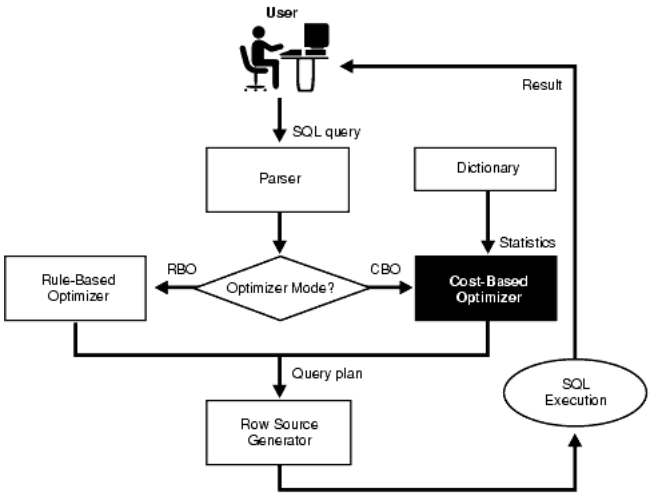
ORACLE DATABASE PL/SQL

ORACLE OPTIMIZER- RBO/CBO

How OPTIMIZER works in ORACLE? What is RULE BASED and COST BASED OPTIMIZATION in ORACLE.

The optimizer determines the most efficient way to execute a SQL statement after considering many factors related to the objects referenced and the conditions specified in the query. This determination is an important step in the processing of any SQL statement and can greatly affect execution time.



IMG Source- https://docs.oracle.com

RBO- Rule Based Optimizer – Whenever we execute any SQL, the Optimizer will use execution plan based on some predefined rules. So, Query should be matched with the rules specified by RBO if not matched then it will result in Full Table scan. It works just like a Machine works on some rules and instructions.

The functionality is still present but no new functionality has been included in it and it is no longer supported by Oracle. It is only present to provide backwards compatibility during the migration to the query optimizer (Cost Based Optimizer).

CBO- Cost Based Optimizer – CBO uses Artificial Intelligence to decide the Execution Plan for SQL Query based on the Query Statistics. The cost-based method means the database must decide which query execution plan to choose using best guess approach that takes into account what data is stored in db. The Oracle cost-based optimizer is designed to determine the most efficient way to carry out a SQL statement, but it can't reach do this without good, up-to-date statistical information on the data being accessed.

With the cost-based approach, the optimizer factors in statistical information about the contents of the particular schema objects (tables, clusters, or indexes) being accessed.

Earlier, the only optimizer in the Oracle database was the Rule-Based Optimizer (RBO). Basically, the RBO used a set of rules to determine how to execute a query. If an index was available on a table, the RBO rules said to always use the index. There are some cases where the use of an index slowed down a query.

For Example:
There is an index on the GENDER column which holds one of two values MALE and FEMALE. Then someone issues the following query:
SELECT * FROM Employee WHERE gender 'FEMALE';

If the above query returned approximately 50 of the rows, then using an index would actually slow things down. It would be faster to read the entire table and throw away all rows that have MALE values. Rule of thumb says if the number of rows returned is more than 5-10 of the total table volume using an index would slow things down. The RBO would always use an index if present because its rules said to.

ORACLE Topics

The biggest problem with the RBO was that it did not take the data distribution into account. So, the Cost-Based Optimizer (CBO) was came into picture. The CBO uses statistics about the table its indexes and the data distribution to make better informed decisions.

Now, assume that the company has employees that are 95 females and 5 males. If you query for females, then you do not want to use the index. If you query for males, then you would like to use the index. The CBO has information at hand to help make these kinds of determinations that were not available in the Rule Based Optimization.
SQL processing uses the following main components to execute a SQL query:

- The Parser checks both syntax and semantic analysis.
- The Optimizer uses costing methods, cost-based optimizer (CBO), or internal rules, rule-based optimizer (RBO), to determine the most efficient way of producing the result of the query.
- The Row Source Generator receives the optimal plan from the optimizer and outputs the execution plan for the SQL statement.
- The SQL Execution Engine operates on the execution plan associated with a SQL statement and then produces the results of the query.

