Oracle White Paper
June 2013

Best Practices for Gathering Optimizer Statistics with Oracle Database 12*c*

Introduction

The Oracle Optimizer examines all of the possible plans for a SQL statement and picks the one with the lowest cost, where cost represents the estimated resource usage for a given plan. In order for the Optimizer to accurately determine the cost for an execution plan it must have information about all of the objects (table and indexes) accessed in the SQL statement as well as information about the system on which the SQL statement will be run.

This necessary information is commonly referred to as **Optimizer statistics**. Understanding and managing Optimizer statistics is key to optimal SQL execution. Knowing when and how to gather statistics in a timely manner is critical to maintaining acceptable performance. This whitepaper is the second of a two part series on Optimizer statistics. The first part of this series, Understanding Optimizer Statistics, focuses on the concepts of statistics and will be referenced several times in this paper as a source of additional information. This paper will discuss in detail, when and how to gather statistics for the most common scenarios seen in an Oracle Database. The topics are

- How to gather statistics
- When to gather statistics
- Improving the efficiency of gathering statistics
- When not to gather statistics
- Gathering other types of statistics

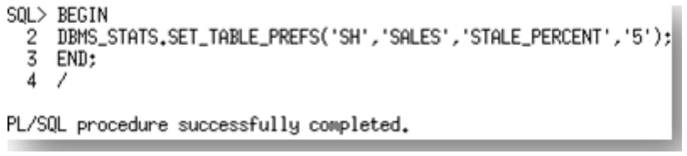
How to gather statistics

The preferred method for gathering statistics in Oracle is to use the supplied automatic statistics-gathering job.

Automatic statistics gathering job

The job collects statistics for all database objects, which are missing statistics or have stale statistics by running an Oracle AutoTask task during a predefined maintenance window. Oracle internally prioritizes the database objects that require statistics, so that those objects, which most need updated statistics, are processed first.

The automatic statistics-gathering job uses the `DBMS_STATS.GATHER_DATABASE_STATS_JOB_PROC` procedure, which uses the same default parameter values as the other `DBMS_STATS.GATHER_*_STATS` procedures. The defaults are sufficient in most cases. However, it is occasionally necessary to change the default value of one of the statistics gathering parameters, which can be accomplished by using the `DBMS_STATS.SET_*_PREF` procedures. Parameter values should be changed at the smallest scope possible, ideally on a per-object bases. For example, if you want to change the staleness threshold for a specific table, so its statistics are considered stale when only 5% of the rows in the table have changed rather than the default 10%, you can change the `STALE_PERCENT` table preference for that one table using the `DBMS_STATS.SET_TABLE_PREFS` procedure. By changing the default value at the smallest scope you limit the amount of non-default parameter values that need to be manually managed.

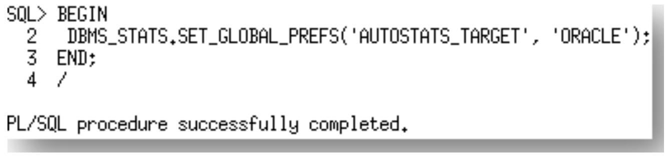


```
SQL> BEGIN
  2  DBMS_STATS.SET_TABLE_PREFS('SH','SALES','STALE_PERCENT','5');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 1. Using DBMS_STATS.SET_TABLE_PREFS procedure to change STALE_PRECENT to 5% on SALES table

Manually statistics collection

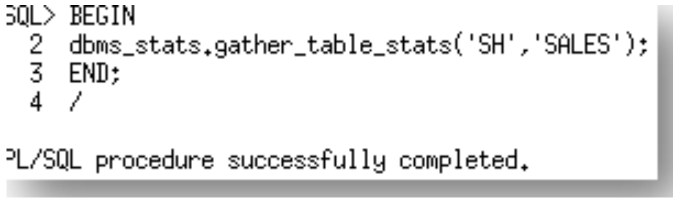
If you already have a well-established statistics gathering procedure or if for some other reason you want to disable automatic statistics gathering for your main application schema, consider leaving it on for the dictionary tables. You can do so by changing the value of `AUTOSTATS_TARGET` parameter to `ORACLE` instead of `AUTO` using `DBMS_STATS.SET_GLOBAL_PREFS` procedure.



```
SQL> BEGIN
  2   DBMS_STATS.SET_GLOBAL_PREFS('AUTOSTATS_TARGET', 'ORACLE');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 2. Changing the automatic statistics gather job to just gather dictionary statistics

