|  |  |  |  |
| --- | --- | --- | --- |
| | Ndb\_api\_trans\_abort\_count\_replica  Ndb\_api\_trans\_close\_count\_replica  Ndb\_api\_pk\_op\_count\_replica  | Ndb\_api\_uk\_op\_count\_replica  | Ndb\_api\_table\_scan\_count\_replica  | Ndb\_api\_range\_scan\_count\_replica  Ndb\_api\_pruned\_scan\_count\_replica  Ndb\_api\_scan\_batch\_count\_replica  | Ndb\_api\_read\_row\_count\_replica  | Ndb\_api\_trans\_local\_read\_row\_count\_replica  | Ndb\_api\_adaptive\_send\_forced\_count\_replica  Ndb\_api\_adaptive\_send\_unforced\_count\_replica  Ndb\_api\_adaptive\_send\_deferred\_count\_replica  | Ndb\_api\_event\_data\_count\_injector  | Ndb\_api\_event\_nondata\_count\_injector  | Ndb\_api\_event\_bytes\_count\_injector  Ndb\_api\_wait\_exec\_complete\_count\_session  Ndb\_api\_wait\_scan\_result\_count\_session  | Ndb\_api\_wait\_meta\_request\_count\_session  | Ndb\_api\_wait\_nanos\_count\_session  | Ndb\_api\_bytes\_sent\_count\_session  Ndb\_api\_bytes\_received\_count\_session  Ndb\_api\_trans\_start\_count\_session  | Ndb\_api\_trans\_commit\_count\_session  | Ndb\_api\_trans\_abort\_count\_session  | Ndb\_api\_trans\_close\_count\_session  Ndb\_api\_pk\_op\_count\_session  Ndb\_api\_uk\_op\_count\_session  | Ndb\_api\_table\_scan\_count\_session  | Ndb\_api\_range\_scan\_count\_session  | Ndb\_api\_pruned\_scan\_count\_session  Ndb\_api\_scan\_batch\_count\_session  Ndb\_api\_read\_row\_count\_session  | Ndb\_api\_trans\_local\_read\_row\_count\_session  | Ndb\_api\_adaptive\_send\_forced\_count\_session  | Ndb\_api\_adaptive\_send\_unforced\_count\_session  | Ndb api adaptive send deferred count session | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |

+----------------------------------------------+-----------+

90 rows in set (0.01 sec)

These status variables are also available from the Performance Schema session\_status and global\_status tables, as shown here:

mysql> **SELECT** **\*** **FROM** **performance\_schema** **.session\_status**

-> **WHERE** **VARIABLE\_NAME** **LIKE** **'ndb\_api%';**

+----------------------------------------------+----------------+

| VARIABLE\_VALUE |

+----------------------------------------------+----------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | Ndb\_api\_wait\_exec\_complete\_count  Ndb\_api\_wait\_scan\_result\_count  Ndb\_api\_wait\_meta\_request\_count  | Ndb\_api\_wait\_nanos\_count  | Ndb\_api\_bytes\_sent\_count  | Ndb\_api\_bytes\_received\_count  Ndb\_api\_trans\_start\_count  Ndb\_api\_trans\_commit\_count  | Ndb\_api\_trans\_abort\_count  | Ndb\_api\_trans\_close\_count  | Ndb\_api\_pk\_op\_count  Ndb\_api\_uk\_op\_count  Ndb\_api\_table\_scan\_count  | Ndb\_api\_range\_scan\_count  | Ndb\_api\_pruned\_scan\_count  | Ndb\_api\_scan\_batch\_count  Ndb\_api\_read\_row\_count  Ndb\_api\_trans\_local\_read\_row\_count  | Ndb\_api\_adaptive\_send\_forced\_count  | Ndb\_api\_adaptive\_send\_unforced\_count  | Ndb\_api\_adaptive\_send\_deferred\_count  Ndb\_api\_event\_data\_count  Ndb\_api\_event\_nondata\_count  | Ndb api event bytes count |  | 617  0  649  335663491  65764  86940  308  308  0  308  311  0  0  0  0  0  307  77  3  614  0  0  0  0 | |  |  |  |  |  |  |  |  |  |  |  |  |  | |

| VARIABLE\_NAME

|  |  |  |  |
| --- | --- | --- | --- |
| | Ndb\_api\_wait\_exec\_complete\_count\_slave  Ndb\_api\_wait\_scan\_result\_count\_slave  Ndb\_api\_wait\_meta\_request\_count\_slave  | Ndb\_api\_wait\_nanos\_count\_slave  | Ndb\_api\_bytes\_sent\_count\_slave  | Ndb\_api\_bytes\_received\_count\_slave  Ndb\_api\_trans\_start\_count\_slave  Ndb\_api\_trans\_commit\_count\_slave  | Ndb\_api\_trans\_abort\_count\_slave  | Ndb\_api\_trans\_close\_count\_slave  | Ndb\_api\_pk\_op\_count\_slave  Ndb\_api\_uk\_op\_count\_slave  Ndb\_api\_table\_scan\_count\_slave  | Ndb\_api\_range\_scan\_count\_slave  | Ndb\_api\_pruned\_scan\_count\_slave  | Ndb\_api\_scan\_batch\_count\_slave  Ndb\_api\_read\_row\_count\_slave  Ndb\_api\_trans\_local\_read\_row\_count\_slave  | Ndb\_api\_adaptive\_send\_forced\_count\_slave  | Ndb\_api\_adaptive\_send\_unforced\_count\_slave  | Ndb\_api\_adaptive\_send\_deferred\_count\_slave  Ndb\_api\_wait\_exec\_complete\_count\_replica  Ndb\_api\_wait\_scan\_result\_count\_replica  | Ndb\_api\_wait\_meta\_request\_count\_replica  | Ndb\_api\_wait\_nanos\_count\_replica  | Ndb\_api\_bytes\_sent\_count\_replica  Ndb\_api\_bytes\_received\_count\_replica  Ndb\_api\_trans\_start\_count\_replica  | Ndb\_api\_trans\_commit\_count\_replica  | Ndb\_api\_trans\_abort\_count\_replica  | Ndb\_api\_trans\_close\_count\_replica  Ndb\_api\_pk\_op\_count\_replica  Ndb\_api\_uk\_op\_count\_replica  | Ndb\_api\_table\_scan\_count\_replica  | Ndb\_api\_range\_scan\_count\_replica  | Ndb\_api\_pruned\_scan\_count\_replica  Ndb\_api\_scan\_batch\_count\_replica  Ndb\_api\_read\_row\_count\_replica  | Ndb\_api\_trans\_local\_read\_row\_count\_replica  | Ndb\_api\_adaptive\_send\_forced\_count\_replica  | Ndb\_api\_adaptive\_send\_unforced\_count\_replica  Ndb\_api\_adaptive\_send\_deferred\_count\_replica  Ndb\_api\_event\_data\_count\_injector  | Ndb\_api\_event\_nondata\_count\_injector  | Ndb\_api\_event\_bytes\_count\_injector  | Ndb\_api\_wait\_exec\_complete\_count\_session  Ndb\_api\_wait\_scan\_result\_count\_session  Ndb\_api\_wait\_meta\_request\_count\_session  | Ndb\_api\_wait\_nanos\_count\_session  | Ndb\_api\_bytes\_sent\_count\_session  | Ndb\_api\_bytes\_received\_count\_session  Ndb\_api\_trans\_start\_count\_session  Ndb\_api\_trans\_commit\_count\_session  | Ndb\_api\_trans\_abort\_count\_session  | Ndb\_api\_trans\_close\_count\_session  | Ndb\_api\_pk\_op\_count\_session  Ndb\_api\_uk\_op\_count\_session  Ndb\_api\_table\_scan\_count\_session  | Ndb\_api\_range\_scan\_count\_session  | Ndb\_api\_pruned\_scan\_count\_session  | Ndb\_api\_scan\_batch\_count\_session  Ndb\_api\_read\_row\_count\_session  Ndb\_api\_trans\_local\_read\_row\_count\_session  | Ndb\_api\_adaptive\_send\_forced\_count\_session  | Ndb\_api\_adaptive\_send\_unforced\_count\_session  | Ndb api adaptive send deferred count session | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |

+----------------------------------------------+----------------+

90 rows in set (0.01 sec)

mysql> **SELECT** **\*** **FROM** **performance\_schema** **.global\_status**

-> **WHERE** **VARIABLE\_NAME** **LIKE** **'ndb\_api%';**

+----------------------------------------------+----------------+

| VARIABLE\_NAME

| VARIABLE\_VALUE |

+----------------------------------------------+----------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | Ndb\_api\_wait\_exec\_complete\_count  Ndb\_api\_wait\_scan\_result\_count  Ndb\_api\_wait\_meta\_request\_count  | Ndb\_api\_wait\_nanos\_count  | Ndb\_api\_bytes\_sent\_count  | Ndb\_api\_bytes\_received\_count  Ndb\_api\_trans\_start\_count  Ndb\_api\_trans\_commit\_count  | Ndb\_api\_trans\_abort\_count  | Ndb\_api\_trans\_close\_count  | Ndb\_api\_pk\_op\_count  Ndb\_api\_uk\_op\_count  Ndb\_api\_table\_scan\_count  | Ndb\_api\_range\_scan\_count  | Ndb\_api\_pruned\_scan\_count  | Ndb\_api\_scan\_batch\_count  Ndb\_api\_read\_row\_count  Ndb\_api\_trans\_local\_read\_row\_count  | Ndb\_api\_adaptive\_send\_forced\_count  | Ndb\_api\_adaptive\_send\_unforced\_count  | Ndb\_api\_adaptive\_send\_deferred\_count  Ndb\_api\_event\_data\_count  Ndb\_api\_event\_nondata\_count  | Ndb\_api\_event\_bytes\_count  | Ndb\_api\_wait\_exec\_complete\_count\_slave  | Ndb\_api\_wait\_scan\_result\_count\_slave  Ndb\_api\_wait\_meta\_request\_count\_slave  Ndb\_api\_wait\_nanos\_count\_slave  | Ndb\_api\_bytes\_sent\_count\_slave  | Ndb\_api\_bytes\_received\_count\_slave  | Ndb\_api\_trans\_start\_count\_slave  Ndb\_api\_trans\_commit\_count\_slave  Ndb\_api\_trans\_abort\_count\_slave  | Ndb\_api\_trans\_close\_count\_slave  | Ndb\_api\_pk\_op\_count\_slave  | Ndb\_api\_uk\_op\_count\_slave  Ndb\_api\_table\_scan\_count\_slave  Ndb\_api\_range\_scan\_count\_slave  | Ndb\_api\_pruned\_scan\_count\_slave  | Ndb\_api\_scan\_batch\_count\_slave  | Ndb\_api\_read\_row\_count\_slave  Ndb\_api\_trans\_local\_read\_row\_count\_slave  Ndb\_api\_adaptive\_send\_forced\_count\_slave  | Ndb\_api\_adaptive\_send\_unforced\_count\_slave  | Ndb\_api\_adaptive\_send\_deferred\_count\_slave  | Ndb\_api\_wait\_exec\_complete\_count\_replica  Ndb\_api\_wait\_scan\_result\_count\_replica  Ndb\_api\_wait\_meta\_request\_count\_replica  | Ndb\_api\_wait\_nanos\_count\_replica  | Ndb\_api\_bytes\_sent\_count\_replica  | Ndb\_api\_bytes\_received\_count\_replica  Ndb\_api\_trans\_start\_count\_replica  Ndb\_api\_trans\_commit\_count\_replica  | Ndb\_api\_trans\_abort\_count\_replica  | Ndb\_api\_trans\_close\_count\_replica  | Ndb\_api\_pk\_op\_count\_replica  Ndb\_api\_uk\_op\_count\_replica  Ndb\_api\_table\_scan\_count\_replica  | Ndb\_api\_range\_scan\_count\_replica  | Ndb\_api\_pruned\_scan\_count\_replica  | Ndb\_api\_scan\_batch\_count\_replica  Ndb\_api\_read\_row\_count\_replica  Ndb\_api\_trans\_local\_read\_row\_count\_replica  | Ndb\_api\_adaptive\_send\_forced\_count\_replica  | Ndb\_api\_adaptive\_send\_unforced\_count\_replica  | Ndb\_api\_adaptive\_send\_deferred\_count\_replica  Ndb\_api\_event\_data\_count\_injector  Ndb\_api\_event\_nondata\_count\_injector  | Ndb\_api\_event\_bytes\_count\_injector  | Ndb\_api\_wait\_exec\_complete\_count\_session | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | 741  0  777  373888309  78124  94988  370  370  0  370  373  0  0  0  0  0  369  93  3  738  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |

|  |  |  |  |
| --- | --- | --- | --- |
| | Ndb\_api\_wait\_scan\_result\_count\_session  Ndb\_api\_wait\_meta\_request\_count\_session  Ndb\_api\_wait\_nanos\_count\_session  | Ndb\_api\_bytes\_sent\_count\_session  | Ndb\_api\_bytes\_received\_count\_session  | Ndb\_api\_trans\_start\_count\_session  Ndb\_api\_trans\_commit\_count\_session  Ndb\_api\_trans\_abort\_count\_session  | Ndb\_api\_trans\_close\_count\_session  | Ndb\_api\_pk\_op\_count\_session  | Ndb\_api\_uk\_op\_count\_session  Ndb\_api\_table\_scan\_count\_session  Ndb\_api\_range\_scan\_count\_session  | Ndb\_api\_pruned\_scan\_count\_session  Ndb\_api\_scan\_batch\_count\_session  Ndb\_api\_read\_row\_count\_session  Ndb\_api\_trans\_local\_read\_row\_count\_session  Ndb\_api\_adaptive\_send\_forced\_count\_session  Ndb\_api\_adaptive\_send\_unforced\_count\_session  Ndb\_api\_adaptive\_send\_deferred\_count\_session | |  |  |  |  |  |  |  |  |  |  |  | | 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 | |  |  |  |  |  |  |  |  |  |  |  | |

+----------------------------------------------+----------------+

90 rows in set (0.01 sec)

|

|

|

|

Each [Ndb](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb.html) object has its own counters. NDB API applications can read the values of the counters for use in optimization or monitoring. For multithreaded clients which use more than one [Ndb](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb.html) object concurrently, it is also possible to obtain a summed view of counters from all [Ndb](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb.html) objects belonging to a given [Ndb\_cluster\_connection](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb-cluster-connection.html).

Four sets of these counters are exposed. One set applies to the current session only; the other 3 are global. *This* *is* *in* *spite* *of* *the* *fact* *that* *their* *values* *can* *be* *obtained* *as* *either* *session* *or* *global* *status* *variables* *in* *the* *mysql* *client*. This means that specifying the SESSION or GLOBAL keyword with SHOW STATUS has no effect on the values reported for NDB API statistics status variables, and the value for each of these variables is the same whether the value is obtained from the equivalent column of the session\_status or the global\_status table.

• *Session* *counters* *(session* *specific)*

Session counters relate to the [Ndb](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb.html) objects in use by (only) the current session. Use of such objects by other MySQL clients does not influence these counts.

In order to minimize confusion with standard MySQL session variables, we refer to the variables that correspond to these NDB API session counters as “\_session variables” , with a leading underscore.

• *Replica* *counters* *(global)*

This set of counters relates to the [Ndb](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb.html) objects used by the replica SQL thread, if any. If this mysqld does not act as a replica, or does not use NDB tables, then all of these counts are 0.

We refer to the related status variables as “\_slave variables” (with a leading underscore).

• *Injector* *counters* *(global)*

Injector counters relate to the [Ndb](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb.html) object used to listen to cluster events by the binary log injector thread. Even when not writing a binary log, mysqld processes attached to an NDB Cluster continue to listen for some events, such as schema changes.

We refer to the status variables that correspond to NDB API injector counters as “\_injector variables” (with a leading underscore).

• *Server* *(Global)* *counters* *(global)*

This set of counters relates to all [Ndb](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb.html) objects currently used by this mysqld. This includes all MySQL client applications, the replica SQL thread (if any), the binary log injector, and the NDB utility thread.

We refer to the status variables that correspond to these counters as “global variables” or “mysqld- level variables” .