A SQL statement can be executed in many different ways, including the following:

- Full table scans
- Index scans
- Nested loops
- Hash joins

Full Table Scans
This type of scan reads all rows from a table and filters out those that do not meet the selection criteria. During a full table scan, all blocks in the table that are under the high-water mark are scanned. Each row is examined to determine whether it satisfies the statement's WHERE clause.
When Oracle performs a full table scan, the blocks are read sequentially. Because the blocks are adjacent, I/O calls larger than a single block can be used to speed up the process.
Why a Full Table Scan Is Faster for Accessing Large Amounts of Data?
Full table scans are cheaper than index range scans when accessing a large fraction of the blocks in a table. This is because full table scans can use larger I/O calls, and making fewer large I/O calls is cheaper than making many smaller calls.

When the Optimizer Uses, Full Table Scans?
The optimizer uses a full table scan in any of the following cases:

- **Lack of Index or Indexed column used with Functions:** If the query is unable to use any existing indexes, then it uses a full table scan. For example, if there is a function used on the indexed column in the query, the optimizer is unable to use the index and instead uses a full table scan

```
SELECT FIRST_NAME, LAST_NAME FROM Employees

WHERE UPPER(LAST_NAME) LIKE :B1; /*Even if there is an Index on LAST_NAME it will not be used by ORACLE*/
```

- **Access Large Amount of Data:** If the optimizer thinks that the query will access most of the blocks in the table, then it uses a full table scan, even though indexes might be available.

- **High Degree of Parallelism:** A high degree of parallelism for a table skews the optimizer toward full table scans over range scans. Examine the DEGREE column in ALL_TABLES for the table to determine the degree of parallelism.

Full Table Scan Hints
FULL hint in ORACLE is used if you want to force the use of a full table scan.

Without Using the FULL Hint

```
SQL> SELECT EMP_NO, ENAME
  2  From EMPLOYEES
  3  Where DEPTNO IN(10,20);

    EMP_NO ENAME
---------- ----------
      1001 Ravi
      1002 Surya
      1006 Rajan
      1007 Manu
      1008 Karan


Execution Plan
----------------------------------------------------------
Plan hash value: 522316573

-------------------------------------------------------------------------------------------
| Id  | Operation                    | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT             |           |     3 |    42 |     2   (0)| 00:00:01 |
|   1 |  INLIST ITERATOR             |           |       |       |            |          |
|   2 |   TABLE ACCESS BY INDEX ROWID| EMPLOYEES |     3 |    42 |     2   (0)| 00:00:01 |
|*  3 |    INDEX RANGE SCAN          | IND_DEP   |     3 |       |     1   (0)| 00:00:01 |
-------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - access("DEPTNO"=10 OR "DEPTNO"=20)


Statistics
----------------------------------------------------------
          0  recursive calls
          0  db block gets
```

```
          5  consistent gets
          0  physical reads
          0  redo size
        702  bytes sent via SQL*Net to client
        519  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
          5  rows processed
```

After Using the FULL Hint

```
SQL> SELECT /*+ FULL(EMP) */  EMP_NO, ENAME
  2  From EMPLOYEES EMP
  3  Where DEPTNO IN(10,20);

    EMP_NO ENAME
---------- ----------
      1001 Ravi
      1002 Surya
      1006 Rajan
      1007 Manu
      1008 Karan


Execution Plan
----------------------------------------------------------
Plan hash value: 1445457117

--------------------------------------------------------------------------------
| Id  | Operation         | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------
|   0 | SELECT STATEMENT  |           |     3 |    42 |     3   (0)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| EMPLOYEES |     3 |    42 |     3   (0)| 00:00:01 |
--------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   1 - filter("DEPTNO"=10 OR "DEPTNO"=20)


Statistics
----------------------------------------------------------
          1  recursive calls
          0  db block gets
          4  consistent gets
          0  physical reads
          0  redo size
        702  bytes sent via SQL*Net to client
        519  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
          5  rows processed
```

Index Scans

In Index Scans rows are accessed and retrieved using an Index on column values specified by the statement. An index scan retrieves data from an index based on the value of one or more columns in the index. To perform an index scan, Oracle searches the index for the indexed column values accessed by the statement.