To manually gather statistics you should used the `PL/SQL` package, `DBMS_STATS`, which replaces the now obsolete, `ANALYZE`[1] command for collecting statistics. The package `DBMS_STATS` provides multiple `DBMS_STATS.GATHER_*_STATS` procedures to gather statistics on both user schema objects as well as dictionary and fixed objects. Ideally you should let all of the parameters for these procedures default except for schema name and object name. The defaults and adaptive parameter settings chosen by the Oracle are sufficient in most cases.



```
SQL> BEGIN
  2  dbms_stats.gather_table_stats('SH','SALES');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 3. Using the DBMS_STATS.GATHER_TABLE_STATS procedure

As mentioned above, if it does become necessary to change the default value of one of the statistics gathering parameters, using the `DBMS_STATS.SET_*_PREF` procedures to make the change at the smallest scope possible, ideally on a per-object bases.

The two parameters most frequently changed from their default values are `ESTIMATE_PERCENT` and `METHOD_OPT`, especially in releases prior to Oracle Database 11g Release 1.

ESTIMATE_PERCENT

The most commonly asked questions around statistics gathering best practices is 'what sample size should I use?' This question relates to setting the `ESTIMATE_PRECENT` parameter of the `DBMS_STATS.GATHER_*_STATS` procedures. The `ESTIMATE_PERCENT` parameter determines the percentage of rows used to calculate the statistics. The most accurate statistics are gathered when all rows in the table are processed (i.e., 100% sample). However, the larger the sample size the longer the statistics gathering operation will take. So how do you come up with a sample size that provides accurate statistics in a timely manner?

ESTIMATE_PERCENT prior to Oracle Database 11g

In Oracle Database 10g, the default value for `ESTIMATE_PRECENT` changed from a 100% sample to `AUTO_SAMPLE_SIZE`. The goal of `AUTO_SAMPLE_SIZE` was for Oracle to determine the appropriate sample size for each table, each time statistics were gathered. This would allow Oracle to automatically change the sample size as the data within each table changed but still ensure statistics were gathered in a timely manner. This approach worked well for most tables but it had some issues if there was an extreme skew in the data. The `AUTO_SAMPLE_SIZE` algorithm often chose too small a sample size

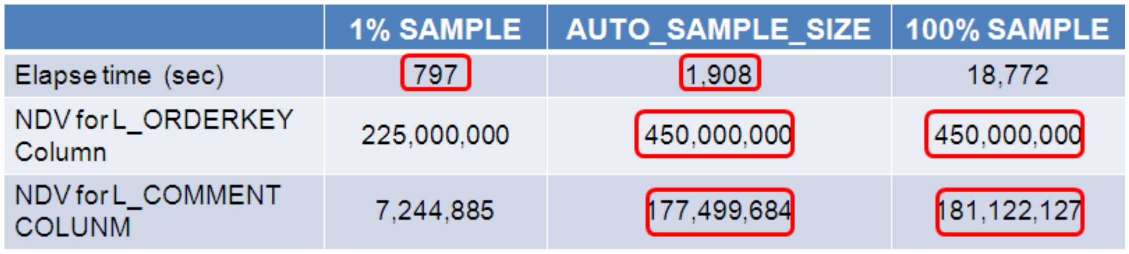
[1] ANALYZE command should only be used to `VALIDATE` or `LIST CHAINED ROWS`.

when an extreme skew was present. In such cases it was still better to manually specify the ESTIMATE_PERCENT.

ESTIMATE_PERCENT from Oracle Database 11g onward

Oracle Database 11g introduced a new one-pass, hash-based distinct algorithm that provides deterministic statistics, addressing the two key aspects of accuracy and speed[2]. It has accuracy close to a 100% sample ("reads all data") but with the cost of, at most, a 10% sample (memory based). This new algorithm is only used when ESTIMATE_PERCENT is set to AUTO_SAMPLE_SIZE (the default) in any of the DBMS_STATS.GATHER_*_STATS procedures.

The table below shows the results, of an easily reproducible test that gathers statistics with a 1% sample, a 100% sample, and AUTO_SAMPLE_SIZE on the Lineitem table (230GB) from the TPC-H benchmark with a scale factor of 300. The first line compares the elapsed time for each run, while the subsequent lines shows the number of distinct values (NDV) calculated for each run for two different columns, L_ORDERKEY and L_COMMENT.



	1% SAMPLE	AUTO_SAMPLE_SIZE	100% SAMPLE
Elapse time (sec)	797	1,908	18,772
NDV for L_ORDERKEY Column	225,000,000	450,000,000	450,000,000
NDV for L_COMMENT COLUMN	7,244,885	177,499,684	181,122,127

Figure 4. Comparison of the elapse time taken & statistic generated by a 1%, 100% sample & AUTO_SAMPLE_SIZE

In this scenario the new AUTO_SAMPLE_SIZE algorithm was 9 times faster than the 100% sample and only 2.4 times slower than the 1 % sample, while the quality of the statistics it produced were nearly identical to a 100% sample (not different enough to change the execution plans). Note the timings for this experiment may vary on your system and the larger the data set, the more speedup you will encounter from the new algorithm.

It is highly recommended from Oracle Database 11g onward you let ESTIMATE_PRECENT default. If you manually set the ESTIMATE_PRECENT parameter, even if it is set to 100%, you will get the old statistics gathering algorithm.

[2] For more information on the AUTO_SAMPLE_SIZE algorithm please refer to the VLDB paper, Efficient and scalable statistics gathering for large databases in Oracle 11g

METHOD_OPT

By far the most controversial parameter in the DBMS_STATS.GATHER_*_STATS procedures is the METHOD_OPT parameter. The METHOD_OPT parameter controls the creation of histograms[3] during statistics collection. Histograms are a special type of column statistic created to provide more detailed information on the data distribution in a table column. So why are histograms such a controversial issue?

Histogram creation does extend the elapse time and the system resources needed for statistics collection but the far bigger concerns people have with histograms comes from their interaction with the bind peeking feature and how their presence affects the cardinality estimates for near popular values.

Histograms and bind peeking

The adverse affect of histograms on bind peeking has been relieved in Oracle Database 11g with the introduction of Adaptive Cursor Sharing but the fear still remains today. In order to explain how Adaptive Cursor Sharing addresses this problem, let's first examine the cause of the problem.

Prior to Oracle Database 11g histograms and bind peeking

Prior to Oracle Database 11g, when optimizing a SQL statement that contains bind variables in the WHERE clause the Optimizer peeks at the values of these bind variables on the first execution (during hard parse) of the statement. The Optimizer then determines the execution plan based on these initial bind values. On subsequent executions of the query, no peeking takes place (no hard parse happens), so the original execution plan, determined with the first set of bind values, will be used by all future executions, even if the values of the bind variables change.

The presence of a histogram on the column used in the expression with the bind variable will help to determine the most optimal execution plan for the initial set of bind values. Consequently, the execution plan for the same SQL statement can be different, depending on the values of the bind variables used for the initial hard parse.

There were two solutions to avoid this behavior: drop the histogram and stop collecting them in the future or disable the bind peeking. You can determine which approach suits your pre-Oracle Database 11g environment best, by answering a simple question; Do all of the SQL statements in this environment use bind variables or not?

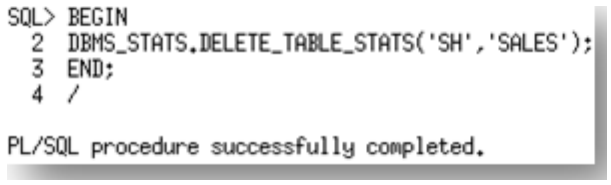
Disabling histogram creation

If your environment only has SQL statements with bind variables then it is better to drop the existing histograms and disable histograms from being created in the future. Disabling histogram creation

[3] More information on the creation of histograms can be found in part one of this series, Understanding Optimizer Statistics.

ensures the execution plan will not change depending on the bind variable value and will furthermore reduce the time it takes to gather statistics. Without the histograms on the column the Optimizer will assume a uniform distribution of rows across the distinct values in a column and will use NDV to determine the cardinality estimate when it peeks at the initial bind values in the SQL statements.

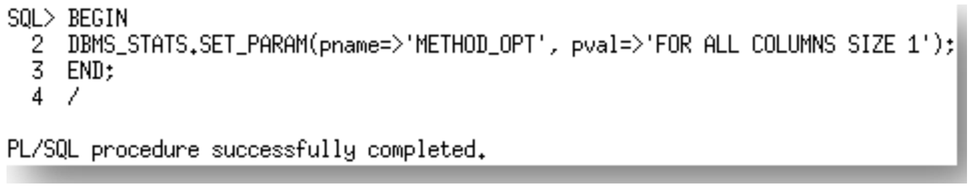
You can begin by dropping the existing statistics including the histogram using the `DBMS_STATS.DELETE_TABLE_STATS` procedure.



```
SQL> BEGIN
  2  DBMS_STATS.DELETE_TABLE_STATS('SH','SALES');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 5. Drop statistics including histograms on the Sales table prior to 11g

Next, change the default value for the `METHOD_OPT` parameter to prevent histograms from being created in the future by using the `DBMS_STATS.SET_PARAM` procedure. This ensures that both the `DBMS_STATS.GATHER_*_STATS` procedures and the automatic statistics gathering job will not collect histograms in the future.



```
SQL> BEGIN
  2  DBMS_STATS.SET_PARAM(pname=>'METHOD_OPT', pval=>'FOR ALL COLUMNS SIZE 1');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 6. Change the default value of the METHOD_OPT parameter prior to 11g

Finally you can re-gather statistics for the effected object using the `DBMS_STATS.GATHER_TABLE_STATS` procedure.

Note from Oracle Database 11g onwards, you can drop unwanted histograms without dropping all column statistics by using `DBMS_STATS.DELETE_COLUMN_STATS` and setting the col_stat_type to histogram. You can also disable histogram creation on a single table or just a column within that table using the `DBMS_STATS.SET_TABLE_PREFS` procedure.

You should be aware that histograms can also be used for some join predicates and dropping them may have an adverse effect on join cardinality estimates. In these cases it may be safer to disable bind peeking.

Disabling bind peeking

If your environment has some SQL statements with bind variables and some with literal values then you should disable bind peeking. By disabling bind peeking you will prevent the Optimizer from peeking at the initial bind value and it will not use the histogram to determine the cardinality estimates for the statement. Instead the Optimizer will assume a uniform distribution of rows across the distinct values in a column and will use NDV to determine the cardinality estimate. This will ensure a consistent execution plan for the statements with binds. But the SQL statements with literal values will still be able to take advantage of the histograms and get the most optimal plan. You can disable bind peeking by setting the underscore parameter `_OPTIM_PEEK_USER_BINDS` to `FALSE`.

Histograms and bind peeking in Oracle Database 11g onwards

In Oracle Database 11g, the Optimizer was enhanced to allow multiple execution plans to be used for a single statement with bind variables. This functionality is called Adaptive Cursor Sharing [4]and relies on the monitoring of execution statistics to ensure the correct plan is used for each bind value.

On the first execution the Optimizer will peek the bind value and determine the execution plan based on the bind values selectivity, just like it did in previous release. The cursor will be marked bind sensitive if the Optimizer believes the optimal plan may depend on the value of the bind variable (for example, a histogram is present on the column or the predicate is a range, or <, >). When a cursor is marked bind sensitive, Oracle monitors the behavior of the cursor using different bind values, to determine if a different plan is called for.

If a different bind value is used in a subsequent execution, it will use the same execution plan because Oracle initially assumes it can be shared. However, the execution statistics for this new bind value will be recorded and compared to the execution statistics for the previous value. If Oracle determines that the new bind value caused the data volumes manipulated by the query to be significantly different it "adapts" and hard parses based on the new bind value on its next execution and the cursor is marked bind-aware. Each bind-aware cursor is associated with a selectivity range of the bind so that the cursor is only shared for a statement when the bind value in the statement is believed to fall within the range.

When another new bind value is used, the Optimizer tries to find a cursor it thinks will be a good fit, based on similarity in the bind value's selectivity. If it cannot find such a cursor, it will create a new one. If the plan for the new cursor is the same as an existing cursor, the two cursors will be merged to save space in the shared pool. And the selectivity range for that cursor will be increased to include the selectivity of the new bind.

By allowing multiple execution plans for a single SQL statement, histograms no longer have a negative impact for statements that use bind variables.

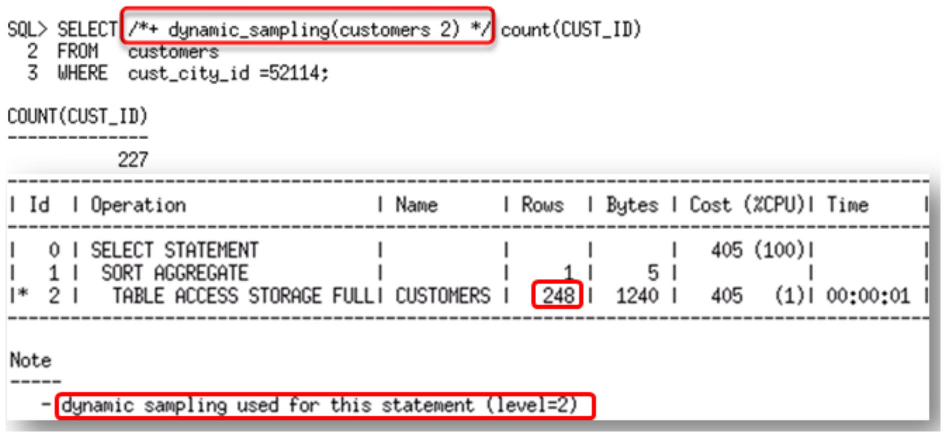
Histograms and near popular values

Prior to Oracle Database 12*c*, a height balanced histogram was created when the number of distinct values in a column was greater than 254. Only values that appear as the end point of two or more buckets of a height balanced histogram are considered popular. One prominent problem with height balanced histograms is that a value with a frequency that falls into the range of 1/254 of the total

[4] More information on Adaptive Cursor Sharing can be found in [Closing the Query Loop in Oracle 11g]

population and 2/254 of the total population may or may not appear as a popular value. Although it might span across two 2 buckets it may only appear as the end point value of one bucket. Such values are referred to as almost popular values. Height balanced histograms do not differentiate between almost popular values and truly unpopular values.

The only way to make the Optimizer aware of these near popular values is to use dynamic sampling[5]. Dynamic sampling collects additional statement-specific object statistics during the optimization of a SQL statement. In this example the dynamic sampling hint is added to the query and the Optimizer get a much more accurate cardinality estimate.