You can obtain values for a particular set of variables by additionally filtering for the substring session, slave, or injector in the variable name (along with the common prefix Ndb\_api). For \_session variables, this can be done as shown here:

mysql> **SHOW** **STATUS** **LIKE** **'ndb\_api%session';**

+--------------------------------------------+---------+

Value |

+--------------------------------------------+---------+

|  |  |  |
| --- | --- | --- |
| | Ndb\_api\_wait\_exec\_complete\_count\_session  Ndb\_api\_wait\_scan\_result\_count\_session  Ndb\_api\_wait\_meta\_request\_count\_session  | Ndb\_api\_wait\_nanos\_count\_session  | Ndb\_api\_bytes\_sent\_count\_session  | Ndb\_api\_bytes\_received\_count\_session  Ndb\_api\_trans\_start\_count\_session  Ndb\_api\_trans\_commit\_count\_session  | Ndb\_api\_trans\_abort\_count\_session  | Ndb\_api\_trans\_close\_count\_session  | Ndb\_api\_pk\_op\_count\_session  Ndb\_api\_uk\_op\_count\_session  Ndb\_api\_table\_scan\_count\_session  | Ndb\_api\_range\_scan\_count\_session  | Ndb\_api\_pruned\_scan\_count\_session  | Ndb\_api\_scan\_batch\_count\_session  Ndb\_api\_read\_row\_count\_session  Ndb api trans local read row count session |  | 2 |  0  1  8144375 |  68 |  84 |  1  1  0 |  1 |  1 |  0  0  0 |  0 |  0 |  1  1 |

+--------------------------------------------+---------+

18 rows in set (0.50 sec)

| Variable\_name

|

To obtain a listing of the NDB API mysqld-level status variables, filter for variable names beginning with ndb\_api and ending in \_count, like this:

mysql> **SELECT** **\*** **FROM** **performance\_schema** **.session\_status**

-> **WHERE** **VARIABLE\_NAME** **LIKE** **'ndb\_api%count';**

+------------------------------------+----------------+

|  |  |
| --- | --- |
| | VARIABLE\_NAME | | VARIABLE\_VALUE | |

+------------------------------------+----------------+

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| | | NDB\_API\_WAIT\_EXEC\_COMPLETE\_COUNT | | | 4 | | |
| | | NDB\_API\_WAIT\_SCAN\_RESULT\_COUNT | | | 3 | | |
| | | NDB\_API\_WAIT\_META\_REQUEST\_COUNT | | | 28 | | |
| | | NDB\_API\_WAIT\_NANOS\_COUNT | | | 53756398 | | |
| | | NDB\_API\_BYTES\_SENT\_COUNT | | | 1060 | | |
| | | NDB\_API\_BYTES\_RECEIVED\_COUNT | | | 9724 | | |
| | | NDB\_API\_TRANS\_START\_COUNT | | | 3 | | |
| | | NDB\_API\_TRANS\_COMMIT\_COUNT | | | 2 | | |
| | | NDB\_API\_TRANS\_ABORT\_COUNT | | | 0 | | |
| | | NDB\_API\_TRANS\_CLOSE\_COUNT | | | 3 | | |
| | | NDB\_API\_PK\_OP\_COUNT | | | 2 | | |
| | | NDB\_API\_UK\_OP\_COUNT | | | 0 | | |
| | | NDB\_API\_TABLE\_SCAN\_COUNT | | | 1 | | |
| | | NDB\_API\_RANGE\_SCAN\_COUNT | | | 0 | | |
| | | NDB\_API\_PRUNED\_SCAN\_COUNT | | | 0 | | |
| | | NDB\_API\_SCAN\_BATCH\_COUNT | | | 0 | | |
| | | NDB\_API\_READ\_ROW\_COUNT | | | 2 | | |
| | | NDB\_API\_TRANS\_LOCAL\_READ\_ROW\_COUNT | | | 2 | | |
| | | NDB\_API\_EVENT\_DATA\_COUNT | | | 0 | | |
| | | NDB\_API\_EVENT\_NONDATA\_COUNT | | | 0 | | |
| | | NDB\_API\_EVENT\_BYTES\_COUNT | | | 0 | | |

+------------------------------------+----------------+

21 rows in set (0.09 sec)

Not all counters are reflected in all 4 sets of status variables. For the event counters DataEventsRecvdCount, NondataEventsRecvdCount, and EventBytesRecvdCount, only \_injector and mysqld-level NDB API status variables are available:

mysql> **SHOW** **STATUS** **LIKE** **'ndb\_api%event%';**

NDB API Statistics Counters and Variables

• Ndb\_api\_wait\_exec\_complete\_count

• Ndb\_api\_wait\_exec\_complete\_count

• [none]

• Ndb\_api\_wait\_exec\_complete\_count

• Ndb\_api\_wait\_scan\_result\_count\_s

• Ndb\_api\_wait\_scan\_result\_count\_s

• [none]

• Ndb\_api\_wait\_scan\_result\_count

• Ndb\_api\_wait\_meta\_request\_count\_

• Ndb\_api\_wait\_meta\_request\_count\_

• [none]

• Ndb\_api\_wait\_meta\_request\_count

+--------------------------------------+-------+

|  |  |
| --- | --- |
| | Variable\_name | | Value | |

+--------------------------------------+-------+

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  |  |  |  |  | | Ndb\_api\_event\_data\_count\_injector  Ndb\_api\_event\_nondata\_count\_injector  Ndb\_api\_event\_bytes\_count\_injector  Ndb\_api\_event\_data\_count  Ndb\_api\_event\_nondata\_count  Ndb\_api\_event\_bytes\_count | |  |  |  |  |  | | 0  0  0  0  0  0 | |  |  |  |  |  | |

+--------------------------------------+-------+

6 rows in set (0.00 sec)

\_injector status variables are not implemented for any other NDB API counters, as shown here:

mysql> **SHOW** **STATUS** **LIKE** **'ndb\_api%injector%';**

+--------------------------------------+-------+

|  |  |
| --- | --- |
| | Variable\_name | | Value | |

+--------------------------------------+-------+

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  |  | | Ndb\_api\_event\_data\_count\_injector  Ndb\_api\_event\_nondata\_count\_injector  Ndb\_api\_event\_bytes\_count\_injector | |  |  | | 0  0  0 | |  |  | |

+--------------------------------------+-------+

3 rows in set (0.00 sec)

The names of the status variables can easily be associated with the names of the corresponding counters. Each NDB API statistics counter is listed in the following table with a description as well as the names of any MySQL server status variables corresponding to this counter.

**Table** **23.67** **NDB** **API** **statistics** **counters**

|  |  |  |
| --- | --- | --- |
| **Counter** **Name** | **Description** | **Status** **Variables** **(by** **statistic** **type):**  **•** **Session**  **•** **Slave** **(replica)**  **•** **Injector**  **•** **Server** |
| WaitExecCompleteCount | Number of times thread has been blocked while waiting for execution of an operation to complete. Includes all [execute()](https://dev.mysql.com/doc/ndbapi/en/ndb-ndbtransaction.html#ndb-ndbtransaction-execute) calls as well as implicit executes for blob operations and auto-increment not visible to clients. |  |
| WaitScanResultCount | Number of times thread has been blocked while waiting for a scan-based signal, such waiting for additional results, or for a scan to close. |  |
| WaitMetaRequestCount | Number of times thread has been blocked waiting for a metadata-based signal; this can occur when waiting for a DDL operation or for an epoch to be started (or ended). |  |

• Ndb\_api\_wait\_nanos\_count\_sess

• Ndb\_api\_wait\_nanos\_count\_slav

• [none]

• Ndb\_api\_wait\_nanos\_count

• Ndb\_api\_bytes\_sent\_count\_sess

• Ndb\_api\_bytes\_sent\_count\_slav

• [none]

• Ndb\_api\_bytes\_sent\_count

• Ndb\_api\_bytes\_received\_count\_

• Ndb\_api\_bytes\_received\_count\_

• [none]

• Ndb\_api\_bytes\_received\_count

• Ndb\_api\_trans\_start\_count\_ses

• Ndb\_api\_trans\_start\_count\_sla

• [none]

• Ndb\_api\_trans\_start\_count

• Ndb\_api\_trans\_commit\_count\_se

• Ndb\_api\_trans\_commit\_count\_sl

• [none]

• Ndb\_api\_trans\_commit\_count

• Ndb\_api\_trans\_abort\_count\_ses

• Ndb\_api\_trans\_abort\_count\_sla

• [none]

• Ndb\_api\_trans\_abort\_count

• Ndb\_api\_trans\_close\_count\_ses

• Ndb\_api\_trans\_close\_count\_sla

• [none]

• Ndb\_api\_trans\_close\_count

|  |  |  |
| --- | --- | --- |
| **Counter** **Name** | **Description** | **Status** **Variables** **(by** **statistic** **type):**  **•** **Session**  **•** **Slave** **(replica)**  **•** **Injector**  **•** **Server** |
| WaitNanosCount | Total time (in nanoseconds) spent waiting for some type of signal from the data nodes. |  |
| BytesSentCount | Amount of data (in bytes) sent to the data nodes |  |
| BytesRecvdCount | Amount of data (in bytes) received from the data nodes |  |
| TransStartCount | Number of transactions started. |  |
| TransCommitCount | Number of transactions  committed. |  |
| TransAbortCount | Number of transactions aborted. |  |
| TransCloseCount | Number of transactions aborted. (This value may be greater than the sum of TransCommitCount and TransAbortCount.) |  |

NDB API Statistics Counters and Variables

• Ndb\_api\_pk\_op\_count\_session

• Ndb\_api\_pk\_op\_count\_slave

• [none]

• Ndb\_api\_pk\_op\_count

• Ndb\_api\_uk\_op\_count\_session

• Ndb\_api\_uk\_op\_count\_slave

• [none]

• Ndb\_api\_uk\_op\_count

• Ndb\_api\_table\_scan\_count\_session

• Ndb\_api\_table\_scan\_count\_slave

• [none]

• Ndb\_api\_table\_scan\_count

• Ndb\_api\_range\_scan\_count\_session

• Ndb\_api\_range\_scan\_count\_slave

• [none]

• Ndb\_api\_range\_scan\_count

• Ndb\_api\_pruned\_scan\_count\_sessio

• Ndb\_api\_pruned\_scan\_count\_slave

• [none]

• Ndb\_api\_pruned\_scan\_count

• Ndb\_api\_scan\_batch\_count\_session

• Ndb\_api\_scan\_batch\_count\_slave

• [none]

• Ndb\_api\_scan\_batch\_count

• Ndb\_api\_read\_row\_count\_session

• Ndb\_api\_read\_row\_count\_slave

• [none]

|  |  |  |
| --- | --- | --- |
| **Counter** **Name** | **Description** | **Status** **Variables** **(by** **statistic** **type):**  **•** **Session**  **•** **Slave** **(replica)**  **•** **Injector**  **•** **Server** |
| PkOpCount | Number of operations based on or using primary keys. This count includes blob-part table operations, implicit unlocking operations, and auto-increment operations, as well as primary key operations normally visible to MySQL clients. |  |
| UkOpCount | Number of operations based on or using unique keys. |  |
| TableScanCount | Number of table scans that have been started. This includes scans of internal tables. |  |
| RangeScanCount | Number of range scans that have been started. |  |
| PrunedScanCount | Number of scans that have been pruned to a single partition. |  |
| ScanBatchCount | Number of batches of rows received. (A *batch* in this context is a set of scan results from a single fragment.) |  |
| ReadRowCount | Total number of rows that have been read. Includes rows read using primary key, unique key, and scan operations. |  |

• Ndb\_api\_trans\_local\_read\_row\_

• Ndb\_api\_trans\_local\_read\_row\_

• [none]

• Ndb\_api\_trans\_local\_read\_row\_

• [none]

• [none]

• Ndb\_api\_event\_data\_count\_inje

• Ndb\_api\_event\_data\_count

• [none]

• [none]

• Ndb\_api\_event\_nondata\_count\_i

• Ndb\_api\_event\_nondata\_count

• [none]

• [none]

• Ndb\_api\_event\_bytes\_count\_inj

• Ndb\_api\_event\_bytes\_count

|  |  |  |
| --- | --- | --- |
| **Counter** **Name** | **Description** | **Status** **Variables** **(by** **statistic** **type):**  api read row count  **•** **Session**  **•** **Slave** **(replica)**  **•** **Injector**  **•** **Server** |
|  |  | • Ndb\_ \_ \_ \_ |
| TransLocalReadRowCount | Number of rows read from the data same node on which the transaction was being run. |  |
| DataEventsRecvdCount | Number of row change events received. |  |
| NondataEventsRecvdCount | Number of events received, other than row change events. |  |
| EventBytesRecvdCount | Number of bytes of events  received. |  |

To see all counts of committed transactions—that is, all TransCommitCount counter status variables —you can filter the results of SHOW STATUS for the substring trans\_commit\_count, like this:

mysql> **SHOW** **STATUS** **LIKE** **'%trans\_commit\_count%';**

+------------------------------------+-------+

|  |  |
| --- | --- |
| | Variable\_name | | Value | |

+------------------------------------+-------+

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  |  | | Ndb\_api\_trans\_commit\_count\_session  Ndb\_api\_trans\_commit\_count\_slave  Ndb\_api\_trans\_commit\_count | |  |  | | 1  0  2 | |  |  | |

+------------------------------------+-------+

3 rows in set (0.00 sec)

From this you can determine that 1 transaction has been committed in the current mysql client session, and 2 transactions have been committed on this mysqld since it was last restarted.

You can see how various NDB API counters are incremented by a given SQL statement by comparing the values of the corresponding \_session status variables immediately before and after performing the statement. In this example, after getting the initial values from SHOW STATUS, we create in the test database an NDB table, named t, that has a single column:

mysql> **SHOW** **STATUS** **LIKE** **'ndb\_api%session%';**

+--------------------------------------------+--------+

| Value |

+--------------------------------------------+--------+

|  |  |  |
| --- | --- | --- |
| | Ndb\_api\_wait\_exec\_complete\_count\_session  Ndb\_api\_wait\_scan\_result\_count\_session  Ndb\_api\_wait\_meta\_request\_count\_session  | Ndb\_api\_wait\_nanos\_count\_session  | Ndb\_api\_bytes\_sent\_count\_session  | Ndb\_api\_bytes\_received\_count\_session  Ndb\_api\_trans\_start\_count\_session  Ndb\_api\_trans\_commit\_count\_session  | Ndb\_api\_trans\_abort\_count\_session  | Ndb\_api\_trans\_close\_count\_session  | Ndb\_api\_pk\_op\_count\_session  Ndb\_api\_uk\_op\_count\_session  Ndb\_api\_table\_scan\_count\_session  | Ndb\_api\_range\_scan\_count\_session  | Ndb\_api\_pruned\_scan\_count\_session  | Ndb\_api\_scan\_batch\_count\_session  Ndb\_api\_read\_row\_count\_session  Ndb api trans local read row count session |  | 2 |  0  3  820705 |  132 |  372 |  1  1  0 |  1 |  1 |  0  0  0 |  0 |  0 |  1  1 |

+--------------------------------------------+--------+

18 rows in set (0.00 sec)

mysql> **USE** **test;**

Database changed

mysql> **CREATE** **TABLE** **t** **(c** **INT)** **ENGINE** **NDBCLUSTER;**

Query OK, 0 rows affected (0.85 sec)

| Variable\_name

Now you can execute a new SHOW STATUS statement and observe the changes, as shown here (with the changed rows highlighted in the output):

mysql> **SHOW** **STATUS** **LIKE** **'ndb\_api%session%';**

+--------------------------------------------+-----------+

|  |  |  |  |
| --- | --- | --- | --- |
| | Variable\_name | | | Value | | |

+--------------------------------------------+-----------+

*|*

Ndb\_api\_wait\_scan\_result\_count\_session

*Ndb\_api\_wait\_meta\_request\_count\_session*

*Ndb\_api\_wait\_nanos\_count\_session*

*Ndb\_api\_bytes\_sent\_count\_session*

*Ndb\_api\_bytes\_received\_count\_session*

*Ndb\_api\_trans\_start\_count\_session*

*Ndb\_api\_trans\_commit\_count\_session*

Ndb\_api\_trans\_abort\_count\_session

*Ndb\_api\_trans\_close\_count\_session*

*Ndb\_api\_pk\_op\_count\_session*

Ndb\_api\_uk\_op\_count\_session

Ndb\_api\_table\_scan\_count\_session

Ndb\_api\_range\_scan\_count\_session

Ndb\_api\_pruned\_scan\_count\_session

Ndb\_api\_scan\_batch\_count\_session

*Ndb\_api\_read\_row\_count\_session*

Ndb\_api\_trans\_local\_read\_row\_count\_session

+--------------------------------------------+-----------+

18 rows in set (0.00 sec)

*8*

0

*17*

*706871709*

*2376*

*3844*

*4*

*4*

0

*4*

*6*

0

0

0

0

0

*2*

1

*Ndb\_api\_wait\_exec\_complete\_count\_session*

*|*

|

*|*

*|*

*|*

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|

Similarly, you can see the changes in the NDB API statistics counters caused by inserting a row into t: Insert the row, then run the same SHOW STATUS statement used in the previous example, as shown here:

mysql> **INSERT** **INTO** **t** **VALUES** **(100);**

Query OK, 1 row affected (0.00 sec)

mysql> **SHOW** **STATUS** **LIKE** **'ndb\_api%session%';**

+--------------------------------------------+-----------+

|  |  |  |  |
| --- | --- | --- | --- |
| | Variable\_name | | | Value | | |

+--------------------------------------------+-----------+

*|*

*|*

*|*

*Ndb\_api\_wait\_exec\_complete\_count\_session*

*Ndb\_api\_wait\_scan\_result\_count\_session*

*Ndb\_api\_wait\_meta\_request\_count\_session*

*11*

*6*

*20*

*|*

*|*

*|*

*|*

*|*

*|*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *|* | *Ndb\_api\_wait\_nanos\_count\_session* | *|* | *707370418* | *|* |
| *|* | *Ndb\_api\_bytes\_sent\_count\_session* | *|* | *2724* | *|* |
| *|* | *Ndb\_api\_bytes\_received\_count\_session* | *|* | *4116* | *|* |
| *|* | *Ndb\_api\_trans\_start\_count\_session* | *|* | *7* | *|* |
| *|* | *Ndb\_api\_trans\_commit\_count\_session* | *|* | *6* | *|* |
| | | Ndb\_api\_trans\_abort\_count\_session | | | 0 | | |
| *|* | *Ndb\_api\_trans\_close\_count\_session* | *|* | *7* | *|* |
| *|* | *Ndb\_api\_pk\_op\_count\_session* | *|* | *8* | *|* |
| | | Ndb\_api\_uk\_op\_count\_session | | | 0 | | |
| *|* | *Ndb\_api\_table\_scan\_count\_session* | *|* | *1* | *|* |
| | | Ndb\_api\_range\_scan\_count\_session | | | 0 | | |
| | | Ndb\_api\_pruned\_scan\_count\_session | | | 0 | | |
| | | Ndb\_api\_scan\_batch\_count\_session | | | 0 | | |
| *|* | *Ndb\_api\_read\_row\_count\_session* | *|* | *3* | *|* |
| *|* | *Ndb\_api\_trans\_local\_read\_row\_count\_session* | *|* | *2* | *|* |

+--------------------------------------------+-----------+

18 rows in set (0.00 sec)

We can make a number of observations from these results:

• Although we created t with no explicit primary key, 5 primary key operations were performed in doing so (the difference in the “before” and “after” values of Ndb\_api\_pk\_op\_count\_session, or 6 minus 1). This reflects the creation of the hidden primary key that is a feature of all tables using the NDB storage engine.

• By comparing successive values for Ndb\_api\_wait\_nanos\_count\_session, we can see that the NDB API operations implementing the CREATE TABLE statement waited much longer (706871709

- 820705 = 706051004 nanoseconds, or approximately 0.7 second) for responses from the data nodes than those executed by the INSERT (707370418 - 706871709 = 498709 ns or roughly .0005 second). The execution times reported for these statements in the mysql client correlate roughly with these figures.

On platforms without sufficient (nanosecond) time resolution, small changes in the value of the WaitNanosCount NDB API counter due to SQL statements that execute very quickly may not always be visible in the values of Ndb\_api\_wait\_nanos\_count\_session, Ndb\_api\_wait\_nanos\_count\_slave, or Ndb\_api\_wait\_nanos\_count.

• The INSERT statement incremented both the ReadRowCount and TransLocalReadRowCount NDB API statistics counters, as reflected by the increased values of Ndb\_api\_read\_row\_count\_session and Ndb\_api\_trans\_local\_read\_row\_count\_session.

**23.6.16** **ndbinfo:** **The** **NDB** **Cluster** **Information** **Database**

ndbinfo is a database containing information specific to NDB Cluster.