Index Scan Hints

A hint might be required if the optimizer chooses some other index or uses a full table scan. The hint INDEX(*table_alias index_name*) specifies the index to use.

```
SQL> SELECT /*+ INDEX(EMP IND_DEP) */  EMP_NO, ENAME, SALARY, DEPTNO, DNAME
  2  From EMPLOYEES EMP
  3  Where DEPTNO IN(10,20,30);

    EMP_NO ENAME          SALARY     DEPTNO DNAME
---------- ---------- ---------- ---------- ----------
      1001 Ravi            48000         10 ACCOUNTS
      1002 Surya           89000         20 SALES
      1006 Rajan           77770         20 SALES
      1007 Manu            98888         20 BANKING
      1008 Karan           48000         20 BANKING
      1003 Ankit           89000         30 ACCOUNTS

6 rows selected.


Execution Plan
----------------------------------------------------------
Plan hash value: 522316573

--------------------------------------------------------------------------------------------
| Id  | Operation                    | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
--------------------------------------------------------------------------------------------
```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```
|   0 | SELECT STATEMENT            |           |     5 |   135 |     2   (0)| 00:00:01 |
|   1 |  INLIST ITERATOR            |           |       |       |            |          |
|   2 |   TABLE ACCESS BY INDEX ROWID| EMPLOYEES |     5 |   135 |     2   (0)| 00:00:01 |
|*  3 |    INDEX RANGE SCAN         | IND_DEP   |     5 |       |     1   (0)| 00:00:01 |
---------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   3 - access("DEPTNO"=10 OR "DEPTNO"=20 OR "DEPTNO"=30)


Statistics
----------------------------------------------------------
          1  recursive calls
          0  db block gets
          5  consistent gets
          0  physical reads
          0  redo size
       1072  bytes sent via SQL*Net to client
        519  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
          6  rows processed
```

Check another example of INDEX Range Scan Descending:

An index range scan descending is identical to an index range scan, except that the data is returned in descending order. Indexes, by default, are stored in ascending order. Usually, this scan is used when ordering data in a descending order to return the most recent data first, or when seeking a value less than a specified value.

```
SQL> SELECT /*+ INDEX_DESC(EMP IND_EMPNO) */  EMP_NO, ENAME, SALARY, DEPTNO, DNAME
  2  From EMPLOYEES EMP
  3  Where EMP_NO<1006 Order By EMP_NO DESC;

    EMP_NO ENAME          SALARY     DEPTNO DNAME
---------- ---------- ---------- ---------- ----------
      1005 Pritesh         48000         50 ACCOUNTS
      1004 Nikhil          77770         40 SALES
      1003 Ankit           89000         30 ACCOUNTS
      1002 Surya           89000         20 SALES
      1001 Ravi            48000         10 ACCOUNTS


Execution Plan
----------------------------------------------------------
Plan hash value: 507161224

-----------------------------------------------------------------------------------------------
| Id  | Operation                    | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
-----------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT             |           |     6 |   162 |     2   (0)| 00:00:01 |
|   1 |  TABLE ACCESS BY INDEX ROWID | EMPLOYEES |     6 |   162 |     2   (0)| 00:00:01 |
|*  2 |   INDEX RANGE SCAN DESCENDING| IND_EMPNO |     6 |       |     1   (0)| 00:00:01 |
-----------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   2 - access("EMP_NO"<1006)


Statistics
----------------------------------------------------------
          1  recursive calls
          0  db block gets
          4  consistent gets
          0  physical reads
          0  redo size
       1037  bytes sent via SQL*Net to client
        519  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
```

When the Optimizer Uses, Nested Loop Joins

The optimizer uses nested loop joins when joining small number of rows, with a good driving condition between the two tables. You drive from the outer loop to the inner loop, so the order of tables in the execution plan is important.

The outer loop is the driving row source. It produces a set of rows for driving the join condition. The row source can be a table accessed using an index scan or a full table scan. Also, the rows can be produced from any other operation. For example, the output from a nested loop join can be used as a row source for another nested loop join.

So, when joining table A and B (A is driving table, B is the probed table), then a nested loop join can take 1st row from A and perform a lookup to B using that value (of the column(s) you join by). Then nested loop takes the next row from A and performs another lookup to table B using

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- ORACLE SQL* Loader
- EXPORT TABLE Data to Flat Files
- ORACLE TABLE PARTITIONING
- UTL_FILE Import Data into ORACLE TA
- ORACLE PL/SQL Tuning
- ORACLE UTL_FILE
- Using BULK Collect

the new value. And so on and so on and so on.

Nested Loop Join Hints

If the optimizer is choosing to use some other join method, you can use the USE_NL(table1 table2) hint, where table1 and table2 are the aliases of the tables being joined.
The USE_NL hint causes Oracle to join each specified table to another row source with a nested loop join, using the specified table as the inner table.