```
SQL> SELECT /*+ dynamic_sampling(customers 2) */ count(CUST_ID)
  2  FROM   customers
  3  WHERE  cust_city_id =52114;

COUNT(CUST_ID)
--------------
           227
-----------------------------------------------------------------------------------
| Id  | Operation                  | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
-----------------------------------------------------------------------------------
|   0 | SELECT STATEMENT           |           |       |       |   405 (100)|          |
|   1 |  SORT AGGREGATE            |           |     1 |     5 |            |          |
|*  2 |   TABLE ACCESS STORAGE FULL| CUSTOMERS |   248 |  1240 |   405   (1)| 00:00:01 |
-----------------------------------------------------------------------------------

Note
-----
   - dynamic sampling used for this statement (level=2)
```

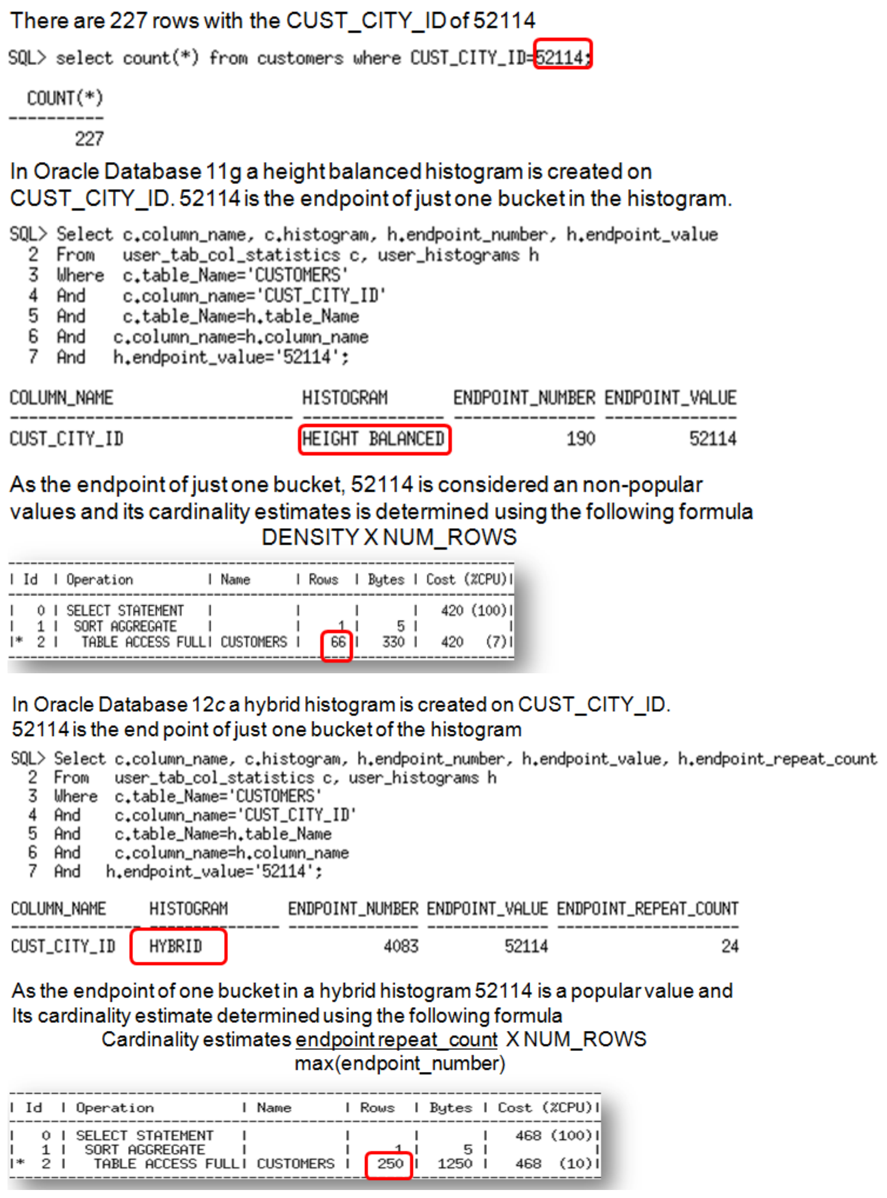
Figure 7. Use dynamic sampling to improve cardinality estimates for non-popular value in height balanced histogram

In Oracle Database 12*c*, a hybrid histogram is created when the number of distinct values in a column is greater than 254. With a hybrid histogram no value will be the endpoint of more than one bucket, thus allowing the histogram to have more endpoint values or effectively more buckets than a height-balanced histogram. So, how does a hybrid histogram indicate a popular value? The frequency of each endpoint value is recorded (in a new column endpoint_repeat_count), thus providing an accurate indication of the popularity of each endpoint value.

Take for example the `CUST_CITY_ID` column in the `CUSTOMERS` table.   There are 55,500 rows in the CUSTOMERS table and 620 distinct values in the `CUST_CITY_ID` column. Neither a frequency nor a top-frequency histogram is an option in this case. In Oracle Database 11g, a height balanced histogram is created on this column. The height balanced histogram has 213 buckets but only represents 42 popular values (value is the endpoint of 2 or more buckets). The actual number of popular values in `CUST_CITY_ID` column is 54 (i.e., column values with a frequency that is larger than num_rows/num_buckets = 55500/254= 54).

[5] More information on dynamic sampling and how it works can be found in part one of this series, Understanding Optimizer Statistics.

In Oracle Database 12*c* a hybrid histogram is created. The hybrid histogram has 254 buckets and represents all 54 popular values. The hybrid histogram actually treats 63 values as popular values. This means that values that were considered as nearly popular (endpoint value of only 1 bucket) in Oracle Database 11g are now treated as popular values and will have a more accurate cardinality estimate. Figure 8 shows an example of how a nearly popular value (52114) in Oracle Database 11g get a much better cardinality estimate in Oracle Database 12*c*.



There are 227 rows with the CUST_CITY_ID of 52114

```
SQL> select count(*) from customers where CUST_CITY_ID=52114;

  COUNT(*)
----------
       227
```

In Oracle Database 11g a height balanced histogram is created on CUST_CITY_ID. 52114 is the endpoint of just one bucket in the histogram.