This database contains a number of tables, each providing a different sort of data about NDB Cluster node status, resource usage, and operations. You can find more detailed information about each of these tables in the next several sections.

ndbinfo is included with NDB Cluster support in the MySQL Server; no special compilation or configuration steps are required; the tables are created by the MySQL Server when it connects to the cluster. You can verify that ndbinfo support is active in a given MySQL Server instance using SHOW PLUGINS; if ndbinfo support is enabled, you should see a row containing ndbinfo in the Name column and ACTIVE in the Status column, as shown here (emphasized text):

mysql> **SHOW** **PLUGINS;**

+----------------------------------+--------+--------------------+---------+---------+

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| | Name | | | Status | | | Type | | Library | License | |

+----------------------------------+--------+--------------------+---------+---------+

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | binlog  | mysql\_native\_password  | sha256\_password  | caching\_sha2\_password  | sha2\_cache\_cleaner  | daemon\_keyring\_proxy\_plugin | |  |  |  |  |  | | ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE | |  |  |  |  |  | | STORAGE ENGINE  AUTHENTICATION  AUTHENTICATION  AUTHENTICATION  AUDIT  DAEMON | |  |  |  |  |  | | NULL  NULL  NULL  NULL  NULL  NULL | |  |  |  |  |  | | GPL  GPL  GPL  GPL  GPL  GPL | |  |  |  |  |  | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  *|*  |  |  |  | | CSV |  MEMORY |  InnoDB |  INNODB\_TRX |  INNODB\_CMP |  INNODB\_CMP\_RESET |  INNODB\_CMPMEM |  INNODB\_CMPMEM\_RESET |  INNODB\_CMP\_PER\_INDEX |  INNODB\_CMP\_PER\_INDEX\_RESET |  INNODB\_BUFFER\_PAGE |  INNODB\_BUFFER\_PAGE\_LRU |  INNODB\_BUFFER\_POOL\_STATS |  INNODB\_TEMP\_TABLE\_INFO |  INNODB\_METRICS |  INNODB\_FT\_DEFAULT\_STOPWORD |  INNODB\_FT\_DELETED |  INNODB\_FT\_BEING\_DELETED |  INNODB\_FT\_CONFIG |  INNODB\_FT\_INDEX\_CACHE |  INNODB\_FT\_INDEX\_TABLE |  INNODB\_TABLES |  INNODB\_TABLESTATS |  INNODB\_INDEXES |  INNODB\_TABLESPACES |  INNODB\_COLUMNS |  INNODB\_VIRTUAL |  INNODB\_CACHED\_INDEXES |  INNODB\_SESSION\_TEMP\_TABLESPACES |  MyISAM |  MRG\_MYISAM |  PERFORMANCE\_SCHEMA |  TempTable |  ARCHIVE |  BLACKHOLE |  ndbcluster |  *ndbinfo* *|*  ndb\_transid\_mysql\_connection\_map |  ngram |  mysqlx\_cache\_cleaner |  mysqlx | | ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  ACTIVE  *ACTIVE*  ACTIVE  ACTIVE  ACTIVE  ACTIVE | |  |  |  |  |  | | --- | --- | --- | --- | --- | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  *|*  |  |  | | STORAGE ENGINE  STORAGE ENGINE  STORAGE ENGINE | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  *|*  |  |  | | NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  NULL  *NULL*  NULL  NULL  NULL | | INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA  INFORMATION SCHEMA | | | STORAGE  STORAGE  STORAGE  STORAGE  STORAGE  STORAGE  STORAGE  *STORAGE* | ENGINE  ENGINE  ENGINE  ENGINE  ENGINE  ENGINE  ENGINE  *ENGINE* | | INFORMATION SCHEMA  FTPARSER  AUDIT | |   | |

+----------------------------------+--------+--------------------+---------+---------+

47 rows in set (0.00 sec)

|  |  |  |
| --- | --- | --- |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  *|*  |  |  | | GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  GPL  *GPL*  GPL  GPL  GPL | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  *|*  |  |  | |

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You can also do this by checking the output of SHOW ENGINES for a line including ndbinfo in the Engine column and YES in the Support column, as shown here (emphasized text):

mysql> SHOW ENG工NES\G

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: ndbcluster

Support: YES

Comment: Clustered, fault-tolerant tables

Transactions: YES

XA: NO

Savepoints: NO

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 2. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: CSV

Support: YES

Comment: CSV storage engine

Transactions: NO

XA: NO

Savepoints: NO

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 3. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: InnoDB

Support: DEFAULT

Comment: Supports transactions, row-level locking, and foreign keys

Transactions: YES

XA: YES

Savepoints: YES

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 4. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: BLACKHOLE

Support: YES

Comment: /dev/null storage engine (anything you write to it disappears)

Transactions: NO

XA: NO

Savepoints: NO

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 5. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: MyISAM

Support: YES

Comment: MyISAM storage engine

Transactions: NO

XA: NO

Savepoints: NO

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 6. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: MRG\_MYISAM

Support: YES

Comment: Collection of identical MyISAM tables

Transactions: NO

XA: NO

Savepoints: NO

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 7. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: ARCHIVE

Support: YES

Comment: Archive storage engine

Transactions: NO

XA: NO

Savepoints: NO

*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\** *8.* *row* *\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\**

*Engine:* *ndbinfo*

*Support:* *YES*

*Comment:* *NDB* *Cluster* *system* *information* *storage* *engine*

*Transactions:* *NO*

*XA:* *NO*

*Savepoints:* *NO*

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 9. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: PERFORMANCE\_SCHEMA

Support: YES

Comment: Performance Schema

Transactions: NO

XA: NO

Savepoints: NO

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 10. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Engine: MEMORY

Support: YES

Comment: Hash based, stored in memory, useful for temporary tables

Transactions: NO

XA: NO

Savepoints: NO

10 rows in set (0.00 sec)

If ndbinfo support is enabled, then you can access ndbinfo using SQL statements in mysql or another MySQL client. For example, you can see ndbinfo listed in the output of SHOW DATABASES, as shown here (emphasized text):

mysql> **SHOW** **DATABASES;**

+--------------------+

|  |  |
| --- | --- |
| | Database | | |

+--------------------+

|  |  |  |
| --- | --- | --- |
| |  |  *|*  |  | | information\_schema  mysql  *ndbinfo*  performance\_schema  sys | |  |  *|*  |  | |

+--------------------+

5 rows in set (0.04 sec)

If the mysqld process was not started with the --ndbcluster option, ndbinfo is not available and is not displayed by SHOW DATABASES. If mysqld was formerly connected to an NDB Cluster but the cluster becomes unavailable (due to events such as cluster shutdown, loss of network connectivity, and so forth), ndbinfo and its tables remain visible, but an attempt to access any tables (other than blocks or config\_params) fails with Got error 157 'Connection to NDB failed' from

NDBINFO.

With the exception of the [blocks](#_bookmark2) and [config\_params](#_bookmark3) tables, what we refer to as ndbinfo “tables” are actually views generated from internal NDB tables not normally visible to the MySQL Server. You can make these tables visible by setting the ndbinfo\_show\_hidden system variable to ON (or 1), but this is normally not necessary.

All ndbinfo tables are read-only, and are generated on demand when queried. Because many of them are generated in parallel by the data nodes while other are specific to a given SQL node, they are not guaranteed to provide a consistent snapshot.

In addition, pushing down of joins is not supported on ndbinfo tables; so joining large ndbinfo tables can require transfer of a large amount of data to the requesting API node, even when the query makes use of a WHERE clause.

ndbinfo tables are not included in the query cache. (Bug #59831)

You can select the ndbinfo database with a USE statement, and then issue a SHOW TABLES statement to obtain a list of tables, just as for any other database, like this:

mysql> **USE** **ndbinfo;**

Database changed

mysql> **SHOW** **TABLES;**

+---------------------------------+

| Tables\_in\_ndbinfo |

+---------------------------------+

| arbitrator\_validity\_detail |

| arbitrator\_validity\_summary |

| backup\_id |

| blobs |

| blocks |

| cluster\_locks |

| cluster\_operations |

| cluster\_transactions |

| config\_nodes |

| config\_params |

| config\_values |

| counters |

| cpudata |

| cpudata\_1sec |

| cpudata\_20sec |

| cpudata\_50ms |

| cpuinfo |

| cpustat |

| cpustat\_1sec |

| cpustat\_20sec |

| cpustat\_50ms |

| dict\_obj\_info |

| dict\_obj\_tree |

| dict\_obj\_types |

| dictionary\_columns |

| dictionary\_tables |

| disk\_write\_speed\_aggregate |

| disk\_write\_speed\_aggregate\_node |

| disk\_write\_speed\_base |

| diskpagebuffer |

| diskstat |

| diskstats\_1sec |

| error\_messages |

| events |

| files |

| foreign\_keys |

| hash\_maps |

| hwinfo |

| index\_columns |

| index\_stats |

| locks\_per\_fragment |

| logbuffers |

| logspaces |

| membership |

|  |  |  |
| --- | --- | --- |
| | | memory\_per\_fragment | | |
| | | memoryusage | | |
| | | nodes | | |
| | | operations\_per\_fragment | | |
| | | pgman\_time\_track\_stats | | |
| | | processes | | |
| | | resources | | |
| | | restart\_info | | |
| | | server\_locks | | |
| | | server\_operations | | |
| | | server\_transactions | | |
| | | table\_distribution\_status | | |
| | | table\_fragments | | |
| | | table\_info | | |
| | | table\_replicas | | |
| | | tc\_time\_track\_stats | | |
| | | threadblocks | | |
| | | threads | | |
| | | threadstat | | |
| | | transporters | | |

+---------------------------------+

64 rows in set (0.00 sec)

In NDB 8.0, all ndbinfo tables use the NDB storage engine; however, an ndbinfo entry still appears in the output of SHOW ENGINES and SHOW PLUGINS as described previously.

You can execute SELECT statements against these tables, just as you would normally expect:

mysql> **SELECT** **\*** **FROM** **memoryusage;**

+---------+---------------------+--------+------------+------------+-------------+

| node\_id | memory\_type | used | used\_pages | total | total\_pages |

+---------+---------------------+--------+------------+------------+-------------+

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | 5 | | | Data | memory |  | | | 425984 | | | 13 | | | 2147483648 | | | 65536 | | |
| | | 5 | | | Long | message | buffer | | | 393216 | | | 1536 | | | 67108864 | | | 262144 | | |
| | | 6 | | | Data | memory |  | | | 425984 | | | 13 | | | 2147483648 | | | 65536 | | |
| | | 6 | | | Long | message | buffer | | | 393216 | | | 1536 | | | 67108864 | | | 262144 | | |
| | | 7 | | | Data | memory |  | | | 425984 | | | 13 | | | 2147483648 | | | 65536 | | |
| | | 7 | | | Long | message | buffer | | | 393216 | | | 1536 | | | 67108864 | | | 262144 | | |
| | | 8 | | | Data | memory |  | | | 425984 | | | 13 | | | 2147483648 | | | 65536 | | |
| | | 8 | | | Long | message | buffer | | | 393216 | | | 1536 | | | 67108864 | | | 262144 | | |

+---------+---------------------+--------+------------+------------+-------------+

8 rows in set (0.09 sec)

More complex queries, such as the two following SELECT statements using the [memoryusage](#_bookmark4) table, are possible:

mysql> **SELECT** **SUM(used)** **as** **'Data** **Memory** **Used,** **All** **Nodes'**

|  |  |
| --- | --- |
| >  > | **FROM** **memoryusage**  **WHERE** **memory\_type** **=** **'Data** **memory';** |

+-----------------------------+

| Data Memory Used, All Nodes |

+-----------------------------+

| 6460 |

+-----------------------------+

1 row in set (0.09 sec)

mysql> **SELECT** **SUM(used)** **as** **'Long** **Message** **Buffer,** **All** **Nodes'**

|  |  |
| --- | --- |
| >  > | **FROM** **memoryusage**  **WHERE** **memory\_type** **=** **'Long** **message** **buffer';** |

+-------------------------------------+

| Long Message Buffer Used, All Nodes |

+-------------------------------------+

| 1179648 |

+-------------------------------------+

1 row in set (0.08 sec)

ndbinfo table and column names are case-sensitive (as is the name of the ndbinfo database itself). These identifiers are in lowercase. Trying to use the wrong lettercase results in an error, as shown in this example:

mysql> **SELECT** **\*** **FROM** **nodes;**

+---------+--------+---------+-------------+-------------------+

| node\_id | uptime | status | start\_phase | config\_generation |

+---------+--------+---------+-------------+-------------------+

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | 5 | | | 17707 | | | STARTED | | | 0 | | | 1 | | |
| | | 6 | | | 17706 | | | STARTED | | | 0 | | | 1 | | |
| | | 7 | | | 17705 | | | STARTED | | | 0 | | | 1 | | |
| | | 8 | | | 17704 | | | STARTED | | | 0 | | | 1 | | |

+---------+--------+---------+-------------+-------------------+

4 rows in set (0.06 sec)

mysql> **SELECT** **\*** **FROM** **Nodes;**

ERROR 1146 (42S02): Table 'ndbinfo.Nodes' doesn't exist

mysqldump ignores the ndbinfo database entirely, and excludes it from any output. This is true even when using the --databases or --all-databases option.

NDB Cluster also maintains tables in the INFORMATION\_SCHEMA information database, including the FILES table which contains information about files used for NDB Cluster Disk Data storage, and the ndb\_transid\_mysql\_connection\_map table, which shows the relationships between transactions, transaction coordinators, and NDB Cluster API nodes. For more information, see the descriptions of the tables or [Section 23.6.17, “INFORMATION\_SCHEMA Tables for NDB Cluster”](#_bookmark5) .

**23.6.16.1** **The** **ndbinfo** **arbitrator\_validity\_detail** **Table**

The arbitrator\_validity\_detail table shows the view that each data node in the cluster has of the arbitrator. It is a subset of the [membership](#_bookmark6) table.

The arbitrator\_validity\_detail table contains the following columns:

• node\_id

This node's node ID

• arbitrator

Node ID of arbitrator

• arb\_ticket

Internal identifier used to track arbitration

• arb\_connected

Whether this node is connected to the arbitrator; either of Yes or No

• arb\_state Arbitration state

**Notes**

The node ID is the same as that reported by ndb\_mgm -e "SHOW".

All nodes should show the same arbitrator and arb\_ticket values as well as the same arb\_state value. Possible arb\_state values are ARBIT\_NULL, ARBIT\_INIT, ARBIT\_FIND, ARBIT\_PREP1, ARBIT\_PREP2, ARBIT\_START, ARBIT\_RUN, ARBIT\_CHOOSE, ARBIT\_CRASH, and

UNKNOWN.

arb\_connected shows whether the current node is connected to the arbitrator.

**23.6.16.2** **The** **ndbinfo** **arbitrator\_validity\_summary** **Table**

The arbitrator\_validity\_summary table provides a composite view of the arbitrator with regard to the cluster's data nodes.

The arbitrator\_validity\_summary table contains the following columns:

• arbitrator

Node ID of arbitrator

• arb\_ticket

Internal identifier used to track arbitration

• arb\_connected

Whether this arbitrator is connected to the cluster

• consensus\_count

Number of data nodes that see this node as arbitrator; either of Yes or No

**Notes**

In normal operations, this table should have only 1 row for any appreciable length of time. If it has more than 1 row for longer than a few moments, then either not all nodes are connected to the arbitrator, or all nodes are connected, but do not agree on the same arbitrator.

The arbitrator column shows the arbitrator's node ID.

arb\_ticket is the internal identifier used by this arbitrator.

arb\_connected shows whether this node is connected to the cluster as an arbitrator.

**23.6.16.3** **The** **ndbinfo** **backup\_id** **Table**

This table provides a way to find the ID of the backup started most recently for this cluster.

The backup\_id table contains a single column id, which corresponds to a backup ID taken using the ndb\_mgm client START BACKUP command. This table contains a single row.

*Example*: Assume the following sequence of START BACKUP commands issued in the NDB management client, with no other backups taken since the cluster was first started:

ndb\_mgm> **START** **BACKUP**

Waiting for completed, this may take several minutes

Node 5: Backup 1 started from node 50

Node 5: Backup 1 started from node 50 completed

StartGCP: 27894 StopGCP: 27897

#Records: 2057 #LogRecords: 0

Data: 51580 bytes Log: 0 bytes

ndb\_mgm> **START** **BACKUP** **5**

Waiting for completed, this may take several minutes

Node 5: Backup 5 started from node 50

Node 5: Backup 5 started from node 50 completed

StartGCP: 27905 StopGCP: 27908

#Records: 2057 #LogRecords: 0

Data: 51580 bytes Log: 0 bytes

ndb\_mgm> **START** **BACKUP**

Waiting for completed, this may take several minutes

Node 5: Backup 6 started from node 50

Node 5: Backup 6 started from node 50 completed

StartGCP: 27912 StopGCP: 27915

#Records: 2057 #LogRecords: 0

Data: 51580 bytes Log: 0 bytes

ndb\_mgm> **START** **BACKUP** **3**

Connected to Management Server at: localhost:1186

Waiting for completed, this may take several minutes

Node 5: Backup 3 started from node 50

Node 5: Backup 3 started from node 50 completed

StartGCP: 28149 StopGCP: 28152

#Records: 2057 #LogRecords: 0

Data: 51580 bytes Log: 0 bytes

ndb\_mgm>

After this, the backup\_id table contains the single row shown here, using the mysql client:

mysql> **USE** **ndbinfo;**

Database changed

mysql> **SELECT** **\*** **FROM** **backup\_id;**

+------+

| id |

+------+

| 3 |

+------+

1 row in set (0.00 sec)

If no backups can be found, the table contains a single row with 0 as the id value. The backup\_id table was added in NDB 8.0.24.

**23.6.16.4** **The** **ndbinfo** **blobs** **Table**

This table provides about blob values stored in NDB. The blobs table has the columns listed here:

• table\_id

Unique ID of the table containing the column

• database\_name

Name of the database in which this table resides

• table\_name Name of the table

• column\_id

The column's unique ID within the table

• column\_name Name of the column

• inline\_size

Inline size of the column

• part\_size

Part size of the column

• stripe\_size

Stripe size of the column

• blob\_table\_name

Name of the blob table containing this column's blob data, if any

Rows exist in this table for those NDB table columns that store BLOB, TEXT values taking up more than 255 bytes and thus require the use of a blob table. Parts of JSON values exceeding 4000 bytes in size are also stored in this table. For more information about how NDB Cluster stores columns of such types, see String Type Storage Requirements.

The part and (NDB 8.0.30 and later) inline sizes of NDB blob columns can be set using CREATE TABLE and ALTER TABLE statements containing NDB table column comments (see NDB\_COLUMN Options); this can also be done in NDB API applications (see [Column::setPartSize()](https://dev.mysql.com/doc/ndbapi/en/ndb-column.html#ndb-column-setpartsize) and [setInlineSize()](https://dev.mysql.com/doc/ndbapi/en/ndb-column.html#ndb-column-setinlinesize)).

The blobs table was added in NDB 8.0.29.