```
SELECT /*+ USE_NL(E D) */ E.EMP_NO, E.ENAME, D.DEPTNAME
  From EMP_TEST E, DEPT_TEST D

  Where E.DEPTNO=D.DEPTNO;
```

Hash Joins

Hash joins are used for joining large data sets. The optimizer uses the smaller of two tables or data sources to build a hash table on the join key in memory. It then scans the larger table, probing the hash table to find the joined rows.

This method is best used when the smaller table fits in available memory. The cost is then limited to a single read pass over the data for the two tables.

Essentially, a hash join is a technique whereby Oracle loads the rows from the driving table (the smallest table, first after the where clause). Oracle then uses a hashing technique to locate the rows in the larger second table. A hash join is often combined with parallel query in cases where both tables are very large.

When the Optimizer Uses, Hash Joins

The optimizer uses a hash join to join two tables if they are joined using an equijoin and if either of the following conditions are true:

- A large amount of data needs to be joined.
- A large fraction of the table needs to be joined.

Hash Join Hints

Apply the USE_HASH hint to advise the optimizer to use a hash join when joining two tables together. If you are having trouble getting the optimizer to use hash joins, investigate the values for the HASH_AREA_SIZE and HASH_JOIN_ENABLED parameters.

```
SQL> SELECT /*+ Use_Hash(E,D) */ E.EMP_NO, E.ENAME, D.DEPTNAME
  2  From EMP_TEST E, DEPT_TEST D
  3  Where E.DEPTNO=D.DEPTNO;

    EMP_NO ENAME      DEPTNAME
---------- ---------- --------------------
      1001 Ravi       Accounts
      1002 Surya      Retail
      1003 Ankit      Insurance
      1004 Nikhil     Banking
      1005 Pritesh    Cloud
      1006 Rajan      Retail
      1007 Manu       Retail
      1008 Karan      Retail

8 rows selected.


Execution Plan
----------------------------------------------------------
Plan hash value: 2815500728

-------------------------------------------------------------------------------
| Id  | Operation          | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |           |     8 |   200 |     7  (15)| 00:00:01 |
|*  1 |  HASH JOIN         |           |     8 |   200 |     7  (15)| 00:00:01 |
|   2 |   TABLE ACCESS FULL| DEPT_TEST |     5 |    55 |     3   (0)| 00:00:01 |
|   3 |   TABLE ACCESS FULL| EMP_TEST  |     8 |   112 |     3   (0)| 00:00:01 |
-------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   1 - access("E"."DEPTNO"="D"."DEPTNO")


Statistics
----------------------------------------------------------
          1  recursive calls
          0  db block gets
         15  consistent gets
          0  physical reads
          0  redo size
        867  bytes sent via SQL*Net to client
        519  bytes received via SQL*Net from client
          2  SQL*Net roundtrips to/from client
          0  sorts (memory)
          0  sorts (disk)
          8  rows processed
```

Hash joins are often faster than nested loop joins, especially in cases where the driving table is filtered into a small number of rows in the query's where clause.

In general, nested loop joins work best when there are useful indexes and the percentage of data returned is small. Hash joins work best when there are no useful indexes or when the join will return a large percentage of rows. It is usually better to avoid hints and let Oracle decide how to build an execution plan.

Get involved and leave your Comments in the Box Below. The more people get involved, the more we all benefit. So, leave your thoughts before you leave the page.

4 comments:

Vicky ETL February 15, 2017 at 8:07 PM

Could you pls explain me when optimizer go for RBO. Becoz as per my knowlege after oracle 9i there is only CBO optimizer , please correct me if I m wrong.

Reply

Replies

Ravikant Baluni February 16, 2017 at 5:24 AM

Yes, I have already written it under RBO section.

Reply

Vicky ETL February 15, 2017 at 8:13 PM

On what basis we decide Driving and driven table
for example
select e.*,d.* from emp e , dept d where e.deptno=d.deptno
which table is driving and driven table.
Could you please explain me and also why ?

Reply

Replies

Ravikant Baluni February 16, 2017 at 8:37 AM

here you go...
https://tipsfororacle.blogspot.in/2017/02/oracle-driving-tables.html

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