```
SQL> Select c.column_name, c.histogram, h.endpoint_number, h.endpoint_value
  2  From   user_tab_col_statistics c, user_histograms h
  3  Where  c.table_Name='CUSTOMERS'
  4  And    c.column_name='CUST_CITY_ID'
  5  And    c.table_Name=h.table_Name
  6  And   c.column_name=h.column_name
  7  And   h.endpoint_value='52114';

COLUMN_NAME                     HISTOGRAM       ENDPOINT_NUMBER ENDPOINT_VALUE
------------------------------- --------------- --------------- --------------
CUST_CITY_ID                    HEIGHT BALANCED             190          52114
```

As the endpoint of just one bucket, 52114 is considered an non-popular values and its cardinality estimates is determined using the following formula

DENSITY X NUM_ROWS

```
--------------------------------------------------------------------------
| Id  | Operation          | Name      | Rows  | Bytes | Cost (%CPU)|
--------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |           |       |       |   420 (100)|
|   1 |  SORT AGGREGATE    |           |     1 |     5 |            |
|*  2 |   TABLE ACCESS FULL| CUSTOMERS |    66 |   330 |   420   (7)|
--------------------------------------------------------------------------
```

In Oracle Database 12*c* a hybrid histogram is created on CUST_CITY_ID. 52114 is the end point of just one bucket of the histogram

```
SQL> Select c.column_name, c.histogram, h.endpoint_number, h.endpoint_value, h.endpoint_repeat_count
  2  From   user_tab_col_statistics c, user_histograms h
  3  Where  c.table_Name='CUSTOMERS'
  4  And    c.column_name='CUST_CITY_ID'
  5  And    c.table_Name=h.table_Name
  6  And    c.column_name=h.column_name
  7  And   h.endpoint_value='52114';

COLUMN_NAME     HISTOGRAM       ENDPOINT_NUMBER ENDPOINT_VALUE ENDPOINT_REPEAT_COUNT
--------------- --------------- --------------- -------------- ---------------------
CUST_CITY_ID    HYBRID                     4083          52114                    24
```

As the endpoint of one bucket in a hybrid histogram 52114 is a popular value and Its cardinality estimate determined using the following formula

$$\text{Cardinality estimates } \frac{\text{endpoint repeat\_count}}{\text{max(endpoint\_number)}} \text{ X NUM\_ROWS}$$

```
--------------------------------------------------------------------------
| Id  | Operation          | Name      | Rows  | Bytes | Cost (%CPU)|
--------------------------------------------------------------------------
|   0 | SELECT STATEMENT   |           |       |       |   468 (100)|
|   1 |  SORT AGGREGATE    |           |     1 |     5 |            |
|*  2 |   TABLE ACCESS FULL| CUSTOMERS |   250 |  1250 |   468  (10)|
--------------------------------------------------------------------------
```

Figure 8. Hybrid histograms achieve more accurate cardinality estimates for what was considered a nearly popular value in Oracle Database 11g

The recommendation from Oracle Database11g onwards is to let `METHOD_OPT` default and to take advantage of Adaptive Cursor Sharing and the new types of histograms available in Oracle Database 12*c*.

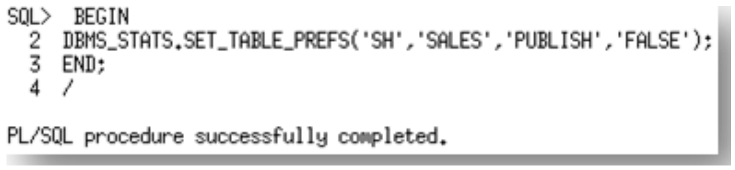
If you plan to manually set the `METHOD_OPT` parameter to a non-default value ensure you specify only the columns that really need a histogram. Setting `METHOD_OPT` to `FOR ALL COLUMNS SIZE 254` will cause Oracle to gather a histogram on every column. This will unnecessarily extend the elapse time and the system resources needed for statistics gathering, as well as increasing the amount of space required to store the statistics.

You should also refrain from setting `METHOD_OPT` to `FOR ALL INDEX COLUMNS SIZE 254` as this will cause Oracle to gather histograms on every column used in an index, which again could waste system resources. This setting also has a nasty side effect of preventing Oracle from collecting basic column statistics for non-index columns.

Please refer to part one of this series, Understanding Optimizer Statistics to determine what type of histogram you should manually create.

Pending Statistics

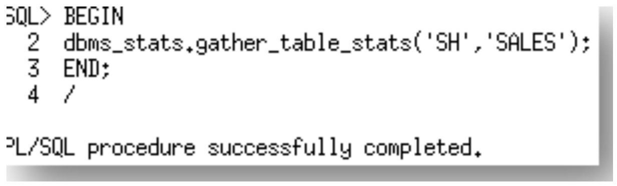
When making changes to the default values of the parameter in the `DBMS_STATS.GATHER_*_STATS` procedures, it is highly recommended that you validate those changes before making the change in a production environment. If you don't have a full scale test environment you should take advantage of pending statistics. With pending statistics, instead of going into the usual dictionary tables, the statistics are stored in pending tables so that they can be enabled and tested in a controlled fashion before they are published and used system-wide. To activate pending statistics collection, you need to use one of the `DBMS_STATS.SET_*_PREFS` procedures to change value of the parameter `PUBLISH` from `TRUE` (default) to `FALSE` for the object(s) you wish to create pending statistics for. In the example below, pending statistics are enabled on the SALES table in the SH schema and then statistics are gathered on the SALES table.



```
SQL>  BEGIN
  2  DBMS_STATS.SET_TABLE_PREFS('SH','SALES','PUBLISH','FALSE');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 9. Enable pending statistics by setting the publish preference to FALSE

Gather statistics on the object(s) as normal.

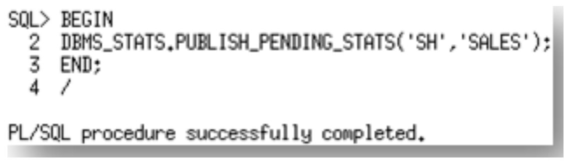


```
SQL> BEGIN
  2  dbms_stats.gather_table_stats('SH','SALES');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 10. Using the DBMS_STATS.GATHER_TABLE_STATS procedure

The statistics gathered for these objects can be displayed using the dictionary views called USER_*_PENDING_STATS.

You can enable the usage of pending statistics by issuing an alter session command to set the initialization parameter OPTIMIZER_USE_PENDING_STATS to TRUE. After enabling pending statistics, any SQL workload run in this session will use the new non-published statistics. For tables accessed in the workload that do not have pending statistics the Optimizer will use the current statistics in the standard data dictionary tables. Once you have validated the pending statistics, you can publish them using the procedure DBMS_STATS.PUBLISH_PENDING_STATS.



```
SQL> BEGIN
  2  DBMS_STATS.PUBLISH_PENDING_STATS('SH','SALES');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

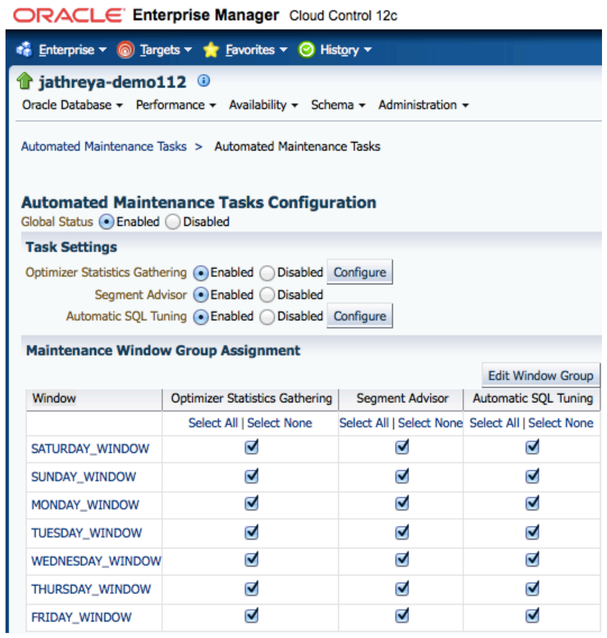
Figure 11. Publishing pending statistics

When to gather statistics

In order to select an optimal execution plan the Optimizer must have representative statistics. Representative statistics are not necessarily up to the minute statistics but a set of statistics that help the Optimizer to determine the correct number of rows it should expect from each operation in the execution plan.

