < 0;
```


```
{
  "attaching_conditions_to_tables": {
    "original_condition": "t2.a = t1.a and t1.a > 1 and t1.a < 5 and cos(t1.b) > 0 and sin(t2.b) <
0",
    "attached_conditions_computation": [],
    "attached_conditions_summary": [
      {
        "table": "t1",
        "attached": "t1.a > 1 and t1.a < 5 and cos(t1.b) > 0"
      },
      {
        "table": "t2",
        "attached": "sin(t2.b) < 0"
      }
    ]
  }
}
```

Multiple-Equality Part #2

- Item_equal(a,b,c) can be:
  - a=b and b=c
  - a=c and c=b

  we choose that which will be calculated earlier

Multiple-Equality Part #3

- With equality substitution we can have limitations like for varchars: X=Y but LENGTH(X) <> LENGTH(Y)

ORDER BY … LIMIT Optimization

Check how to satisfy ORDER BY LIMIT:

- Are we using an index that produces data in the required ordering
- If yes: disable optimizations that “break ordering” (e.g. join buffer)
- If not: check if we can use a different index to produce data in the required ordering (and if this would be cheaper, but we can only change the index for the first table in the join)

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Other kinds of plan refinement

- Distinct, Window functions.
- Convert DISTINCT into GROUP BY if possible
- ...