**23.6.16.5** **The** **ndbinfo** **blocks** **Table**

The blocks table is a static table which simply contains the names and internal IDs of all NDB kernel blocks (see [NDB Kernel Blocks](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks.html)). It is for use by the other [ndbinfo](#_bookmark1) tables (most of which are actually

views) in mapping block numbers to block names for producing human-readable output. The blocks table contains the following columns:

• block\_number Block number

• block\_name Block name

**Notes**

To obtain a list of all block names, simply execute SELECT block\_name FROM ndbinfo.blocks. Although this is a static table, its content can vary between different NDB Cluster releases.

**23.6.16.6** **The** **ndbinfo** **cluster\_locks** **Table**

The cluster\_locks table provides information about current lock requests holding and waiting for locks on NDB tables in an NDB Cluster, and is intended as a companion table to [cluster\_operations](#_bookmark7). Information obtain from the cluster\_locks table may be useful in investigating stalls and deadlocks.

The cluster\_locks table contains the following columns:

• node\_id

ID of reporting node

• block\_instance

ID of reporting LDM instance

• tableid

ID of table containing this row

• fragmentid

ID of fragment containing locked row

• rowid

ID of locked row

• transid

Transaction ID

• mode

Lock request mode

• state Lock state

• detail

Whether this is first holding lock in row lock queue

• op

Operation type

• duration\_millis

Milliseconds spent waiting or holding lock

• lock\_num

ID of lock object

• waiting\_for

Waiting for lock with this ID

**Notes**

The table ID (tableid column) is assigned internally, and is the same as that used in other ndbinfo tables. It is also shown in the output of ndb\_show\_tables.

The transaction ID (transid column) is the identifier generated by the NDB API for the transaction requesting or holding the current lock.

The mode column shows the lock mode; this is always one of S (indicating a shared lock) or X (an exclusive lock). If a transaction holds an exclusive lock on a given row, all other locks on that row have the same transaction ID.

The state column shows the lock state. Its value is always one of H (holding) or W (waiting). A waiting lock request waits for a lock held by a different transaction.

When the detail column contains a \* (asterisk character), this means that this lock is the first holding lock in the affected row's lock queue; otherwise, this column is empty. This information can be used to help identify the unique entries in a list of lock requests.

The op column shows the type of operation requesting the lock. This is always one of the values READ, INSERT, UPDATE, DELETE, SCAN, or REFRESH.

The duration\_millis column shows the number of milliseconds for which this lock request has been waiting or holding the lock. This is reset to 0 when a lock is granted for a waiting request.

The lock ID (lockid column) is unique to this node and block instance.

The lock state is shown in the lock\_state column; if this is W, the lock is waiting to be granted, and the waiting\_for column shows the lock ID of the lock object this request is waiting for. Otherwise, the waiting\_for column is empty. waiting\_for can refer only to locks on the same row, as identified by node\_id, block\_instance, tableid, fragmentid, and rowid.

**23.6.16.7** **The** **ndbinfo** **cluster\_operations** **Table**

The cluster\_operations table provides a per-operation (stateful primary key op) view of all activity in the NDB Cluster from the point of view of the local data management (LQH) blocks (see [The DBLQH](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dblqh.html) [Block](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dblqh.html)).

The cluster\_operations table contains the following columns:

• node\_id

Node ID of reporting LQH block

• block\_instance LQH block instance

• transid

Transaction ID

• operation\_type

Operation type (see text for possible values)

• state

Operation state (see text for possible values)

• tableid

Table ID

• fragmentid Fragment ID

• client\_node\_id Client node ID

• client\_block\_ref Client block reference

• tc\_node\_id

Transaction coordinator node ID

• tc\_block\_no

Transaction coordinator block number

• tc\_block\_instance

Transaction coordinator block instance

**Notes**

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's [getTransactionId()](https://dev.mysql.com/doc/ndbapi/en/ndb-ndbtransaction.html#ndb-ndbtransaction-gettransactionid) method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The operation\_type column can take any one of the values READ, READ-SH, READ-EX, INSERT, UPDATE, DELETE, WRITE, UNLOCK, REFRESH, SCAN, SCAN-SH, SCAN-EX, or <unknown>.

The state column can have any one of the values ABORT\_QUEUED, ABORT\_STOPPED,

COMMITTED, COMMIT\_QUEUED, COMMIT\_STOPPED, COPY\_CLOSE\_STOPPED, COPY\_FIRST\_STOPPED, COPY\_STOPPED, COPY\_TUPKEY, IDLE, LOG\_ABORT\_QUEUED, LOG\_COMMIT\_QUEUED, LOG\_COMMIT\_QUEUED\_WAIT\_SIGNAL, LOG\_COMMIT\_WRITTEN, LOG\_COMMIT\_WRITTEN\_WAIT\_SIGNAL, LOG\_QUEUED, PREPARED, PREPARED\_RECEIVED\_COMMIT, SCAN\_CHECK\_STOPPED, SCAN\_CLOSE\_STOPPED, SCAN\_FIRST\_STOPPED,

SCAN\_RELEASE\_STOPPED, SCAN\_STATE\_USED, SCAN\_STOPPED, SCAN\_TUPKEY, STOPPED,

TC\_NOT\_CONNECTED, WAIT\_ACC, WAIT\_ACC\_ABORT, WAIT\_AI\_AFTER\_ABORT, WAIT\_ATTR,

WAIT\_SCAN\_AI, WAIT\_TUP, WAIT\_TUPKEYINFO, WAIT\_TUP\_COMMIT, or WAIT\_TUP\_TO\_ABORT. (If the MySQL Server is running with ndbinfo\_show\_hidden enabled, you can view this list of states by selecting from the ndb$dblqh\_tcconnect\_state table, which is normally hidden.)

You can obtain the name of an NDB table from its table ID by checking the output of ndb\_show\_tables.

The fragid is the same as the partition number seen in the output of ndb\_desc --extra- partition-info (short form -p).

In client\_node\_id and client\_block\_ref, client refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The block\_instance and tc\_block\_instance column provide, respectively, the [DBLQH](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dblqh.html) and [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html) block instance numbers. You can use these along with the block names to obtain information about specific threads from the [threadblocks](#_bookmark8) table.

**23.6.16.8** **The** **ndbinfo** **cluster\_transactions** **Table**

The cluster\_transactions table shows information about all ongoing transactions in an NDB

Cluster.

The cluster\_transactions table contains the following columns:

• node\_id

Node ID of transaction coordinator

• block\_instance TC block instance

• transid

Transaction ID

• state

Operation state (see text for possible values)

• count\_operations

Number of stateful primary key operations in transaction (includes reads with locks, as well as DML operations)

• outstanding\_operations

Operations still being executed in local data management blocks

• inactive\_seconds Time spent waiting for API

• client\_node\_id Client node ID

• client\_block\_ref Client block reference

**Notes**

The transaction ID is a unique 64-bit number which can be obtained using the NDB API's [getTransactionId()](https://dev.mysql.com/doc/ndbapi/en/ndb-ndbtransaction.html#ndb-ndbtransaction-gettransactionid) method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

block\_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the [threadblocks](#_bookmark8) table.

The state column can have any one of the values CS\_ABORTING, CS\_COMMITTING,

CS\_COMMIT\_SENT, CS\_COMPLETE\_SENT, CS\_COMPLETING, CS\_CONNECTED, CS\_DISCONNECTED, CS\_FAIL\_ABORTED, CS\_FAIL\_ABORTING, CS\_FAIL\_COMMITTED, CS\_FAIL\_COMMITTING, CS\_FAIL\_COMPLETED, CS\_FAIL\_PREPARED, CS\_PREPARE\_TO\_COMMIT, CS\_RECEIVING, CS\_REC\_COMMITTING, CS\_RESTART, CS\_SEND\_FIRE\_TRIG\_REQ, CS\_STARTED,

CS\_START\_COMMITTING, CS\_START\_SCAN, CS\_WAIT\_ABORT\_CONF, CS\_WAIT\_COMMIT\_CONF,

CS\_WAIT\_COMPLETE\_CONF, CS\_WAIT\_FIRE\_TRIG\_REQ. (If the MySQL Server is running with ndbinfo\_show\_hidden enabled, you can view this list of states by selecting from the ndb $dbtc\_apiconnect\_state table, which is normally hidden.)

In client\_node\_id and client\_block\_ref, client refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The tc\_block\_instance column provides the [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html) block instance number. You can use this along with the block name to obtain information about specific threads from the [threadblocks](#_bookmark8) table.

**23.6.16.9** **The** **ndbinfo** **config\_nodes** **Table**

The config\_nodes table shows nodes configured in an NDB Cluster config.ini file. For each node, the table displays a row containing the node ID, the type of node (management node, data node, or API node), and the name or IP address of the host on which the node is configured to run.

This table does not indicate whether a given node is actually running, or whether it is currently connected to the cluster. Information about nodes connected to an NDB Cluster can be obtained from the [nodes](#_bookmark11) and [processes](#_bookmark12) table.

The config\_nodes table contains the following columns:

• node\_id The node's ID

• node\_type The type of node

• node\_hostname

The name or IP address of the host on which the node resides

**Notes**

The node\_id column shows the node ID used in the config.ini file for this node; if none is specified, the node ID that would be assigned automatically to this node is displayed.

The node\_type column displays one of the following three values:

• MGM: Management node.

• NDB: Data node.

• API: API node; this includes SQL nodes.

The node\_hostname column shows the node host as specified in the config.ini file. This can be empty for an API node, if HostName has not been set in the cluster configuration file. If HostName has not been set for a data node in the configuration file, localhost is used here. localhost is also used if HostName has not been specified for a management node.

**23.6.16.10** **The** **ndbinfo** **config\_params** **Table**

The config\_params table is a static table which provides the names and internal ID numbers of and other information about NDB Cluster configuration parameters. This table can also be used in conjunction with the [config\_values](#_bookmark13) table for obtaining realtime information about node configuration parameters.

The config\_params table contains the following columns:

• param\_number

The parameter's internal ID number

• param\_name

The name of the parameter

• param\_description

A brief description of the parameter

• param\_type

The parameter's data type

• param\_default

The parameter's default value, if any

• param\_min

The parameter's maximum value, if any

• param\_max

The parameter's minimum value, if any

• param\_mandatory

This is 1 if the parameter is required, otherwise 0

• param\_status Currently unused

**Notes**

This table is read-only.

Although this is a static table, its content can vary between NDB Cluster installations, since supported parameters can vary due to differences between software releases, cluster hardware configurations, and other factors.

**23.6.16.11** **The** **ndbinfo** **config\_values** **Table**

The config\_values table provides information about the current state of node configuration parameter values. Each row in the table corresponds to the current value of a parameter on a given node.

The config\_values table contains the following columns:

• node\_id

ID of the node in the cluster

• config\_param

The parameter's internal ID number

• config\_value

Current value of the parameter

**Notes**

This table's config\_param column and the [config\_params](#_bookmark3) table's param\_number column use the same parameter identifiers. By joining the two tables on these columns, you can obtain detailed information about desired node configuration parameters. The query shown here provides the current values for all parameters on each data node in the cluster, ordered by node ID and parameter name:

|  |  |
| --- | --- |
| SELECT  FROM  JOIN  ON  WHERE  ORDER BY | v.node\_id AS 'Node Id',  p .param\_name AS 'Parameter',  v .config\_value AS 'Value'  config\_values v  config\_params p  v .config\_param=p .param\_number  p .param\_name NOT LIKE '\\_\\_%'  v.node\_id, p.param\_name; |

Partial output from the previous query when run on a small example cluster used for simple testing:

+---------+------------------------------------------+----------------+

|

+---------+------------------------------------------+----------------+

|

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...

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+---------+------------------------------------------+----------------+

248 rows in set (0.02 sec)

TotalSendBufferMemory

TransactionBufferMemory

TransactionDeadlockDetectionTimeout

TransactionInactiveTimeout

TwoPassInitialNodeRestartCopy

UndoDataBuffer

UndoIndexBuffer

Arbitration

ArbitrationTimeout

BackupDataBufferSize

BackupDataDir

BackupDiskWriteSpeedPct

BackupLogBufferSize

1

7500

16777216

/home/jon/data

50

16777216

0

1048576

1200

4294967039

0

16777216

2097152

| Node Id | Parameter

3

3

3

3

3

3

3

2

2

2

2

2

2

|

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Value

|

|

The WHERE clause filters out parameters whose names begin with a double underscore (\_\_); these parameters are reserved for testing and other internal uses by the NDB developers, and are not intended for use in a production NDB Cluster.

You can obtain output that is more specific, more detailed, or both by issuing the proper queries. This example provides all types of available information about the NodeId, NoOfReplicas, HostName, DataMemory, IndexMemory, and TotalSendBufferMemory parameters as currently set for all data nodes in the cluster:

SELECT p.param\_name AS Name,

v .node\_id AS Node,

p.param\_type AS Type,

p .param\_default AS 'Default',

p .param\_min AS Minimum,

p .param\_max AS Maximum,

CASE p .param\_mandatory WHEN 1 THEN 'Y' ELSE 'N' END AS 'Required',

v .config\_value AS Current

FROM config\_params p

JOIN config\_values v

ON p .param\_number = v .config\_param

WHERE p. param\_name

IN ('NodeId', 'NoOfReplicas', 'HostName',

'DataMemory', 'IndexMemory', 'TotalSendBufferMemory')\G

The output from this query when run on a small NDB Cluster with 2 data nodes used for simple testing is shown here:

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: NodeId

Node: 2

Type: unsigned

Default:

Minimum: 1

Maximum: 144

Required: Y

Current: 2

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 2. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: HostName

Node: 2

Type: string

Default: localhost

Minimum:

Maximum:

Required: N

Current: 127.0.0.1

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 3. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: TotalSendBufferMemory

Node: [2](#_bookmark14)

Type: unsigned

Default: 0

Minimum: 262144

Maximum: 4294967039

Required: N

Current: 0

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 4. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: NoOfReplicas

Node: 2

Type: unsigned

Default: 2

Minimum: 1

Maximum: 4

Required: N

Current: 2

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 5. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: DataMemory

Node: 2

Type: unsigned

Default: 102760448

Minimum: 1048576

Maximum: 1099511627776

Required: N

Current: 524288000

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 6. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: NodeId

Node: 3

Type: unsigned

Default:

Minimum: 1

Maximum: 144

Required: Y

Current: 3

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 7. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: HostName

Node: 3

Type: string

Default: localhost

Minimum:

Maximum:

Required: N

Current: 127.0.0.1

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 8. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: TotalSendBufferMemory

Node: [3](#_bookmark15)

Type: unsigned

Default: 0

Minimum: 262144

Maximum: 4294967039

Required: N

Current: 0

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 9. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: NoOfReplicas

Node: 3

Type: unsigned

Default: 2

Minimum: 1

Maximum: 4

Required: N

Current: 2

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 10. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Name: DataMemory

Node: 3

Type: unsigned

Default: 102760448

Minimum: 1048576

Maximum: 1099511627776

Required: N

Current: 524288000

10 rows in set (0.01 sec)

**23.6.16.12** **The** **ndbinfo** **counters** **Table**

The counters table provides running totals of events such as reads and writes for specific kernel blocks and data nodes. Counts are kept from the most recent node start or restart; a node start or

restart resets all counters on that node. Not all kernel blocks have all types of counters. The counters table contains the following columns:

• node\_id The data node ID

• block\_name

Name of the associated NDB kernel block (see [NDB Kernel Blocks](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks.html)).

• block\_instance Block instance

• counter\_id

The counter's internal ID number; normally an integer between 1 and 10, inclusive.

• counter\_name

The name of the counter. See text for names of individual counters and the NDB kernel block with which each counter is associated.

• val

The counter's value

**Notes**

Each counter is associated with a particular NDB kernel block.

The OPERATIONS counter is associated with the [DBLQH](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dblqh.html) (local query handler) kernel block. A primary- key read counts as one operation, as does a primary-key update. For reads, there is one operation in [DBLQH](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dblqh.html) per operation in [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html). For writes, there is one operation counted per fragment replica.

The ATTRINFO, TRANSACTIONS, COMMITS, READS, LOCAL\_READS, SIMPLE\_READS, WRITES, LOCAL\_WRITES, ABORTS, TABLE\_SCANS, and RANGE\_SCANS counters are associated with the [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html) (transaction co-ordinator) kernel block.

LOCAL\_WRITES and LOCAL\_READS are primary-key operations using a transaction coordinator in a node that also holds the primary fragment replica of the record.

The READS counter includes all reads. LOCAL\_READS includes only those reads of the primary fragment replica on the same node as this transaction coordinator. SIMPLE\_READS includes only those reads in which the read operation is the beginning and ending operation for a given transaction. Simple reads do not hold locks but are part of a transaction, in that they observe uncommitted changes made by the transaction containing them but not of any other uncommitted transactions. Such reads are “simple” from the point of view of the TC block; since they hold no locks they are not durable, and once [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html) has routed them to the relevant LQH block, it holds no state for them.

ATTRINFO keeps a count of the number of times an interpreted program is sent to the data node. See [NDB Protocol Messages](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-ndb-protocol-messages.html), for more information about ATTRINFO messages in the NDB kernel.

The LOCAL\_TABLE\_SCANS\_SENT, READS\_RECEIVED, PRUNED\_RANGE\_SCANS\_RECEIVED, RANGE\_SCANS\_RECEIVED, LOCAL\_READS\_SENT, CONST\_PRUNED\_RANGE\_SCANS\_RECEIVED,

LOCAL\_RANGE\_SCANS\_SENT, REMOTE\_READS\_SENT, REMOTE\_RANGE\_SCANS\_SENT,

READS\_NOT\_FOUND, SCAN\_BATCHES\_RETURNED, TABLE\_SCANS\_RECEIVED, and SCAN\_ROWS\_RETURNED counters are associated with the [DBSPJ](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbspj.html) (select push-down join) kernel block.

The block\_name and block\_instance columns provide, respectively, the applicable NDB kernel block name and instance number. You can use these to obtain information about specific threads from the [threadblocks](#_bookmark8) table.

A number of counters provide information about transporter overload and send buffer sizing when troubleshooting such issues. For each LQH instance, there is one instance of each counter in the following list:

• LQHKEY\_OVERLOAD: Number of primary key requests rejected at the LQH block instance due to transporter overload

• LQHKEY\_OVERLOAD\_TC: Count of instances of LQHKEY\_OVERLOAD where the TC node transporter was overloaded

• LQHKEY\_OVERLOAD\_READER: Count of instances of LQHKEY\_OVERLOAD where the API reader (reads only) node was overloaded.