Automatic statistics gathering job

Oracle automatically collects statistics for all database objects, which are missing statistics or have stale statistics during a predefined maintenance window (10pm to 2am weekdays and 6am to 2am at the weekends). You can change the maintenance window that the job will run in via Enterprise Manager or using the DBMS_SCHEDULER and DBMS_AUTO_TASK_ADMIN packages.



Automated Maintenance Tasks Configuration

Global Status [✓ Enabled] Disabled

Task Settings

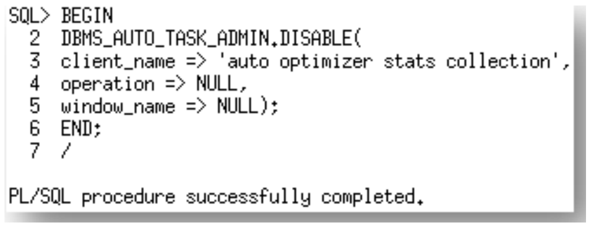
Optimizer Statistics Gathering	[✓ Enabled] Disabled
Segment Advisor	[✓ Enabled] Disabled
Automatic SQL Tuning	[✓ Enabled] Disabled

Maintenance Window Group Assignment

Window	Optimizer Statistics Gathering	Segment Advisor	Automatic SQL Tuning
SATURDAY_WINDOW	✓	✓	✓
SUNDAY_WINDOW	✓	✓	✓
MONDAY_WINDOW	✓	✓	✓
TUESDAY_WINDOW	✓	✓	✓
WEDNESDAY_WINDOW	✓	✓	✓
THURSDAY_WINDOW	✓	✓	✓
FRIDAY_WINDOW	✓	✓	✓

Figure 12. Changing the maintenance window during which the auto stats gathering job runs

If you already have a well-established statistics gathering procedure or if for some other reason you want to disable automatic statistics gathering you can disable the task altogether:



```
SQL> BEGIN
  2  DBMS_AUTO_TASK_ADMIN.DISABLE(
  3  client_name => 'auto optimizer stats collection',
  4  operation => NULL,
  5  window_name => NULL);
  6  END;
  7  /

PL/SQL procedure successfully completed.
```

Figure 13. Disabling the automatic statistics gather job

Manual statistics collection

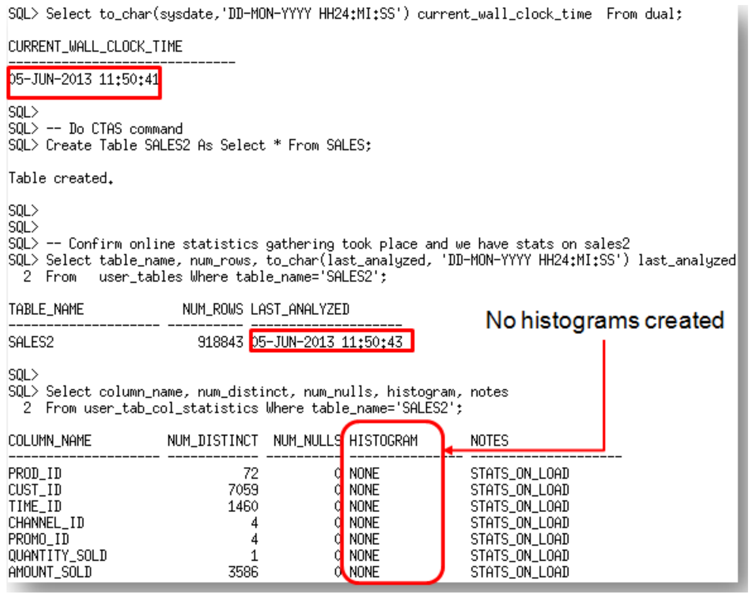
If you plan to manually maintain Optimizer statistics you will need to determine when statistics should be gathered.

You can determine when statistics should be gathered based on staleness, as it is for the automatic job, or based on when new data is loaded in your environment. It is not recommended to continually re-gather statistics if the underlying data has not changed significantly as this will unnecessarily waste system resources.

If data is only loaded into your environment during a pre-defined ETL or ELT job then the statistics gathering operations can be scheduled as part of this process. You should try and take advantage of online statistics gathering and incremental statistics as part of your statistics maintenance strategy.

Online statistics gathering

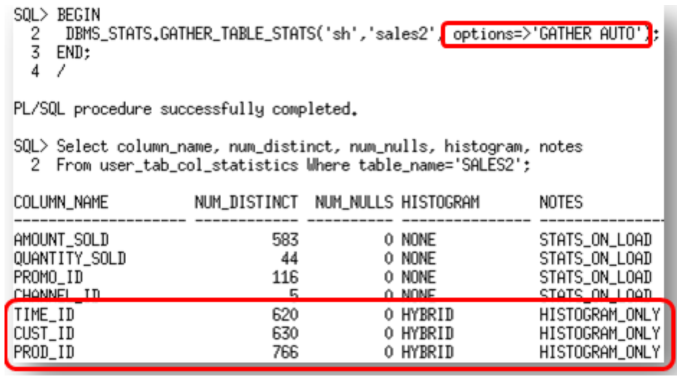
In Oracle Database 12*c,* online statistics gathering "piggybacks" statistics gather as part of a direct-path data loading operation such as, create table as select (CTAS) and insert as select (IAS) operations. Gathering statistics as part of the data loading operation, means no additional full data scan is required to have statistics available immediately after the data is loaded.



```
SQL> Select to_char(sysdate,'DD-MON-YYYY HH24:MI:SS') current_wall_clock_time  From dual;

CURRENT_WALL_CLOCK_TIME
-----------------------------
05-JUN-2013 11:50:41

SQL>
SQL> -- Do CTAS command
SQL> Create Table SALES2 As Select * From SALES;

Table created.

SQL>
SQL>
SQL> -- Confirm online statistics gathering took place and we have stats on sales2
SQL> Select table_name, num_rows, to_char(last_analyzed, 'DD-MON-YYYY HH24:MI:SS') last_analyzed
  2  From   user_tables Where table_name='SALES2';

TABLE_NAME              NUM_ROWS LAST_ANALYZED
-------------------- ---------- --------------------
SALES2                    918843 05-JUN-2013 11:50:43

SQL>
SQL> Select column_name, num_distinct, num_nulls, histogram, notes
  2  From user_tab_col_statistics Where table_name='SALES2';

COLUMN_NAME          NUM_DISTINCT  NUM_NULLS HISTOGRAM        NOTES
-------------------- ------------ ---------- ---------------- --------------------
PROD_ID                        72          0 NONE             STATS_ON_LOAD
CUST_ID                      7059          0 NONE             STATS_ON_LOAD
TIME_ID                      1460          0 NONE             STATS_ON_LOAD
CHANNEL_ID                      4          0 NONE             STATS_ON_LOAD
PROMO_ID                        4          0 NONE             STATS_ON_LOAD
QUANTITY_SOLD                   1          0 NONE             STATS_ON_LOAD
AMOUNT_SOLD                  3586          0 NONE             STATS_ON_LOAD
```

Figure 14. Online statistic gathering provides both table and column statistics for newly created SALES2 table

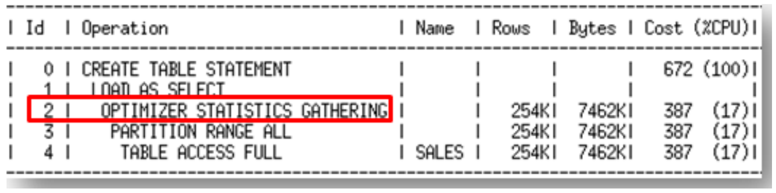
Online statistics gathering does not gather histograms or index statistics, as these types of statistics require additional data scans, which could have a large impact on the performance of the data load. To gather the necessary histogram and index statistics without re-gathering the base column statistics use the `DBMS_STATS.GATHER_TABLE_STATS` procedure with the new options parameter set to GATHER AUTO.



```
SQL> BEGIN
  2   DBMS_STATS.GATHER_TABLE_STATS('sh','sales2', options=>'GATHER AUTO');
  3  END;
  4  /

PL/SQL procedure successfully completed.

SQL> Select column_name, num_distinct, num_nulls, histogram, notes
  2  From user_tab_col_statistics Where table_name='SALES2';

COLUMN_NAME          NUM_DISTINCT  NUM_NULLS HISTOGRAM       NOTES
-------------------- ------------ ---------- --------------- ---------------
AMOUNT_SOLD                   583          0 NONE            STATS_ON_LOAD
QUANTITY_SOLD                  44          0 NONE            STATS_ON_LOAD
PROMO_ID                      116          0 NONE            STATS_ON_LOAD
CHANNEL_ID                      5          0 NONE            STATS_ON_LOAD
TIME_ID                       620          0 HYBRID          HISTOGRAM_ONLY
CUST_ID                       630          0 HYBRID          HISTOGRAM_ONLY
PROD_ID                       766          0 HYBRID          HISTOGRAM_ONLY
```

Figure 15. Set options to GATHER AUTO creates histograms on SALES2 table without regarding the base statistics

The notes column "HISTOGRAM_ONLY" indicates that histograms were gathered without re-gathering basic column statistics. There are two ways to confirm online statistics gathering has occurred: check the execution plan to see if the new row source OPTIMIZER STATISTICS GATHERING appears in the plan or look in the new notes column of the USER_TAB_COL_STATISTICS table for the status STATS_ON_LOAD.



```
---------------------------------------------------------------------------------
| Id  | Operation                        | Name  | Rows  | Bytes | Cost (%CPU)|
---------------------------------------------------------------------------------
|   0 | CREATE TABLE STATEMENT           |       |       |       |   672 (100)|
|   1 |  LOAD AS SELECT                  |       |       |       |            |
|   2 |   OPTIMIZER STATISTICS GATHERING |       |  254K|  7462K|   387  (17)|
|   3 |    PARTITION RANGE ALL           |       |  254K|  7462K|   387  (17)|
|   4 |     TABLE ACCESS FULL            | SALES |  254K|  7462K|   387  (17)|
---------------------------------------------------------------------------------
```

Figure 16. Execution plan for an on-line statistics gathering operation

Since online statistics gathering was designed to have a minimal impact on the performance of a direct path load operation it can only occur when data is being loaded into an empty object. To ensure online statistics gathering kicks in when loading into a new partition of an existing table, use extended syntax to specify the partition explicitly. In this case partition level statistics will be created but global level (table level) statistics will not be updated. If incremental statistics have been enabled on the partitioned table a synopsis will be created as part of the data load operation.

Incremental statistics and partition exchange data loading

Gathering statistics on partitioned tables consists of gathering statistics at both the table level (global statistics) and (sub)partition level. If the INCREMENTAL[6] preference for a partitioned table is set to TRUE, the DBMS_STATS.GATHER_*_STATS parameter GRANULARITY includes GLOBAL, and ESTIMATE_PERCENT is set to AUTO_SAMPLE_SIZE, Oracle will accurately derive all global level statistics by scanning only those partitions that have been added or modified, and not the entire table. Incremental global statistics works by storing a *synopsis* for each partition in the table. A synopsis is statistical metadata for that partition and the columns in the partition. Aggregating the partition level statistics and the synopses from each partition will accurately generate global level statistics, thus eliminating the need to scan the entire table. When a new partition is added to the table, you only need to gather statistics for the new partition. The table level statistics will be automatically and accurately calculated using the new partition synopsis and the existing partitions' synopses.

Note, partition statistics are not aggregated from subpartition statistics when incremental statistics are enabled.

If you are using partition exchange loads and wish to take advantage of incremental statistics, you will need to set the DBMS_STATS table preference INCREMENTAL_LEVEL on the non-partitioned table to identify that it will be used in partition exchange load. By setting the INCREMENTAL_LEVEL to TABLE (default is PARTITION), Oracle will automatically create a synopsis for the table when statistics are

[6] More information on Incremental Statistics can be found in part one of this series, Understanding Optimizer Statistics.

gathered on it. This table level synopsis will then become the partition level synopsis after the load the exchange.

However, if your environment has more trickle feeds or online transactions that only insert a small number of rows but these operations occur throughout the day, you will need to determine when your statistics are stale and then trigger the statistics gathering job. If you plan to rely on the `STALE_STATS` column in `USER_TAB_STATISTICS` to determine if statistics are stale you should be aware that this information is updated on a daily basis only. If you need more timely information on what `DML` has occurred on your tables you will need to look in `USER_TAB_MODIFICATIONS`, which lists the number of `INSERTS`, `UPDATES`, and `DELETES` that occurs on each table, whether the table has been truncated (TRUNCATED column) and calculate staleness yourself. Again, you should note this information is automatically updated, from memory, periodically. If you need the latest information you will need to manual flush the information using the `DBMS_STATS.FLUSH_DATABASE_MONITORING_INFO` function.

Preventing "out of range" condition

Regardless of whether you use the automatic statistics gathering job or you manually gather statistics, if end-users start to query newly inserted data before statistics have been gathered, it is possible to get a suboptimal execution plan due to stale statistics, even if less than 10% of the rows have changed in the table. One of the most common cases of this occurs when the value supplied in a where clause predicate is outside the domain of values represented by the [minimum, maximum] column statistics. This is commonly known as an 'out-of-range' error. In this case, the Optimizer prorates the selectivity based on the distance between the predicate value, and the maximum value (assuming the value is higher than the max), that is, the farther the value is from the maximum or minimum value, the lower the selectivity will be.

This scenario is very common with range partitioned tables. A new partition is added to an existing range partitioned table, and rows are inserted into just that partition. End-users begin to query this new data before statistics have been gathered on this new partition. For partitioned tables, you can use the `DBMS_STATS.COPY_TABLE_STATS`[7] procedure (available from Oracle Database 10.2.0.4 onwards) to prevent "Out of Range" conditions. This procedure copies the statistics of a representative source [sub] partition to the newly created and empty destination [sub] partition. It also copies the statistics of the dependent objects: columns, local (partitioned) indexes, etc. and sets the high bound partitioning value as the max value of the partitioning column and high bound partitioning value of the previous partition as the min value of the partitioning column. The copied statistics should only be considered as

[7] More information on `DBMS_STATS.COPY_TABLE_STATS` can be found in part one of this series, Understanding Optimizer Statistics.

temporary solution until it is possible to gather accurate statistics for the partition. Copying statistics should not be used as a substitute for actually gathering statistics.

Note by default, DBMS_STATS.COPY_TABLE_STATS only adjust partition statistics and not global or table level statistics. If you want the global level statistics to be updated for the partition column as part of the copy you need to set the flags parameter of the DBMS_STATS.COPY_TABLE_STATS to 8.

For non-partitioned tables you can manually set the max value for a column using the DBMS_STATS.SET_COLUMN_STATS procedure. This approach is not recommended in general and is not a substitute for actually gathering statistics.

Improving the efficiency of gathering statistics

As data volumes grow and maintenance windows shrink, it is more important than ever to gather statistics in a timely manner. Oracle offers a variety of ways to speed up the statistics collection, from parallelizing the statistics gathering operations to generating statistics rather than collecting them.

Using parallelism

Parallelism can be leveraged in several ways for statistics collection

- Intra object parallelism
- Inter object parallelism
- A combination of both intra and inter object parallelism

Intra object parallelism

Intra object parallelism is controlled by the DEGREE parameter in the DBMS_STATS.GATHER_*_STATS procedures. The DEGREE parameter controls the number of parallel server processes that will be used to gather the statistics.