• LQHKEY\_OVERLOAD\_NODE\_PEER: Count of instances of LQHKEY\_OVERLOAD where the next backup data node (writes only) was overloaded

• LQHKEY\_OVERLOAD\_SUBSCRIBER: Count of instances of LQHKEY\_OVERLOAD where a event subscriber (writes only) was overloaded.

• LQHSCAN\_SLOWDOWNS: Count of instances where a fragment scan batch size was reduced due to scanning API transporter overload.

**23.6.16.13** **The** **ndbinfo** **cpudata** **Table**

The cpudata table provides data about CPU usage during the last second.

The cpustat table contains the following columns:

• node\_id

Node ID

• cpu\_no

CPU ID

• cpu\_online

1 if the CPU is currently online, otherwise 0

• cpu\_userspace\_time

CPU time spent in userspace

• cpu\_idle\_time CPU time spent idle

• cpu\_system\_time

CPU time spent in system time

• cpu\_interrupt\_time

CPU time spent handling interrupts (hardware and software)

• cpu\_exec\_vm\_time

CPU time spent in virtual machine execution

**Notes**

The cpudata table is available only on Linux and Solaris operating systems.

This table was added in NDB 8.0.23.

**23.6.16.14** **The** **ndbinfo** **cpudata\_1sec** **Table**

The cpudata\_1sec table provides data about CPU usage per second over the last 20 seconds. The cpustat table contains the following columns:

• node\_id

Node ID

• measurement\_id

Measurement sequence ID; later measurements have lower IDs

• cpu\_no

CPU ID

• cpu\_online

1 if the CPU is currently online, otherwise 0

• cpu\_userspace\_time

CPU time spent in userspace

• cpu\_idle\_time CPU time spent idle

• cpu\_system\_time

CPU time spent in system time

• cpu\_interrupt\_time

CPU time spent handling interrupts (hardware and software)

• cpu\_exec\_vm\_time

CPU time spent in virtual machine execution

• elapsed\_time

Time in microseconds used for this measurement

**Notes**

The cpudata\_1sec table is available only on Linux and Solaris operating systems. This table was added in NDB 8.0.23.

**23.6.16.15** **The** **ndbinfo** **cpudata\_20sec** **Table**

The cpudata\_20sec table provides data about CPU usage per 20-second interval over the last 400 seconds.

The cpustat table contains the following columns:

• node\_id

Node ID

• measurement\_id

Measurement sequence ID; later measurements have lower IDs

• cpu\_no

CPU ID

• cpu\_online

1 if the CPU is currently online, otherwise 0

• cpu\_userspace\_time

CPU time spent in userspace

• cpu\_idle\_time CPU time spent idle

• cpu\_system\_time

CPU time spent in system time

• cpu\_interrupt\_time

CPU time spent handling interrupts (hardware and software)

• cpu\_exec\_vm\_time

CPU time spent in virtual machine execution

• elapsed\_time

Time in microseconds used for this measurement

**Notes**

The cpudata\_20sec table is available only on Linux and Solaris operating systems. This table was added in NDB 8.0.23.

**23.6.16.16** **The** **ndbinfo** **cpudata\_50ms** **Table**

The cpudata\_50ms table provides data about CPU usage per 50-millisecond interval over the last second.

The cpustat table contains the following columns:

• node\_id

Node ID

• measurement\_id

Measurement sequence ID; later measurements have lower IDs

• cpu\_no

CPU ID

• cpu\_online

1 if the CPU is currently online, otherwise 0

• cpu\_userspace\_time

CPU time spent in userspace

• cpu\_idle\_time CPU time spent idle

• cpu\_system\_time

CPU time spent in system time

• cpu\_interrupt\_time

CPU time spent handling interrupts (hardware and software)

• cpu\_exec\_vm\_time

CPU time spent in virtual machine execution

• elapsed\_time

Time in microseconds used for this measurement

**Notes**

The cpudata\_50ms table is available only on Linux and Solaris operating systems.

This table was added in NDB 8.0.23.

**23.6.16.17** **The** **ndbinfo** **cpuinfo** **Table**

The cpuinfo table provides information about the CPU on which a given data node executes. The cpuinfo table contains the following columns:

• node\_id

Node ID

• cpu\_no

CPU ID

• cpu\_online

1 if the CPU is online, otherwise 0

• core\_id CPU core ID

• socket\_id CPU socket ID

**Notes**

The cpuinfo table is available on all operating systems supported by NDB, with the exception of MacOS and FreeBSD.

This table was added in NDB 8.0.23.

**23.6.16.18** **The** **ndbinfo** **cpustat** **Table**

The cpustat table provides per-thread CPU statistics gathered each second, for each thread running in the NDB kernel.

The cpustat table contains the following columns:

• node\_id

ID of the node where the thread is running

• thr\_no

Thread ID (specific to this node)

• OS\_user

OS user time

• OS\_system

OS system time

• OS\_idle OS idle time

• thread\_exec

Thread execution time

• thread\_sleeping Thread sleep time

• thread\_spinning Thread spin time

• thread\_send Thread send time

• thread\_buffer\_full Thread buffer full time

• elapsed\_time Elapsed time

**23.6.16.19** **The** **ndbinfo** **cpustat\_50ms** **Table**

The cpustat\_50ms table provides raw, per-thread CPU data obtained each 50 milliseconds for each thread running in the NDB kernel.

Like [cpustat\_1sec](#_bookmark17) and [cpustat\_20sec](#_bookmark18), this table shows 20 measurement sets per thread, each referencing a period of the named duration. Thus, cpsustat\_50ms provides 1 second of history.

The cpustat\_50ms table contains the following columns:

• node\_id

ID of the node where the thread is running

• thr\_no

Thread ID (specific to this node)

• OS\_user\_time OS user time

• OS\_system\_time OS system time

• OS\_idle\_time OS idle time

• exec\_time

Thread execution time

• sleep\_time Thread sleep time

• spin\_time Thread spin time

• send\_time

Thread send time

• buffer\_full\_time Thread buffer full time

• elapsed\_time Elapsed time

**23.6.16.20** **The** **ndbinfo** **cpustat\_1sec** **Table**

The cpustat-1sec table provides raw, per-thread CPU data obtained each second for each thread running in the NDB kernel.

Like [cpustat\_50ms](#_bookmark16) and [cpustat\_20sec](#_bookmark18), this table shows 20 measurement sets per thread, each referencing a period of the named duration. Thus, cpsustat\_1sec provides 20 seconds of history.

The cpustat\_1sec table contains the following columns:

• node\_id

ID of the node where the thread is running

• thr\_no

Thread ID (specific to this node)

• OS\_user\_time OS user time

• OS\_system\_time OS system time

• OS\_idle\_time OS idle time

• exec\_time

Thread execution time

• sleep\_time Thread sleep time

• spin\_time Thread spin time

• send\_time Thread send time

• buffer\_full\_time Thread buffer full time

• elapsed\_time Elapsed time

**23.6.16.21** **The** **ndbinfo** **cpustat\_20sec** **Table**

The cpustat\_20sec table provides raw, per-thread CPU data obtained each 20 seconds, for each thread running in the NDB kernel.

Like [cpustat\_50ms](#_bookmark16) and [cpustat\_1sec](#_bookmark17), this table shows 20 measurement sets per thread, each referencing a period of the named duration. Thus, cpsustat\_20sec provides 400 seconds of history.

The cpustat\_20sec table contains the following columns:

• node\_id

ID of the node where the thread is running

• thr\_no

Thread ID (specific to this node)

• OS\_user\_time OS user time

• OS\_system\_time OS system time

• OS\_idle\_time OS idle time

• exec\_time

Thread execution time

• sleep\_time Thread sleep time

• spin\_time Thread spin time

• send\_time Thread send time

• buffer\_full\_time Thread buffer full time

• elapsed\_time Elapsed time

**23.6.16.22** **The** **ndbinfo** **dictionary\_columns** **Table**

The table provides NDB dictionary information about columns of NDB tables. dictionary\_columns has the columns listed here (with brief descriptions):

• table\_id

ID of the table containing the column

• column\_id

The column's unique ID

• name

Name of the column

• column\_type

Data type of the column from the NDB API; see [Column::Type](https://dev.mysql.com/doc/ndbapi/en/ndb-column.html#ndb-column-type), for possible values

• default\_value

The column's default value, if any

• nullable

Either of NULL or NOT NULL

• array\_type

The column's internal attribute storage format; one of FIXED, SHORT\_VAR, or MEDIUM\_VAR; for more information, see [Column::ArrayType](https://dev.mysql.com/doc/ndbapi/en/ndb-column.html#ndb-column-arraytype), in the NDB API documentation

• storage\_type

Type of storage used by the table; either of MEMORY or DISK

• primary\_key

1 if this is a primary key column, otherwise 0

• partition\_key

1 if this is a partitioning key column, otherwise 0

• dynamic

1 if the column is dynamic, otherwise 0

• auto\_inc

1 if this is an AUTO\_INCREMENT column, otherwise 0

You can obtain information about all of the columns in a given table by joining dictionary\_columns with the [dictionary\_tables](#_bookmark19) table, like this:

SELECT dc.\*

FROM dictionary\_columns dc

JOIN dictionary\_tables dt

ON dc .table\_id=dt .table\_id

WHERE dt .table\_name='t1'

AND dt.database\_name='mydb';

The dictionary\_columns table was added in NDB 8.0.29.

**Note**

Blob columns are not shown in this table. This is a known issue.

**23.6.16.23** **The** **ndbinfo** **dictionary\_tables** **Table**

This table provides NDB dictionary information for NDB tables. dictionary\_tables contains the columns listed here:

• table\_id The table' unique ID

• database\_name

Name of the database containing the table

• table\_name Name of the table

• status

The table status; one of New, Changed, Retrieved, Invalid, or Altered. (See [Object::Status](https://dev.mysql.com/doc/ndbapi/en/ndb-object.html#ndb-object-status), for more information about object status values.)

• attributes

Number of table attributes

• primary\_key\_cols

Number of columns in the table's primary key

• primary\_key

A comma-separated list of the columns in the table's primary key

• storage

Type of storage used by the table; one of memory, disk, or default

• logging

Whether logging is enabled for this table

• dynamic

1 if the table is dynamic, otherwise 0; the table is considered dynamic if *table*- >[getForceVarPart()](https://dev.mysql.com/doc/ndbapi/en/ndb-table.html#ndb-table-getforcevarpart) is true, or if at least one table column is dynamic

• read\_backup

1 if read from any replica (READ\_BACKUP option is enabled for this table, otherwise 0; see Section 13.1.20.12, “Setting NDB Comment Options”)

• fully\_replicated

1 if FULLY\_REPLICATED is enabled for this table (each data node in the cluster has a complete copy of the table), 0 if not; see Section 13.1.20.12, “Setting NDB Comment Options”

• checksum

If this table uses a checksum, the value in this column is 1; if not, it is 0

• row\_size

The amount of data, in bytes that can be stored in one row, not including any blob data stored separately in blob tables; see [Table::getRowSizeInBytes()](https://dev.mysql.com/doc/ndbapi/en/ndb-table.html#ndb-table-getrowsizeinbytes), in the API documentation, for more information

• min\_rows

Minimum number of rows, as used for calculating partitions; see [Table::getMinRows()](https://dev.mysql.com/doc/ndbapi/en/ndb-table.html#ndb-table-getminrows), in the API documentation, for more information

• max\_rows

Maximum number of rows, as used for calculating partitions; see [Table::getMaxRows()](https://dev.mysql.com/doc/ndbapi/en/ndb-table.html#ndb-table-getmaxrows), in the API documentation, for more information

• tablespace

ID of the tablespace to which the table belongs, if any; this is 0, if the table does not use data on disk

• fragment\_type

The table's fragment type; one of Single, AllSmall, AllMedium, AllLarge, DistrKeyHash, DistrKeyLin, UserDefined, unused, or HashMapPartition; for more information, see [Object::FragmentType](https://dev.mysql.com/doc/ndbapi/en/ndb-object.html#ndb-object-fragmenttype), in the NDB API documentation

• hash\_map

The hash map used by the table

• fragments

Number of table fragments

• partitions

Number of partitions used by the table

• partition\_balance

Type of partition balance used, if any; one of FOR\_RP\_BY\_NODE, FOR\_RA\_BY\_NODE, FOR\_RP\_BY\_LDM, FOR\_RA\_BY\_LDM, FOR\_RA\_BY\_LDM\_X\_2, FOR\_RA\_BY\_LDM\_X\_3, or FOR\_RA\_BY\_LDM\_X\_4; see Section 13.1.20.12, “Setting NDB Comment Options”

• contains\_GCI

1 if the table includes a global checkpoint index, otherwise 0

• single\_user\_mode

Type of access allowed to the table when single user mode is in effect; one of locked, read\_only, or read\_write; these are equivalent to the values SingleUserModeLocked, SingleUserModeReadOnly, and SingleUserModeReadWrite, respectively, of the [Table::SingleUserMode](https://dev.mysql.com/doc/ndbapi/en/ndb-table.html#ndb-table-singleusermode) type in the NDB API

• force\_var\_part

This is 1 if *table*->[getForceVarPart()](https://dev.mysql.com/doc/ndbapi/en/ndb-table.html#ndb-table-getforcevarpart) is true for this table, and 0 if it is not

• GCI\_bits Used in testing

• author\_bits Used in testing

The dictionary\_tables table was added in NDB 8.0.29.

**23.6.16.24** **The** **ndbinfo** **dict\_obj\_info** **Table**

The dict\_obj\_info table provides information about NDB data dictionary ([DICT](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbdict.html)) objects such as tables and indexes. (The [dict\_obj\_types](#_bookmark21) table can be queried for a list of all the types.) This information includes the object's type, state, parent object (if any), and fully qualified name.

The dict\_obj\_info table contains the following columns:

• type

Type of [DICT](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbdict.html) object; join on [dict\_obj\_types](#_bookmark21) to obtain the name

• id

Object identifier; for Disk Data undo log files and data files, this is the same as the value shown in the LOGFILE\_GROUP\_NUMBER column of the Information Schema FILES table; for undo log files, it also the same as the value shown for the log\_id column in the ndbinfo [logbuffers](#_bookmark22) and [logspaces](#_bookmark23) tables

• version Object version

• state

Object state; see [Object::State](https://dev.mysql.com/doc/ndbapi/en/ndb-object.html#ndb-object-state) for values and descriptions.

• parent\_obj\_type

Parent object's type (a dict\_obj\_types type ID); 0 indicates that the object has no parent

• parent\_obj\_id

Parent object ID (such as a base table); 0 indicates that the object has no parent

• fq\_name

Fully qualified object name; for a table, this has the form *database\_name*/def/*table\_name*, for a primary key, the form is sys/def/*table\_id*/PRIMARY, and for a unique key it is sys/ def/*table\_id*/*uk\_name*$unique

**23.6.16.25** **The** **ndbinfo** **dict\_obj\_tree** **Table**

The dict\_obj\_tree table provides a tree-based view of table information from the [dict\_obj\_info](#_bookmark20) table. This is intended primarily for use in testing, but can be useful in visualizing hierarchies of NDB database objects.

The dict\_obj\_tree table contains the following columns:

• type

Type of [DICT](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbdict.html) object; join on [dict\_obj\_types](#_bookmark21) to obtain the name of the object type

• id

Object identifier; same as the id column in [dict\_obj\_info](#_bookmark20)

For Disk Data undo log files and data files, this is the same as the value shown in the LOGFILE\_GROUP\_NUMBER column of the Information Schema FILES table; for undo log files, it also the same as the value shown for the log\_id column in the ndbinfo [logbuffers](#_bookmark22) and [logspaces](#_bookmark23) tables

• name

The fully qualified name of the object; the same as the fq\_name column in [dict\_obj\_info](#_bookmark20)

For a table, this is *database\_name*/def/*table\_name* (the same as its *parent\_name*); for an

index of any type, this takes the form NDB$INDEX\_*index\_id*\_CUSTOM

• parent\_type

The *DICT* object type of this object's parent object; join on [dict\_obj\_types](#_bookmark21) to obtain the name of the object type

• parent\_id

Identifier for this object's parent object; the same as the [dict\_obj\_info](#_bookmark20) table's id column • parent\_name

Fully qualified name of this object's parent object; the same as the [dict\_obj\_info](#_bookmark20) table's fq\_name column

For a table, this has the form *database\_name*/def/*table\_name*. For an index, the name is sys/ def/*table\_id*/*index\_name*. For a primary key, it is sys/def/*table\_id*/PRIMARY, and for a unique key it is sys/def/*table\_id*/*uk\_name*$unique

• root\_type

The *DICT* object type of the root object; join on [dict\_obj\_types](#_bookmark21) to obtain the name of the object type

• root\_id

Identifier for the root object; the same as the [dict\_obj\_info](#_bookmark20) table's id column

• root\_name

Fully qualified name of the root object; the same as the [dict\_obj\_info](#_bookmark20) table's fq\_name column

• level

Level of the object in the hierarchy

• path

Complete path to the object in the *NDB* object hierarchy; objects are separated by a right arrow (represented as ->), starting with the root object on the left

• indented\_name

The name prefixed with a right arrow (represented as ->) with a number of spaces preceding it that correspond to the object's depth in the hierarchy

The path column is useful for obtaining a complete path to a given NDB database object in a single line, whereas the indented\_name column can be used to obtain a tree-like layout of complete hierarchy information for a desired object.