By default Oracle uses the same number of parallel server processes specified as an attribute of the table in the data dictionary (Degree of Parallelism). All tables in an Oracle database have this attribute set to 1 by default. It may be useful to explicitly set this parameter for the statistics collection on a large table to speed up statistics collection.

Alternatively you can set DEGREE to AUTO_DEGREE; Oracle will automatically determine the appropriate number of parallel server processes that should be used to gather statistics, based on the size of an object. The value can be between 1 (serial execution) for small objects to DEFAULT_DEGREE (PARALLEL_THREADS_PER_CPU X CPU_COUNT) for larger objects.

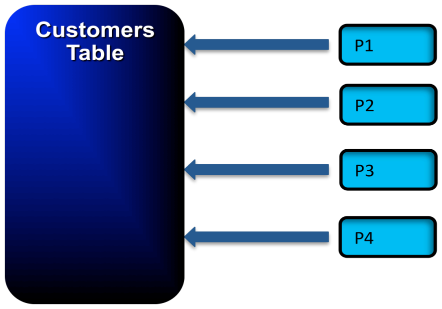


Figure 17. Use Intra object parallelism via the `DEGREE` parameter of the `DBMS_STATS.GATHER_*_STATS` procedures

You should note that setting the `DEGREE` for a partitioned table means that multiple parallel sever processes will be used to gather statistics on each partition but the statistics will not be gathered concurrently on the different partitions. Statistics will be gathered on each partition one after the other.

Inter object parallelism

In Oracle Database 11.2.0.2, inter object parallelism was introduced and is controlled by the global statistics gathering preference `CONCURRENT`[8]. When `CONCURRENT` is enabled, Oracle employs the Oracle Job Scheduler and Advanced Queuing components to create and manage multiple statistics gathering jobs concurrently. Gathering statistics on multiple tables and (sub)partitions concurrently can reduce the overall time it takes to gather statistics by allowing Oracle to fully utilize a multi-processor environment.

The maximum number of active concurrent statistics gathering jobs is controlled by the `JOB_QUEUE_PROCESSES` parameter. By default the `JOB_QUEUE_PROCESSES` is set to 1000. Typically this is too high for a `CONCURRENT` statistics gathering operation especially if parallel execution will also be employed. A more appropriate value would be 2 X total number of CPU cores (this is a per node parameter in a RAC environment). You need to make sure that you set this parameter system-wise (`ALTER SYSTEM` ... or in init.ora file) rather than at the session level (`ALTER SESSION`). You should also considering enabling resource manager to help manage system resource when concurrent statistics gathering is enabled.

From Oracle Database 12c onward, it is possible to use concurrent statistics gathering to help improve the efficiency of the automatic statistics gather task. By setting the preference `CONCURRENT` to `AUTOMATIC` or `ALL` the automatic statistics gather task can start multiple statistics gathering jobs in the maintenance window. This will enable the automatic statistics gathering task to fully utilize all

[8] More information on concurrent statistics gathering can be found in part one of this series, Understanding Optimizer Statistics.

available system resources to gather statistics on any object with stale or missing statistics in the given window.

Combining Intra and Inter parallelism

Each of the statistics gathering jobs in a concurrent statistics gather operation can execute in parallel. Combining concurrent statistics gathering and parallel execution can greatly reduce the time it takes to gather statistics.

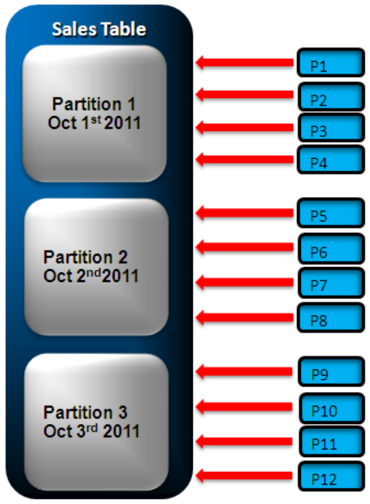
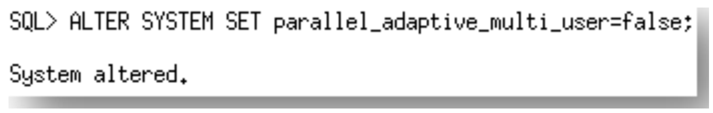


Figure 18. Use Inter and Intra object parallelism to speed up a `DBMS_STATS.GATHER_TABLE_STATS` on a partitioned table.

When using parallel execution as part of a concurrent statistics gathering you should disable the `PARALLEL_ADAPTIVE_MULTI_USER` initialization parameter to prevent the parallel jobs from being down graded to serial. Again this should be done at a system level and not at a session level. That is;



```
SQL> ALTER SYSTEM SET parallel_adaptive_multi_user=false;

System altered.
```

Figure 19. Disable parallel_adaptive_mutli_user parameter

When not to gather statistics

Although the Optimizer needs accurate statistics to select an optimal plan, there are scenarios where gathering statistics can be difficult, too costly, or cannot be accomplished in a timely manner and an alternative strategy is required.

Volatile tables

A volatile table is one where the volume of data changes dramatically over time. For example, an orders queue table, which at the start of the day the table is empty. As the day progresses and orders are placed the table begins to fill up. Once each order is processed it is deleted from the tables, so by the end of the day the table is empty again.

If you relied on the automatic statistics gather job to maintain statistics on such tables then the statistics would always show the table was empty because it was empty over night when the job ran. However, during the course of the day the table may have hundreds of thousands of rows in it.

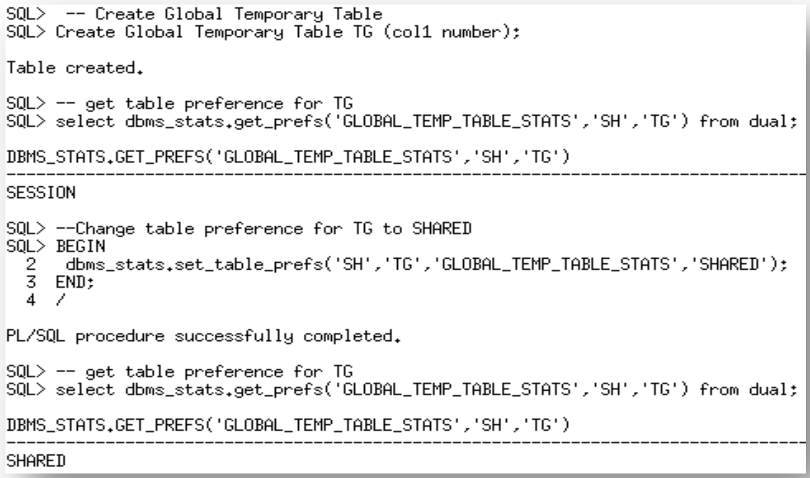
In such cases it is better to gather a representative set of statistics for the table during the day when the table is populated and then lock them. Locking the statistics will prevent the automatic statistics gathering job from over writing them. Alternatively, you could rely on dynamic sampling to gather statistics on these tables. The Optimizer uses dynamic sampling during the compilation of a SQL statement to gather basic statistics on the tables before optimizing the statement. Although the statistics gathered by dynamic sampling are not as high a quality or as complete as the statistics gathered using the `DBMS_STATS` package, they should be good enough in most cases.

Global Temporary Tables

Global temporary tables are often used to store intermediate results in an application context. A global temporary table shares its definition system-wide with all users with appropriate privileges, but the data content is always session-private. No physical storage is allocated unless data is inserted into the table. A global temporary table can be transaction specific (delete rows on commit) or session-specific (preserves rows on commit). Gathering statistics on transaction specific tables leads to the truncation of the table. In contrast, it is possible to gather statistics on a global temporary table (that persist rows) but in previous releases its wasn't always a good idea as all sessions using the GTT had to share a single set of statistics so a lot of systems relied on dynamic statistics.