*Example*: Assuming the existence of a test database and no existing table named t1 in this database, execute the following SQL statement:

CREATE TABLE test.t1 (

a INT PRIMARY KEY,

b INT,

UNIQUE KEY(b)

) ENGINE = NDB;

You can obtain the path to the table just created using the query shown here:

mysql> **SELECT** **path** **FROM** **ndbinfo.dict\_obj\_tree**

-> **WHERE** **name** **LIKE** **'test%t1';**

+-------------+

| path |

+-------------+

| test/def/t1 |

+-------------+

1 row in set (0.14 sec)

You can see the paths to all dependent objects of this table using the path to the table as the root name in a query like this one:

mysql> **SELECT** **path** **FROM** **ndbinfo** **.dict\_obj\_tree**

-> **WHERE** **root\_name** **=** **'test/def/t1';**

+----------------------------------------------------------+

| path |

+----------------------------------------------------------+

| test/def/t1 |

| test/def/t1 -> sys/def/13/b |

| test/def/t1 -> sys/def/13/b -> NDB$INDEX\_15\_CUSTOM |

| test/def/t1 -> sys/def/13/b$unique |

| test/def/t1 -> sys/def/13/b$unique -> NDB$INDEX\_16\_UI |

| test/def/t1 -> sys/def/13/PRIMARY |

| test/def/t1 -> sys/def/13/PRIMARY -> NDB$INDEX\_14\_CUSTOM |

+----------------------------------------------------------+

7 rows in set (0.16 sec)

To obtain a hierarchical view of the t1 table with all its dependent objects, execute a query similar to this one which selects the indented name of each object having test/def/t1 as the name of its root object:

mysql> **SELECT** **indented\_name** **FROM** **ndbinfo** **.dict\_obj\_tree**

-> **WHERE** **root\_name** **=** **'test/def/t1';**

+----------------------------+

| indented\_name |

+----------------------------+

| test/def/t1 |

| -> sys/def/13/b |

| -> NDB$INDEX\_15\_CUSTOM |

| -> sys/def/13/b$unique |

| -> NDB$INDEX\_16\_UI |

| -> sys/def/13/PRIMARY |

| -> NDB$INDEX\_14\_CUSTOM |

+----------------------------+

7 rows in set (0.15 sec)

When working with Disk Data tables, note that, in this context, a tablespace or log file group is considered a root object. This means that you must know the name of any tablespace or log file group associated with a given table, or obtain this information from SHOW CREATE TABLE and then querying INFORMATION\_SCHEMA.FILES, or similar means as shown here:

mysql> **SHOW** **CREATE** **TABLE** **test** **.dt\_1\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Table: dt\_1

Create Table: CREATE TABLE `dt\_1` (

`member\_id` int unsigned NOT NULL AUTO\_INCREMENT,

`last\_name` varchar(50) NOT NULL,

`first\_name` varchar(50) NOT NULL,

`dob` date NOT NULL,

`joined` date NOT NULL,

PRIMARY KEY (`member\_id`),

KEY `last\_name` (`last\_name`,`first\_name`)

) /\*!50100 TABLESPACE `ts\_1` STORAGE DISK \*/ ENGINE=ndbcluster DEFAULT CHARSET=utf8mb4 COLLATE=utf8mb4\_

1 row in set (0.00 sec)

mysql> **SELECT** **DISTINCT** **TABLESPACE\_NAME,** **LOGFILE\_GROUP\_NAME**

-> **FROM** **INFORMATION\_SCHEMA.FILES** **WHERE** **TABLESPACE\_NAME='ts\_1';**

+-----------------+--------------------+

| TABLESPACE\_NAME | LOGFILE\_GROUP\_NAME |

+-----------------+--------------------+

| ts\_1 | lg\_1 |

+-----------------+--------------------+

1 row in set (0.00 sec)

Now you can obtain hierarchical information for the table, tablespace, and log file group like this:

mysql> **SELECT** **indented\_name** **FROM** **ndbinfo** **.dict\_obj\_tree**

-> **WHERE** **root\_name** **=** **'test/def/dt\_1';**

+----------------------------+

|

+----------------------------+

| test/def/dt\_1 |

| -> sys/def/23/last\_name |

| -> NDB$INDEX\_25\_CUSTOM |

| -> sys/def/23/PRIMARY |

| -> NDB$INDEX\_24\_CUSTOM |

+----------------------------+

5 rows in set (0.15 sec)

mysql> **SELECT** **indented\_name** **FROM** **ndbinfo** **.dict\_obj\_tree**

-> **WHERE** **root\_name** **=** **'ts\_1';**

+-----------------+

| indented\_name |

+-----------------+

| ts\_1 |

| -> data\_1 .dat |

| -> data\_2 .dat |

+-----------------+

3 rows in set (0.17 sec)

mysql> **SELECT** **indented\_name** **FROM** **ndbinfo** **.dict\_obj\_tree**

-> **WHERE** **root\_name** **LIKE** **'lg\_1';**

+-----------------+

| indented\_name |

+-----------------+

| lg\_1 |

| -> undo\_1 .log |

| -> undo\_2 .log |

+-----------------+

3 rows in set (0.16 sec)

| indented\_name

The dict\_obj\_tree table was added in NDB 8.0.24.

**23.6.16.26** **The** **ndbinfo** **dict\_obj\_types** **Table**

The dict\_obj\_types table is a static table listing possible dictionary object types used in the NDB kernel. These are the same types defined by [Object::Type](https://dev.mysql.com/doc/ndbapi/en/ndb-object.html#ndb-object-type) in the NDB API.

The dict\_obj\_types table contains the following columns:

• type\_id

The type ID for this type

• type\_name The name of this type

**23.6.16.27** **The** **ndbinfo** **disk\_write\_speed\_base** **Table**

The disk\_write\_speed\_base table provides base information about the speed of disk writes during LCP, backup, and restore operations.

The disk\_write\_speed\_base table contains the following columns:

• node\_id

Node ID of this node

• thr\_no

Thread ID of this LDM thread

• millis\_ago

Milliseconds since this reporting period ended

• millis\_passed

Milliseconds elapsed in this reporting period

• backup\_lcp\_bytes\_written

Number of bytes written to disk by local checkpoints and backup processes during this period

• redo\_bytes\_written

Number of bytes written to REDO log during this period

• target\_disk\_write\_speed

Actual speed of disk writes per LDM thread (base data)

**23.6.16.28** **The** **ndbinfo** **disk\_write\_speed\_aggregate** **Table**

The disk\_write\_speed\_aggregate table provides aggregated information about the speed of disk writes during LCP, backup, and restore operations.

The disk\_write\_speed\_aggregate table contains the following columns:

• node\_id

Node ID of this node

• thr\_no

Thread ID of this LDM thread

• backup\_lcp\_speed\_last\_sec

Number of bytes written to disk by backup and LCP processes in the last second

• redo\_speed\_last\_sec

Number of bytes written to REDO log in the last second

• backup\_lcp\_speed\_last\_10sec

Number of bytes written to disk by backup and LCP processes per second, averaged over the last 10 seconds

• redo\_speed\_last\_10sec

Number of bytes written to REDO log per second, averaged over the last 10 seconds

• std\_dev\_backup\_lcp\_speed\_last\_10sec

Standard deviation in number of bytes written to disk by backup and LCP processes per second, averaged over the last 10 seconds

• std\_dev\_redo\_speed\_last\_10sec

Standard deviation in number of bytes written to REDO log per second, averaged over the last 10 seconds

• backup\_lcp\_speed\_last\_60sec

Number of bytes written to disk by backup and LCP processes per second, averaged over the last 60 seconds

• redo\_speed\_last\_60sec

Number of bytes written to REDO log per second, averaged over the last 10 seconds

• std\_dev\_backup\_lcp\_speed\_last\_60sec

Standard deviation in number of bytes written to disk by backup and LCP processes per second, averaged over the last 60 seconds

• std\_dev\_redo\_speed\_last\_60sec

Standard deviation in number of bytes written to REDO log per second, averaged over the last 60 seconds

• slowdowns\_due\_to\_io\_lag

Number of seconds since last node start that disk writes were slowed due to REDO log I/O lag

• slowdowns\_due\_to\_high\_cpu

Number of seconds since last node start that disk writes were slowed due to high CPU usage

• disk\_write\_speed\_set\_to\_min

Number of seconds since last node start that disk write speed was set to minimum

• current\_target\_disk\_write\_speed

Actual speed of disk writes per LDM thread (aggregated)

**23.6.16.29** **The** **ndbinfo** **disk\_write\_speed\_aggregate\_node** **Table**

The disk\_write\_speed\_aggregate\_node table provides aggregated information per node about the speed of disk writes during LCP, backup, and restore operations.

The disk\_write\_speed\_aggregate\_node table contains the following columns:

• node\_id

Node ID of this node

• backup\_lcp\_speed\_last\_sec

Number of bytes written to disk by backup and LCP processes in the last second

• redo\_speed\_last\_sec

Number of bytes written to the redo log in the last second

• backup\_lcp\_speed\_last\_10sec

Number of bytes written to disk by backup and LCP processes per second, averaged over the last 10 seconds

• redo\_speed\_last\_10sec

Number of bytes written to the redo log each second, averaged over the last 10 seconds • backup\_lcp\_speed\_last\_60sec

Number of bytes written to disk by backup and LCP processes per second, averaged over the last 60 seconds

• redo\_speed\_last\_60sec

Number of bytes written to the redo log each second, averaged over the last 60 seconds

**23.6.16.30** **The** **ndbinfo** **diskpagebuffer** **Table**

The diskpagebuffer table provides statistics about disk page buffer usage by NDB Cluster Disk Data tables.

The diskpagebuffer table contains the following columns:

• node\_id The data node ID

• block\_instance Block instance

• pages\_written

Number of pages written to disk.

• pages\_written\_lcp

Number of pages written by local checkpoints.

• pages\_read

Number of pages read from disk

• log\_waits

Number of page writes waiting for log to be written to disk

• page\_requests\_direct\_return

Number of requests for pages that were available in buffer

• page\_requests\_wait\_queue

Number of requests that had to wait for pages to become available in buffer

• page\_requests\_wait\_io

Number of requests that had to be read from pages on disk (pages were unavailable in buffer)

**Notes**

You can use this table with NDB Cluster Disk Data tables to determine whether DiskPageBufferMemory is sufficiently large to allow data to be read from the buffer rather from disk; minimizing disk seeks can help improve performance of such tables.

You can determine the proportion of reads from DiskPageBufferMemory to the total number of reads using a query such as this one, which obtains this ratio as a percentage:

SELECT

node\_id,

100 \* page\_requests\_direct\_return /

(page\_requests\_direct\_return + page\_requests\_wait\_io)

AS hit\_ratio



FROM ndbinfo .diskpagebuffer;

The result from this query should be similar to what is shown here, with one row for each data node in the cluster (in this example, the cluster has 4 data nodes):

+---------+-----------+

| node\_id | hit\_ratio |

+---------+-----------+

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  |  |  | | 5  6  7  8 | |  |  |  | | 97.6744  97.6879  98.1776  98.1343 | |  |  |  | |

+---------+-----------+

4 rows in set (0.00 sec)

hit\_ratio values approaching 100% indicate that only a very small number of reads are being made from disk rather than from the buffer, which means that Disk Data read performance is approaching an optimum level. If any of these values are less than 95%, this is a strong indicator that the setting for DiskPageBufferMemory needs to be increased in the config.ini file.

**Note**

A change in DiskPageBufferMemory requires a rolling restart of all of the cluster's data nodes before it takes effect.

block\_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the [threadblocks](#_bookmark8) table. Using this information, you can obtain information about disk page buffer metrics relating to individual threads; an example query using LIMIT 1 to limit the output to a single thread is shown here:

mysql> **SELECT**

> **node\_id,** **thr\_no,** **block\_name,** **thread\_name,** **pages\_written,**

> **pages\_written\_lcp,** **pages\_read,** **log\_waits,**

> **page\_requests\_direct\_return,** **page\_requests\_wait\_queue,**

> **page\_requests\_wait\_io**

> **FROM** **ndbinfo** **.diskpagebuffer**

> **INNER** **JOIN** **ndbinfo** **.threadblocks** **USING** **(node\_id,** **block\_instance)**

> **INNER** **JOIN** **ndbinfo** **.threads** **USING** **(node\_id,** **thr\_no)**

> **WHERE** **block\_name** **=** **'PGMAN'** **LIMIT** **1\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

node\_id: 1

thr\_no: 1

block\_name: PGMAN

thread\_name: rep

pages\_written: 0

pages\_written\_lcp: 0

pages\_read: 1

log\_waits: 0

page\_requests\_direct\_return: 4

page\_requests\_wait\_queue: 0

page\_requests\_wait\_io: 1

1 row in set (0.01 sec)

**23.6.16.31** **The** **ndbinfo** **diskstat** **Table**

The diskstat table provides information about writes to Disk Data tablespaces during the past 1 second.

The diskstat table contains the following columns:

• node\_id

Node ID of this node

• block\_instance

ID of reporting instance of [PGMAN](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-pgman.html)

• pages\_made\_dirty

Number of pages made dirty during the past second

• reads\_issued

Reads issued during the past second

• reads\_completed

Reads completed during the past second

• writes\_issued

Writes issued during the past second

• writes\_completed

Writes completed during the past second

• log\_writes\_issued

Number of times a page write has required a log write during the past second

• log\_writes\_completed

Number of log writes completed during the last second

• get\_page\_calls\_issued

Number of get\_page() calls issued during the past second

• get\_page\_reqs\_issued

Number of times that a get\_page() call has resulted in a wait for I/O or completion of I/O already begun during the past second

• get\_page\_reqs\_completed

Number of get\_page() calls waiting for I/O or I/O completion that have completed during the past second

**Notes**

Each row in this table corresponds to an instance of [PGMAN](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-pgman.html); there is one such instance per LDM thread plus an additional instance for each data node.

**23.6.16.32** **The** **ndbinfo** **diskstats\_1sec** **Table**

The diskstats\_1sec table provides information about writes to Disk Data tablespaces over the past 20 seconds.

The diskstat table contains the following columns:

• node\_id

Node ID of this node

• block\_instance

ID of reporting instance of [PGMAN](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-pgman.html)

• pages\_made\_dirty

Pages made dirty during the designated 1-second interval

• reads\_issued

Reads issued during the designated 1-second interval

• reads\_completed

Reads completed during the designated 1-second interval

• writes\_issued

Writes issued during the designated 1-second interval

• writes\_completed

Writes completed during the designated 1-second interval

• log\_writes\_issued

Number of times a page write has required a log write during the designated 1-second interval

• log\_writes\_completed

Number of log writes completed during the designated 1-second interval

• get\_page\_calls\_issued

Number of get\_page() calls issued during the designated 1-second interval

• get\_page\_reqs\_issued

Number of times that a get\_page() call has resulted in a wait for I/O or completion of I/O already begun during the designated 1-second interval

• get\_page\_reqs\_completed

Number of get\_page() calls waiting for I/O or I/O completion that have completed during the designated 1-second interval

• seconds\_ago

Number of 1-second intervals in the past of the interval to which this row applies

**Notes**

Each row in this table corresponds to an instance of [PGMAN](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-pgman.html) during a 1-second interval occurring from 0 to 19 seconds ago; there is one such instance per LDM thread plus an additional instance for each data node.

**23.6.16.33** **The** **ndbinfo** **error\_messages** **Table**

The error\_messages table provides information about

The error\_messages table contains the following columns:

• error\_code Numeric error code

• error\_description Description of error

• error\_status Error status code

• error\_classification Error classification code

**Notes**

error\_code is a numeric NDB error code. This is the same error code that can be supplied to ndb\_perror.

error\_description provides a basic description of the condition causing the error.

The error\_status column provides status information relating to the error. Possible values for this column are listed here:

• No error

• Illegal connect string

• Illegal server handle

• Illegal reply from server

• Illegal number of nodes

• Illegal node status

• Out of memory

• Management server not connected

• Could not connect to socket

• Start failed

• Stop failed

• Restart failed

• Could not start backup

• Could not abort backup

• Could not enter single user mode

• Could not exit single user mode

• Failed to complete configuration change

• Failed to get configuration

• Usage error

• Success

• Permanent error

• Temporary error

• Unknown result

• Temporary error, restart node

• Permanent error, external action needed

• Ndbd file system error, restart node initial

• Unknown

The error\_classification column shows the error classification. See [NDB Error Classifications](https://dev.mysql.com/doc/ndbapi/en/ndb-error-classifications.html), for information about classification codes and their meanings.

**23.6.16.34** **The** **ndbinfo** **events** **Table**

This table provides information about event subscriptions in NDB. The columns of the events table are listed here, with short descriptions of each:

• event\_id The event ID

• name

The name of the event

• table\_id

The ID of the table on which the event occurred

• reporting

One of updated, all, subscribe, or DDL

• columns

A comma-separated list of columns affected by the event

• table\_event

One or more of INSERT, DELETE, UPDATE, SCAN, DROP, ALTER, CREATE, GCP\_COMPLETE, CLUSTER\_FAILURE, STOP, NODE\_FAILURE, SUBSCRIBE, UNSUBSCRIBE, and ALL (defined by [Event::TableEvent](https://dev.mysql.com/doc/ndbapi/en/ndb-event.html#ndb-event-tableevent) in the NDB API)

The events table was added in NDB 8.0.29.

**23.6.16.35** **The** **ndbinfo** **files** **Table**

The files tables provides information about files and other objects used by NDB disk data tables, and contains the columns listed here:

• id

Object ID

• type

The type of object; one of Log file group, Tablespace, Undo file, or Data file

• name

The name of the object

• parent

ID of the parent object

• parent\_name

Name of the parent object

• free\_extents Number of free extents

• total\_extents

Total number of extents

• extent\_size Extent size (MB)

• initial\_size Initial size (bytes)

• maximum\_size Maximum size (bytes)

• autoextend\_size Autoextend size (bytes)

For log file groups and tablespaces, parent is always 0, and the parent\_name, free\_extents, total\_extents, extent\_size, initial\_size, maximum\_size, and autoentend\_size columns are all NULL.

The files table is empty if no disk data objects have been created in NDB. See Section 23.6.11.1, “NDB Cluster Disk Data Objects” , for more information.

The files table was added in NDB 8.0.29.

See also Section 26.3.15, “The INFORMATION\_SCHEMA FILES Table” .

**23.6.16.36** **The** **ndbinfo** **foreign\_keys** **Table**

The foreign\_keys table provides information about foreign keys on NDB tables. This table has the following columns:

• object\_id

The foreign key's object ID

• name

Name of the foreign key

• parent\_table

The name of the foreign key's parent table

• parent\_columns

A comma-delimited list of parent columns

• child\_table

The name of the child table

• child\_columns

A comma-separated list of child columns

• parent\_index

Name of the parent index

• child\_index

Name of the child index

• on\_update\_action

The ON UPDATE action specified for the foreign key; one of No Action, Restrict, Cascade, Set Null, or Set Default

• on\_delete\_action

The ON DELETE action specified for the foreign key; one of No Action, Restrict, Cascade, Set Null, or Set Default

The foreign\_keys table was added in NDB 8.0.29.

**23.6.16.37** **The** **ndbinfo** **hash\_maps** **Table**

• id

The hash map's unique ID

• version

Hash map version (integer)

• state

Hash map state; see [Object::State](https://dev.mysql.com/doc/ndbapi/en/ndb-object.html#ndb-object-state) for values and descriptions.

• fq\_name

The hash map's fully qualified name

The hash\_maps table is actually a view consisting of the four columns having the same names of the [dict\_obj\_info](#_bookmark20) table, as shown here:

CREATE VIEW hash\_maps AS

SELECT id, version, state, fq\_name

FROM dict\_obj\_info

WHERE type=24; # Hash map; defined in [dict\_obj\_types](#_bookmark21)

See the description of [dict\_obj\_info](#_bookmark20) for more information.

The hash\_maps table was added in NDB 8.0.29.