However, in Oracle Database 12*c*, it is now possible to have a separate set of statistics for every session using a GTT. Statistics sharing on a GTT is controlled using a new `DBMS_STATS` preference `GLOBAL_TEMP_TABLE_STATS`. By default the preference is set to SESSION, meaning each session accessing the GTT will have it's own set of statistics. The optimizer will try to use session statistics first but if session statistics do not exist, then optimizer will use shared statistics. If you want to revert back to the prior behavior of only one set of statistics used by all session, set the

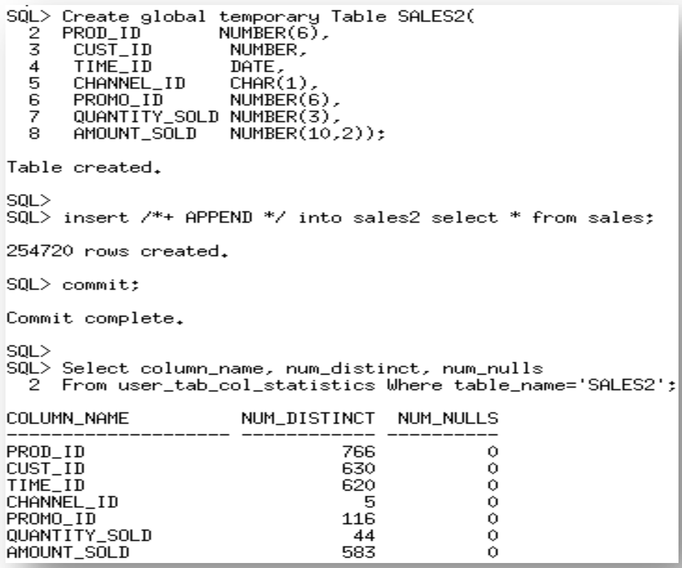
`GLOBAL_TEMP_TABLE_STATS` preference to SHARED.



```
SQL>  -- Create Global Temporary Table
SQL> Create Global Temporary Table TG (col1 number);

Table created.

SQL> -- get table preference for TG
SQL> select dbms_stats.get_prefs('GLOBAL_TEMP_TABLE_STATS','SH','TG') from dual;

DBMS_STATS.GET_PREFS('GLOBAL_TEMP_TABLE_STATS','SH','TG')
--------------------------------------------------------------------------------
SESSION

SQL> --Change table preference for TG to SHARED
SQL> BEGIN
  2   dbms_stats.set_table_prefs('SH','TG','GLOBAL_TEMP_TABLE_STATS','SHARED');
  3  END;
  4  /

PL/SQL procedure successfully completed.

SQL> -- get table preference for TG
SQL> select dbms_stats.get_prefs('GLOBAL_TEMP_TABLE_STATS','SH','TG') from dual;

DBMS_STATS.GET_PREFS('GLOBAL_TEMP_TABLE_STATS','SH','TG')
--------------------------------------------------------------------------------
SHARED
```

Figure 20. Changing the default behavior of not sharing statistics on a GTT to forcing statistics sharing

When populating a GTT (that persists rows on commit) using a direct path operation, session level statistics will be automatically created due to online statistics gathering, which will remove the necessity to run additional statistics gathering command and will not impact the statistics used by any other session.



```
SQL> Create global temporary Table SALES2(
  2  PROD_ID        NUMBER(6),
  3   CUST_ID        NUMBER,
  4   TIME_ID        DATE,
  5   CHANNEL_ID     CHAR(1),
  6   PROMO_ID       NUMBER(6),
  7   QUANTITY_SOLD NUMBER(3),
  8   AMOUNT_SOLD    NUMBER(10,2));

Table created.

SQL>
SQL> insert /*+ APPEND */ into sales2 select * from sales;

254720 rows created.

SQL> commit;

Commit complete.

SQL>
SQL> Select column_name, num_distinct, num_nulls
  2  From user_tab_col_statistics Where table_name='SALES2';

COLUMN_NAME          NUM_DISTINCT  NUM_NULLS
-------------------- ------------ ----------
PROD_ID                       766          0
CUST_ID                       630          0
TIME_ID                       620          0
CHANNEL_ID                      5          0
PROMO_ID                      116          0
QUANTITY_SOLD                  44          0
AMOUNT_SOLD                   583          0
```

Figure 21. Populating a GTT using a direct path operation results in session level statistics being automatically gathered

Intermediate work tables

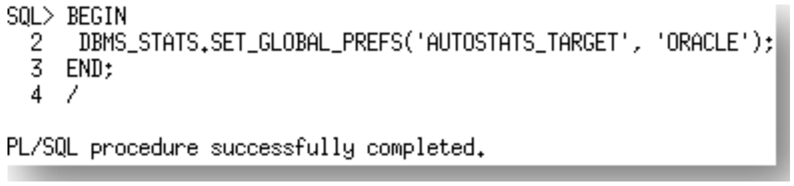
Intermediate work tables are typically seen as part of an ELT process or a complex transaction. These tables are written to only once, read once, and then truncated or deleted. In such cases the cost of gathering statistics outweighs the benefit, since the statistics will be used just once. Instead dynamic sampling should be used in these cases. It is recommended you lock statistics on intermediate work tables that are persistent to prevent the automatic statistics gathering job from attempting to gather statistics on them.

Gathering other types of statistics

Since the Cost Based Optimizer is now the only supported optimizer, all tables in the database need to have statistics, including all of the dictionary tables (tables owned by 'SYS',SYSTEM, etc, and residing in the system and SYSAUX tablespace) and the x$ tables used by the dynamic v$ performance views.

Dictionary statistics

Statistics on the dictionary tables are maintained via the automatic statistics gathering job run during the nightly maintenance window. It is highly recommended that you allow Oracle to automatic statistics gather job to maintain dictionary statistics even if you choose to switch off the automatic statistics gathering job for your main application schema. You can do this by changing the value of AUTOSTATS_TARGET to ORACLE instead of AUTO using the procedure DBMS_STATS.SET_GLOBAL_PREFS.



```
SQL> BEGIN
  2   DBMS_STATS.SET_GLOBAL_PREFS('AUTOSTATS_TARGET', 'ORACLE');
  3  END;
  4  /

PL/SQL procedure successfully completed.
```

Figure 22. Modify the automatic statistics gather job to gather dictionary statistics only

Fixed object statistics

The automatic statistics gathering job does not gather fixed object statistics. And unlike other database tables, dynamic sampling is not automatically used for SQL statements involving X$ tables when optimizer statistics are missing. The Optimizer uses predefined default values for the statistics if they are missing. These defaults may not be representative and could potentially lead to a suboptimal execution plan, which could cause severe performance problems in your system. It is for this reason that we strongly recommend you manually gather fixed objects statistics.

You can collect statistics on fixed objects using DBMS_STATS.GATHER_FIXED_OBJECTS_STATS procedure. Because of the transient nature of the x$ tables it is import that you gather fixed object statistics when there is a representative workload on the system. This may not always be feasible on large systems due to additional resources needed to gather the statistics. If you can't do it during peak load you should do it after the system has warmed up and the three key types of fixed object tables have been populated:

- Structural data - for example, views covering datafiles, controlfile contents, etc.
- Session based data - for example, `v$session, v$access`, etc.
- Workload data - for example, `v$sql, v$sql_plan`, etc

It is recommended that you re-gather fixed object statistics if you do a major database or application upgrade, implement a new module, or make changes to the database configuration. For example if you increase the SGA size then all of the x$ tables that contain information about the buffer cache and shared pool may change significantly, such as x$ tables used in `v$buffer_pool` or `v$shared_pool_advice`.

System statistics

System statistics enable the Optimizer to more accurately cost each operation in an execution plan by using information about the actual system hardware executing the statement, such as CPU speed and IO performance. System statistics are enabled by default, and are automatically initialized with default values; these values are representative for most systems.

Conclusion

In order for the Optimizer to accurately determine the cost for an execution plan it must have accurate statistics about all of the objects (table and indexes) accessed in the SQL statement and information about the system on which the SQL statement will be run. This two part white paper series explains in detail what Optimizer statistics are necessary, how they are used, and the different statistics collection method available to you.

By using a combination of the automatic statistics gathering job and the other techniques described in this paper a DBA can maintain an accurate set of statistics for their environment and ensure the Optimizer always has the necessary information in order to select the most optimal plan. Once a statistics gathering strategy has been put in place, changes to the strategy should be done in a controlled manner and take advantage of key features such as pending statistics to ensure they do not have an adverse effect on application performance.

Oracle is committed to developing practices and products that help protect the environment

Best Practices for Gathering Optimizer Statistics with Oracle Database 12*c*

June 2013
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