**23.6.16.38** **The** **ndbinfo** **hwinfo** **Table**

The hwinfo table provides information about the hardware on which a given data node executes. The hwinfo table contains the following columns:

• node\_id

Node ID

• cpu\_cnt\_max

Number of processors on this host

• cpu\_cnt

Number of processors available to this node

• num\_cpu\_cores

Number of CPU cores on this host

• num\_cpu\_sockets

Number of CPU sockets on this host

• HW\_memory\_size

Amount of memory available on this host

• model\_name CPU model name

**Notes**

The hwinfo table is available on all operating systems supported by NDB.

This table was added in NDB 8.0.23.

**23.6.16.39** **The** **ndbinfo** **index\_columns** **Table**

This table provides information about indexes on NDB tables. The columns of the index\_columns table are listed here, along with brief descriptions:

• table\_id

Unique ID of the NDB table for which the index is defined

• Name of the database containing this table

varchar(64)

• table\_name Name of the table

• index\_object\_id Object ID of this index

• index\_name

Name of the index; if the index is not named, the name of the first column in the index is used

• index\_type

Type of index; normally this is 3 (unique hash index) or 6 (ordered index); the values are the same as those in the type\_id column of the [dict\_obj\_types](#_bookmark21) table

• status

One of new, changed, retrieved, invalid, or altered

• columns

A comma-delimited list of columns making up the index

The index\_columns table was added in NDB 8.0.29.

**23.6.16.40** **The** **ndbinfo** **index\_stats** **Table**

The index\_stats table provides basic information about NDB index statistics.

More complete index statistics information can be obtained using the ndb\_index\_stat utility. The index\_stats table contains the following columns:

• index\_id

Index ID

• index\_version Index version

• sample\_version Sample version

**Notes**

This table was added in NDB 8.0.28.

**23.6.16.41** **The** **ndbinfo** **locks\_per\_fragment** **Table**

The locks\_per\_fragment table provides information about counts of lock claim requests, and the outcomes of these requests on a per-fragment basis, serving as a companion table to [operations\_per\_fragment](#_bookmark24) and [memory\_per\_fragment](#_bookmark25). This table also shows the total time spent waiting for locks successfully and unsuccessfully since fragment or table creation, or since the most recent restart.

The locks\_per\_fragment table contains the following columns:

• fq\_name

Fully qualified table name

• parent\_fq\_name

Fully qualified name of parent object

• type

Table type; see text for possible values

• table\_id

Table ID

• node\_id Reporting node ID

• block\_instance LDM instance ID

• fragment\_num Fragment identifier

• ex\_req

Exclusive lock requests started

• ex\_imm\_ok

Exclusive lock requests immediately granted

• ex\_wait\_ok

Exclusive lock requests granted following wait

• ex\_wait\_fail

Exclusive lock requests not granted

• sh\_req

Shared lock requests started

• sh\_imm\_ok

Shared lock requests immediately granted

• sh\_wait\_ok

Shared lock requests granted following wait

• sh\_wait\_fail

Shared lock requests not granted

• wait\_ok\_millis

Time spent waiting for lock requests that were granted, in milliseconds

• wait\_fail\_millis

Time spent waiting for lock requests that failed, in milliseconds

**Notes**

block\_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the [threadblocks](#_bookmark8) table.

fq\_name is a fully qualified database object name in *database*/*schema*/*name* format, such as test/ def/t1 or sys/def/10/b$unique.

parent\_fq\_name is the fully qualified name of this object's parent object (table).

table\_id is the table's internal ID generated by NDB. This is the same internal table ID shown in other ndbinfo tables; it is also visible in the output of ndb\_show\_tables.

The type column shows the type of table. This is always one of System table, User table, Unique hash index, Hash index, Unique ordered index, Ordered index, Hash index trigger, Subscription trigger, Read only constraint, Index trigger, Reorganize trigger, Tablespace, Log file group, Data file, Undo file, Hash map, Foreign key definition, Foreign key parent trigger, Foreign key child trigger, or Schema transaction.

The values shown in all of the columns ex\_req, ex\_req\_imm\_ok, ex\_wait\_ok, ex\_wait\_fail, sh\_req, sh\_req\_imm\_ok, sh\_wait\_ok, and sh\_wait\_fail represent cumulative numbers of requests since the table or fragment was created, or since the last restart of this node, whichever of these occurred later. This is also true for the time values shown in the wait\_ok\_millis and wait\_fail\_millis columns.

Every lock request is considered either to be in progress, or to have completed in some way (that is, to have succeeded or failed). This means that the following relationships are true:

ex\_req >= (ex\_req\_imm\_ok + ex\_wait\_ok + ex\_wait\_fail)

sh\_req >= (sh\_req\_imm\_ok + sh\_wait\_ok + sh\_wait\_fail)

The number of requests currently in progress is the current number of incomplete requests, which can be found as shown here:

[exclusive lock requests in progress] =

ex\_req - (ex\_req\_imm\_ok + ex\_wait\_ok + ex\_wait\_fail)

[shared lock requests in progress] =

sh\_req - (sh\_req\_imm\_ok + sh\_wait\_ok + sh\_wait\_fail)

A failed wait indicates an aborted transaction, but the abort may or may not be caused by a lock wait timeout. You can obtain the total number of aborts while waiting for locks as shown here:

[aborts while waiting for locks] = ex\_wait\_fail + sh\_wait\_fail

**23.6.16.42** **The** **ndbinfo** **logbuffers** **Table**

The logbuffer table provides information on NDB Cluster log buffer usage.

The logbuffers table contains the following columns:

• node\_id

The ID of this data node.

• log\_type

Type of log. One of: REDO, DD-UNDO, BACKUP-DATA, or BACKUP-LOG.

• log\_id

The log ID; for Disk Data undo log files, this is the same as the value shown in the LOGFILE\_GROUP\_NUMBER column of the Information Schema FILES table as well as the value shown for the log\_id column of the ndbinfo [logspaces](#_bookmark23) table

• log\_part

The log part number

• total

Total space available for this log

• used

Space used by this log

**Notes**

logbuffers table rows reflecting two additional log types are available when performing an NDB backup. One of these rows has the log type BACKUP-DATA, which shows the amount of data buffer used during backup to copy fragments to backup files. The other row has the log type BACKUP- LOG, which displays the amount of log buffer used during the backup to record changes made after

the backup has started. One each of these log\_type rows is shown in the logbuffers table for each data node in the cluster. These rows are not present unless an NDB backup is currently being performed.

**23.6.16.43** **The** **ndbinfo** **logspaces** **Table**

This table provides information about NDB Cluster log space usage.

The logspaces table contains the following columns:

• node\_id

The ID of this data node.

• log\_type

Type of log; one of: REDO or DD-UNDO.

• node\_id

The log ID; for Disk Data undo log files, this is the same as the value shown in the LOGFILE\_GROUP\_NUMBER column of the Information Schema FILES table, as well as the value shown for the log\_id column of the ndbinfo [logbuffers](#_bookmark22) table

• log\_part

The log part number.

• total

Total space available for this log.

• used

Space used by this log.

**23.6.16.44** **The** **ndbinfo** **membership** **Table**

The membership table describes the view that each data node has of all the others in the cluster, including node group membership, president node, arbitrator, arbitrator successor, arbitrator connection states, and other information.

The membership table contains the following columns:

• node\_id

This node's node ID

• group\_id

Node group to which this node belongs

• left node

Node ID of the previous node

• right\_node

Node ID of the next node

• president President's node ID

• successor

Node ID of successor to president

• succession\_order

Order in which this node succeeds to presidency

• Conf\_HB\_order

-

• arbitrator

Node ID of arbitrator

• arb\_ticket

Internal identifier used to track arbitration

• arb\_state Arbitration state

• arb\_connected

Whether this node is connected to the arbitrator; either of Yes or No

• connected\_rank1\_arbs Connected arbitrators of rank 1

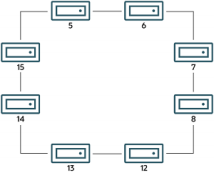
• connected\_rank2\_arbs Connected arbitrators of rank 1

**Notes**

The node ID and node group ID are the same as reported by ndb\_mgm -e "SHOW".

left\_node and right\_node are defined in terms of a model that connects all data nodes in a circle, in order of their node IDs, similar to the ordering of the numbers on a clock dial, as shown here:

**Figure** **23.6** **Circular** **Arrangement** **of** **NDB** **Cluster** **Nodes**



In this example, we have 8 data nodes, numbered 5, 6, 7, 8, 12, 13, 14, and 15, ordered clockwise in a circle. We determine “left” and “right” from the interior of the circle. The node to the left of node 5 is node 15, and the node to the right of node 5 is node 6. You can see all these relationships by running the following query and observing the output:

mysql> **SELECT** **node\_id,left\_node,right\_node**

-> **FROM** **ndbinfo** **.membership;**



+---------+-----------+------------+

| node\_id | left\_node | right\_node |

+---------+-----------+------------+

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  | | 5  6  7  8  12  13  14  15 | |  |  |  |  |  |  |  | | 15  5  6  7  8  12  13  14 | |  |  |  |  |  |  |  | | 6  7  8  12  13  14  15  5 | |  |  |  |  |  |  |  | |

+---------+-----------+------------+

8 rows in set (0.00 sec)

The designations “left” and “right” are used in the event log in the same way.

The president node is the node viewed by the current node as responsible for setting an arbitrator (see [NDB Cluster Start Phases](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-start-phases.html)). If the president fails or becomes disconnected, the current node expects the node whose ID is shown in the successor column to become the new president. The succession\_order column shows the place in the succession queue that the current node views itself as having.

In a normal NDB Cluster, all data nodes should see the same node as president, and the same node (other than the president) as its successor. In addition, the current president should see itself as 1 in the order of succession, the successor node should see itself as 2, and so on.

All nodes should show the same arb\_ticket values as well as the same arb\_state values. Possible arb\_state values are ARBIT\_NULL, ARBIT\_INIT, ARBIT\_FIND, ARBIT\_PREP1, ARBIT\_PREP2, ARBIT\_START, ARBIT\_RUN, ARBIT\_CHOOSE, ARBIT\_CRASH, and UNKNOWN.

arb\_connected shows whether this node is connected to the node shown as this node's arbitrator.

The connected\_rank1\_arbs and connected\_rank2\_arbs columns each display a list of 0 or more arbitrators having an ArbitrationRank equal to 1, or to 2, respectively.

**Note**

Both management nodes and API nodes are eligible to become arbitrators.

**23.6.16.45** **The** **ndbinfo** **memoryusage** **Table**

Querying this table provides information similar to that provided by the ALL REPORT MemoryUsage command in the ndb\_mgm client, or logged by [ALL DUMP 1000](https://dev.mysql.com/doc/ndb-internals/en/dump-command-1000.html).

The memoryusage table contains the following columns:

• node\_id

The node ID of this data node.

• memory\_type

One of Data memory, Index memory, or Long message buffer.

• used

Number of bytes currently used for data memory or index memory by this data node.

• used\_pages

Number of pages currently used for data memory or index memory by this data node; see text.

• total

Total number of bytes of data memory or index memory available for this data node; see text.

• total\_pages

Total number of memory pages available for data memory or index memory on this data node; see text.

**Notes**

The total column represents the total amount of memory in bytes available for the given resource (data memory or index memory) on a particular data node. This number should be approximately equal to the setting of the corresponding configuration parameter in the config.ini file.

Suppose that the cluster has 2 data nodes having node IDs 5 and 6, and the config.ini file contains the following:

[ndbd default]

DataMemory = 1G

IndexMemory = 1G

Suppose also that the value of the LongMessageBuffer configuration parameter is allowed to assume its default (64 MB).

The following query shows approximately the same values:

mysql> SELECT node\_id, memory\_type, total

> FROM ndbinfo .memoryusage;

+---------+---------------------+------------+

| node\_id | memory\_type | total |

+---------+---------------------+------------+

|

|

| 5 | Long message buffer | 67108864 |

|

|

| 6 | Long message buffer | 67108864 |

+---------+---------------------+------------+

6 rows in set (0.00 sec)

5 | Data memory

5 | Index memory

6 | Data memory

6 | Index memory

1073741824

1074003968

1073741824

1074003968

|

|

|

|

|

|

|

|

In this case, the total column values for index memory are slightly higher than the value set of

IndexMemory due to internal rounding.

For the used\_pages and total\_pages columns, resources are measured in pages, which are 32K in size for DataMemory and 8K for IndexMemory. For long message buffer memory, the page size is 256 bytes.

**23.6.16.46** **The** **ndbinfo** **memory\_per\_fragment** **Table**

The memory\_per\_fragment table provides information about the usage of memory by individual fragments.

The memory\_per\_fragment table contains the following columns:

• fq\_name

Name of this fragment

• parent\_fq\_name

Name of this fragment's parent

• type

Type of object; see text for possible values

• table\_id

Table ID for this table

• node\_id

Node ID for this node

• block\_instance Kernel block instance ID

• fragment\_num Fragment ID (number)

• fixed\_elem\_alloc\_bytes

Number of bytes allocated for fixed-sized elements

• fixed\_elem\_free\_bytes

Free bytes remaining in pages allocated to fixed-size elements

• fixed\_elem\_size\_bytes

Length of each fixed-size element in bytes

• fixed\_elem\_count

Number of fixed-size elements

• fixed\_elem\_free\_count

Number of free rows for fixed-size elements

• var\_elem\_alloc\_bytes

Number of bytes allocated for variable-size elements

• var\_elem\_free\_bytes

Free bytes remaining in pages allocated to variable-size elements

• var\_elem\_count

Number of variable-size elements

• hash\_index\_alloc\_bytes

Number of bytes allocated to hash indexes

**Notes**

The type column from this table shows the dictionary object type used for this fragment ([Object::Type](https://dev.mysql.com/doc/ndbapi/en/ndb-object.html#ndb-object-type), in the NDB API), and can take any one of the values shown in the following list:

• System table

• User table

• Unique hash index

• Hash index

• Unique ordered index

• Ordered index

• Hash index trigger

• Subscription trigger

• Read only constraint

• Index trigger

• Reorganize trigger

• Tablespace

• Log file group

• Data file

• Undo file

• Hash map

• Foreign key definition

• Foreign key parent trigger

• Foreign key child trigger

• Schema transaction

You can also obtain this list by executing SELECT \* FROM [ndbinfo.dict\_obj\_types](#_bookmark21) in the mysql client.

The block\_instance column provides the NDB kernel block instance number. You can use this to obtain information about specific threads from the [threadblocks](#_bookmark8) table.

**23.6.16.47** **The** **ndbinfo** **nodes** **Table**

This table contains information on the status of data nodes. For each data node that is running in the cluster, a corresponding row in this table provides the node's node ID, status, and uptime. For nodes

that are starting, it also shows the current start phase.

The nodes table contains the following columns:

• node\_id

The data node's unique node ID in the cluster.

• uptime

Time since the node was last started, in seconds.

• status

Current status of the data node; see text for possible values.

• start\_phase

If the data node is starting, the current start phase.

• config\_generation

The version of the cluster configuration file in use on this data node.

**Notes**

The uptime column shows the time in seconds that this node has been running since it was last started or restarted. This is a BIGINT value. This figure includes the time actually needed to start the node; in other words, this counter starts running the moment that ndbd or ndbmtd is first invoked; thus, even for a node that has not yet finished starting, uptime may show a nonzero value.

The status column shows the node's current status. This is one of: NOTHING, CMVMI, STARTING, STARTED, SINGLEUSER, STOPPING\_1, STOPPING\_2, STOPPING\_3, or STOPPING\_4. When the status is STARTING, you can see the current start phase in the start\_phase column (see later in this section). SINGLEUSER is displayed in the status column for all data nodes when the cluster is in single user mode (see Section 23.6.6, “NDB Cluster Single User Mode” ). Seeing one of the STOPPING states does not necessarily mean that the node is shutting down but can mean rather that it is entering a new state. For example, if you put the cluster in single user mode, you can sometimes see data nodes report their state briefly as STOPPING\_2 before the status changes to SINGLEUSER.

The start\_phase column uses the same range of values as those used in the output of the ndb\_mgm client *node\_id* STATUS command (see Section 23.6.1, “Commands in the NDB Cluster Management Client” ). If the node is not currently starting, then this column shows 0. For a listing of NDB Cluster start phases with descriptions, see Section 23.6.4, “Summary of NDB Cluster Start Phases” .

The config\_generation column shows which version of the cluster configuration is in effect on each data node. This can be useful when performing a rolling restart of the cluster in order to make changes in configuration parameters. For example, from the output of the following SELECT statement, you can see that node 3 is not yet using the latest version of the cluster configuration ( 6) although nodes 1, 2, and 4 are doing so:

mysql> **USE** **ndbinfo;**

Database changed

mysql> **SELECT** **\*** **FROM** **nodes;**

+---------+--------+---------+-------------+-------------------+

| node\_id | uptime | status | start\_phase | config\_generation |

+---------+--------+---------+-------------+-------------------+

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | 1 | | | 10462 | | | STARTED | | | 0 | | | 6 | | |
| | | 2 | | | 10460 | | | STARTED | | | 0 | | | 6 | | |
| | | 3 | | | 10457 | | | STARTED | | | 0 | | | 5 | | |
| | | 4 | | | 10455 | | | STARTED | | | 0 | | | 6 | | |

+---------+--------+---------+-------------+-------------------+

2 rows in set (0.04 sec)

Therefore, for the case just shown, you should restart node 3 to complete the rolling restart of the cluster.

Nodes that are stopped are not accounted for in this table. Suppose that you have an NDB Cluster with 4 data nodes (node IDs 1, 2, 3 and 4), and all nodes are running normally, then this table contains 4 rows, 1 for each data node:

mysql> **USE** **ndbinfo;**

Database changed

mysql> **SELECT** **\*** **FROM** **nodes;**

+---------+--------+---------+-------------+-------------------+

| node\_id | uptime | status | start\_phase | config\_generation |

+---------+--------+---------+-------------+-------------------+

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | 1 | | | 11776 | | | STARTED | | | 0 | | | 6 | | |
| | | 2 | | | 11774 | | | STARTED | | | 0 | | | 6 | | |
| | | 3 | | | 11771 | | | STARTED | | | 0 | | | 6 | | |
| | | 4 | | | 11769 | | | STARTED | | | 0 | | | 6 | | |

+---------+--------+---------+-------------+-------------------+

4 rows in set (0.04 sec)

If you shut down one of the nodes, only the nodes that are still running are represented in the output of this SELECT statement, as shown here:

ndb\_mgm> **2** **STOP**

Node 2: Node shutdown initiated

Node 2: Node shutdown completed.

Node 2 has shutdown.

mysql> **SELECT** **\*** **FROM** **nodes;**

+---------+--------+---------+-------------+-------------------+

| node\_id | uptime | status | start\_phase | config\_generation |

+---------+--------+---------+-------------+-------------------+

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | 1 | | | 11807 | | | STARTED | | | 0 | | | 6 | | |
| | | 3 | | | 11802 | | | STARTED | | | 0 | | | 6 | | |
| | | 4 | | | 11800 | | | STARTED | | | 0 | | | 6 | | |

+---------+--------+---------+-------------+-------------------+

3 rows in set (0.02 sec)

**23.6.16.48** **The** **ndbinfo** **operations\_per\_fragment** **Table**

The operations\_per\_fragment table provides information about the operations performed on individual fragments and fragment replicas, as well as about some of the results from these operations.

The operations\_per\_fragment table contains the following columns:

• fq\_name

Name of this fragment

• parent\_fq\_name

Name of this fragment's parent

• type

Type of object; see text for possible values

• table\_id

Table ID for this table

• node\_id

Node ID for this node

• block\_instance Kernel block instance ID

• fragment\_num Fragment ID (number)

• tot\_key\_reads

Total number of key reads for this fragment replica

• tot\_key\_inserts

Total number of key inserts for this fragment replica

• tot\_key\_updates

total number of key updates for this fragment replica

• tot\_key\_writes

Total number of key writes for this fragment replica

• tot\_key\_deletes

Total number of key deletes for this fragment replica

• tot\_key\_refs

Number of key operations refused

• tot\_key\_attrinfo\_bytes

Total size of all attrinfo attributes

• tot\_key\_keyinfo\_bytes

Total size of all keyinfo attributes

• tot\_key\_prog\_bytes

Total size of all interpreted programs carried by attrinfo attributes

• tot\_key\_inst\_exec

Total number of instructions executed by interpreted programs for key operations

• tot\_key\_bytes\_returned

Total size of all data and metadata returned from key read operations

• tot\_frag\_scans

Total number of scans performed on this fragment replica

• tot\_scan\_rows\_examined

Total number of rows examined by scans

• tot\_scan\_rows\_returned

Total number of rows returned to client

• tot\_scan\_bytes\_returned

Total size of data and metadata returned to the client

• tot\_scan\_prog\_bytes

Total size of interpreted programs for scan operations

• tot\_scan\_bound\_bytes

Total size of all bounds used in ordered index scans

• tot\_scan\_inst\_exec

Total number of instructions executed for scans

• tot\_qd\_frag\_scans

Number of times that scans of this fragment replica have been queued

• conc\_frag\_scans

Number of scans currently active on this fragment replica (excluding queued scans)

• conc\_qd\_frag\_scans

Number of scans currently queued for this fragment replica

• tot\_commits

Total number of row changes committed to this fragment replica

**Notes**

The fq\_name contains the fully qualified name of the schema object to which this fragment replica belongs. This currently has the following formats:

• Base table: *DbName*/def/*TblName*

• BLOB table: *DbName*/def/NDB$BLOB\_*BaseTblId*\_*ColNo*

• Ordered index: sys/def/*BaseTblId*/*IndexName*

• Unique index: sys/def/*BaseTblId*/*IndexName*$unique

The $unique suffix shown for unique indexes is added by mysqld; for an index created by a different NDB API client application, this may differ, or not be present.

The syntax just shown for fully qualified object names is an internal interface which is subject to change in future releases.

Consider a table t1 created and modified by the following SQL statements:

CREATE DATABASE mydb;

USE mydb;

CREATE TABLE t1 (

a INT NOT NULL,

b INT NOT NULL,

t TEXT NOT NULL,

PRIMARY KEY (b)

) ENGINE=ndbcluster;

CREATE UNIQUE INDEX ix1 ON t1(b) USING HASH;

If t1 is assigned table ID 11, this yields the fq\_name values shown here:

• Base table: mydb/def/t1

• BLOB table: mydb/def/NDB$BLOB\_11\_2

• Ordered index (primary key): sys/def/11/PRIMARY

• Unique index: sys/def/11/ix1$unique

For indexes or BLOB tables, the parent\_fq\_name column contains the fq\_name of the corresponding base table. For base tables, this column is always NULL.

The type column shows the schema object type used for this fragment, which can take any one of the values System table, User table, Unique hash index, or Ordered index. BLOB tables are shown as User table.

The table\_id column value is unique at any given time, but can be reused if the corresponding object has been deleted. The same ID can be seen using the ndb\_show\_tables utility.

The block\_instance column shows which LDM instance this fragment replica belongs to. You can use this to obtain information about specific threads from the [threadblocks](#_bookmark8) table. The first such instance is always numbered 0.



Since there are typically two fragment replicas, and assuming that this is so, each fragment\_num value should appear twice in the table, on two different data nodes from the same node group.

Since NDB does not use single-key access for ordered indexes, the counts for tot\_key\_reads, tot\_key\_inserts, tot\_key\_updates, tot\_key\_writes, and tot\_key\_deletes are not incremented by ordered index operations.

**Note**

When using tot\_key\_writes, you should keep in mind that a write operation in this context updates the row if the key exists, and inserts a new row otherwise. (One use of this is in the NDB implementation of the REPLACE SQL statement.)

The tot\_key\_refs column shows the number of key operations refused by the LDM. Generally, such a refusal is due to duplicate keys (inserts), Key not found errors (updates, deletes, and reads), or the operation was rejected by an interpreted program used as a predicate on the row matching the key.

The attrinfo and keyinfo attributes counted by the tot\_key\_attrinfo\_bytes and tot\_key\_keyinfo\_bytes columns are attributes of an LQHKEYREQ signal (see [The NDB](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-ndb-protocol.html) [Communication Protocol](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-ndb-protocol.html)) used to initiate a key operation by the LDM. An attrinfo typically contains tuple field values (inserts and updates) or projection specifications (for reads); keyinfo contains the primary or unique key needed to locate a given tuple in this schema object.

The value shown by tot\_frag\_scans includes both full scans (that examine every row) and scans of subsets. Unique indexes and BLOB tables are never scanned, so this value, like other scan-related counts, is 0 for fragment replicas of these.

tot\_scan\_rows\_examined may display less than the total number of rows in a given fragment replica, since ordered index scans can limited by bounds. In addition, a client may choose to end a scan before all potentially matching rows have been examined; this occurs when using an SQL statement containing a LIMIT or EXISTS clause, for example. tot\_scan\_rows\_returned is always less than or equal to tot\_scan\_rows\_examined.

tot\_scan\_bytes\_returned includes, in the case of pushed joins, projections returned to the [DBSPJ](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbspj.html) block in the NDB kernel.

tot\_qd\_frag\_scans can be effected by the setting for the MaxParallelScansPerFragment data node configuration parameter, which limits the number of scans that may execute concurrently on a single fragment replica.

**23.6.16.49** **The** **ndbinfo** **pgman\_time\_track\_stats** **Table**

This table provides information regarding the latency of disk operations for NDB Cluster Disk Data tablespaces.

The pgman\_time\_track\_stats table contains the following columns:

• node\_id

Unique node ID of this node in the cluster

• block\_number

Block number (from [blocks](#_bookmark2) table)

• block\_instance Block instance number

• upper\_bound Upper bound

• page\_reads

Page read latency (ms)

• page\_writes

Page write latency (ms)

• log\_waits

Log wait latency (ms)

• get\_page

Latency of get\_page() calls (ms)

**Notes**

The read latency (page\_reads column) measures the time from when the read request is sent to the file system thread until the read is complete and has been reported back to the execution thread. The write latency (page\_writes) is calculated in a similar fashion. The size of the page read to or written from a Disk Data tablespace is always 32 KB.

Log wait latency (log\_waits column) is the length of time a page write must wait for the undo log to be flushed, which must be done prior to each page write.

**23.6.16.50** **The** **ndbinfo** **processes** **Table**

This table contains information about NDB Cluster node processes; each node is represented by the row in the table. Only nodes that are connected to the cluster are shown in this table. You can obtain information about nodes that are configured but not connected to the cluster from the [nodes](#_bookmark11) and [config\_nodes](#_bookmark10) tables.

The processes table contains the following columns:

• node\_id

The node's unique node ID in the cluster

• node\_type

Type of node (management, data, or API node; see text)

• node\_version

Version of the NDB software program running on this node.

• process\_id

This node's process ID

• angel\_process\_id

Process ID of this node's angel process

• process\_name

Name of the executable

• service\_URI

Service URI of this node (see text)

**Notes**

node\_id is the ID assigned to this node in the cluster.

The node\_type column displays one of the following three values:

• MGM: Management node.

• NDB: Data node.

• API: API or SQL node.

For an executable shipped with the NDB Cluster distribution, node\_version shows the software Cluster version string, such as 8.0.34-ndb-8.0.34.

process\_id is the node executable's process ID as shown by the host operating system using a process display application such as top on Linux, or the Task Manager on Windows platforms.

angel\_process\_id is the system process ID for the node's angel process, which ensures that a data node or SQL is automatically restarted in cases of failures. For management nodes and API nodes other than SQL nodes, the value of this column is NULL.

The process\_name column shows the name of the running executable. For management nodes, this is ndb\_mgmd. For data nodes, this is ndbd (single-threaded) or ndbmtd (multithreaded). For SQL nodes, this is mysqld. For other types of API nodes, it is the name of the executable program connected to the cluster; NDB API applications can set a custom value for this using [Ndb\_cluster\_connection::set\_name()](https://dev.mysql.com/doc/ndbapi/en/ndb-ndb-cluster-connection.html#ndb-ndb-cluster-connection-set-name).

service\_URI shows the service network address. For management nodes and data nodes, the scheme used is ndb://. For SQL nodes, this is mysql://. By default, API nodes other than SQL nodes use ndb:// for the scheme; NDB API applications can set this to a custom value using Ndb\_cluster\_connection::set\_service\_uri(). regardless of the node type, the scheme is followed by the IP address used by the NDB transporter for the node in question. For management nodes and SQL nodes, this address includes the port number (usually 1186 for management nodes and 3306 for SQL nodes). If the SQL node was started with the bind\_address system variable set, this address is used instead of the transporter address, unless the bind address is set to \*, 0.0.0.0, or ::.

Additional path information may be included in the service\_URI value for an SQL node reflecting various configuration options. For example, mysql://198.51.100.3/tmp/mysql.sock indicates that the SQL node was started with the skip\_networking system variable enabled, and mysql://198.51.100.3:3306/?server-id=1 shows that replication is enabled for this SQL node.

**23.6.16.51** **The** **ndbinfo** **resources** **Table**

This table provides information about data node resource availability and usage.

These resources are sometimes known as *super-pools*.

The resources table contains the following columns:

• node\_id

The unique node ID of this data node.

• resource\_name

Name of the resource; see text.

• reserved

The amount reserved for this resource, as a number of 32KB pages.

• used

The amount actually used by this resource, as a number of 32KB pages.

• max

The maximum amount (number of 32KB pages) of this resource used, since the node was last started.

**Notes**

The resource\_name can be any one of the names shown in the following table:

• RESERVED: Reserved by the system; cannot be overridden.

• TRANSACTION\_MEMORY: Memory allocated for transactions on this data node. In NDB 8.0.19 and later this can be controlled using the TransactionMemory configuration parameter.

• DISK\_OPERATIONS: If a log file group is allocated, the size of the undo log buffer is used to set the size of this resource. This resource is used only to allocate the undo log buffer for an undo log file group; there can only be one such group. Overallocation occurs as needed by CREATE LOGFILE GROUP.

• DISK\_RECORDS: Records allocated for Disk Data operations.

• DATA\_MEMORY: Used for main memory tuples, indexes, and hash indexes. Sum of DataMemory and IndexMemory, plus 8 pages of 32 KB each if IndexMemory has been set. Cannot be overallocated.

• JOBBUFFER: Used for allocating job buffers by the NDB scheduler; cannot be overallocated. This is approximately 2 MB per thread plus a 1 MB buffer in both directions for all threads that can communicate. For large configurations this consume several GB.

• FILE\_BUFFERS: Used by the redo log handler in the [DBLQH](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dblqh.html) kernel block; cannot be overallocated. Size is NoOfFragmentLogParts \* RedoBuffer, plus 1 MB per log file part.

• TRANSPORTER\_BUFFERS: Used for send buffers by ndbmtd; the sum of TotalSendBufferMemory and ExtraSendBufferMemory. This resource that can be overallocated by up to 25 percent. TotalSendBufferMemory is calculated by summing the send buffer memory per node, the default value of which is 2 MB. Thus, in a system having four data nodes and eight API nodes, the data nodes have 12 \* 2 MB send buffer memory.

ExtraSendBufferMemory is used by ndbmtd and amounts to 2 MB extra memory per thread. Thus, with 4 LDM threads, 2 TC threads, 1 main thread, 1 replication thread, and 2 receive threads, ExtraSendBufferMemory is 10 \* 2 MB. Overallocation of this resource can be performed by setting the SharedGlobalMemory data node configuration parameter.

• DISK\_PAGE\_BUFFER: Used for the disk page buffer; determined by the DiskPageBufferMemory configuration parameter. Cannot be overallocated.

• QUERY\_MEMORY: Used by the [DBSPJ](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbspj.html) kernel block.

• SCHEMA\_TRANS\_MEMORY: Minimum is 2 MB; can be overallocated to use any remaining available memory.

**23.6.16.52** **The** **ndbinfo** **restart\_info** **Table**

The restart\_info table contains information about node restart operations. Each entry in the table corresponds to a node restart status report in real time from a data node with the given node ID. Only

the most recent report for any given node is shown.

The restart\_info table contains the following columns:

• node\_id

Node ID in the cluster

• node\_restart\_status

Node status; see text for values. Each of these corresponds to a possible value of node\_restart\_status\_int.

• node\_restart\_status\_int

Node status code; see text for values.

• secs\_to\_complete\_node\_failure

Time in seconds to complete node failure handling

• secs\_to\_allocate\_node\_id

Time in seconds from node failure completion to allocation of node ID

• secs\_to\_include\_in\_heartbeat\_protocol

Time in seconds from allocation of node ID to inclusion in heartbeat protocol

• secs\_until\_wait\_for\_ndbcntr\_master

Time in seconds from being included in heartbeat protocol until waiting for [NDBCNTR](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-ndbcntr.html) master began

• secs\_wait\_for\_ndbcntr\_master

Time in seconds spent waiting to be accepted by [NDBCNTR](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-ndbcntr.html) master for starting

• secs\_to\_get\_start\_permitted

Time in seconds elapsed from receiving of permission for start from master until all nodes have accepted start of this node

• secs\_to\_wait\_for\_lcp\_for\_copy\_meta\_data

Time in seconds spent waiting for LCP completion before copying metadata

• secs\_to\_copy\_meta\_data

Time in seconds required to copy metadata from master to newly starting node

• secs\_to\_include\_node

Time in seconds waited for GCP and inclusion of all nodes into protocols

• secs\_starting\_node\_to\_request\_local\_recovery

Time in seconds that the node just starting spent waiting to request local recovery

• secs\_for\_local\_recovery

Time in seconds required for local recovery by node just starting

• secs\_restore\_fragments

Time in seconds required to restore fragments from LCP files

• secs\_undo\_disk\_data

Time in seconds required to execute undo log on disk data part of records

• secs\_exec\_redo\_log

Time in seconds required to execute redo log on all restored fragments

• secs\_index\_rebuild

Time in seconds required to rebuild indexes on restored fragments

• secs\_to\_synchronize\_starting\_node

Time in seconds required to synchronize starting node from live nodes

• secs\_wait\_lcp\_for\_restart

Time in seconds required for LCP start and completion before restart was completed

• secs\_wait\_subscription\_handover

Time in seconds spent waiting for handover of replication subscriptions

• total\_restart\_secs

Total number of seconds from node failure until node is started again

**Notes**

The following list contains values defined for the node\_restart\_status\_int column with their internal status names (in parentheses), and the corresponding messages shown in the node\_restart\_status column:

• 0 (ALLOCATED\_NODE\_ID) Allocated node id

• 1 ( INCLUDED\_IN\_HB\_PROTOCOL) Included in heartbeat protocol

• 2 (NDBCNTR\_START\_WAIT)

Wait for NDBCNTR master to permit us to start

• 3 (NDBCNTR\_STARTED)

NDBCNTR master permitted us to start

• 4 (START\_PERMITTED)

All nodes permitted us to start

• 5 (WAIT\_LCP\_TO\_COPY\_DICT)

Wait for LCP completion to start copying metadata

• 6 (COPY\_DICT\_TO\_STARTING\_NODE) Copying metadata to starting node

• 7 ( INCLUDE\_NODE\_IN\_LCP\_AND\_GCP)

Include node in LCP and GCP protocols

• 8 (LOCAL\_RECOVERY\_STARTED)

Restore fragments ongoing

• 9 (COPY\_FRAGMENTS\_STARTED)

Synchronizing starting node with live nodes

• 10 (WAIT\_LCP\_FOR\_RESTART)

Wait for LCP to ensure durability

• 11 (WAIT\_SUMA\_HANDOVER)

Wait for handover of subscriptions

• 12 (RESTART\_COMPLETED) Restart completed

• 13 (NODE\_FAILED)

Node failed, failure handling in progress

• 14 (NODE\_FAILURE\_COMPLETED)

Node failure handling completed

• 15 (NODE\_GETTING\_PERMIT) All nodes permitted us to start

• 16 (NODE\_GETTING\_INCLUDED)

Include node in LCP and GCP protocols

• 17 (NODE\_GETTING\_SYNCHED)

Synchronizing starting node with live nodes

• 18 (NODE\_GETTING\_LCP\_WAITED) [none]

• 19 (NODE\_ACTIVE) Restart completed

• 20 (NOT\_DEFINED\_IN\_CLUSTER) [none]

• 21 (NODE\_NOT\_RESTARTED\_YET) Initial state

Status numbers 0 through 12 apply on master nodes only; the remainder of those shown in the table apply to all restarting data nodes. Status numbers 13 and 14 define node failure states; 20 and 21 occur when no information about the restart of a given node is available.

See also Section 23.6.4, “Summary of NDB Cluster Start Phases” .

**23.6.16.53** **The** **ndbinfo** **server\_locks** **Table**

The server\_locks table is similar in structure to the cluster\_locks table, and provides a subset of the information found in the latter table, but which is specific to the SQL node (MySQL server) where it resides. (The cluster\_locks table provides information about all locks in the cluster.) More precisely, server\_locks contains information about locks requested by threads belonging to the

current mysqld instance, and serves as a companion table to [server\_operations](#_bookmark26). This may be useful for correlating locking patterns with specific MySQL user sessions, queries, or use cases.

The server\_locks table contains the following columns:

• mysql\_connection\_id MySQL connection ID

• node\_id

ID of reporting node

• block\_instance

ID of reporting LDM instance

• tableid

ID of table containing this row

• fragmentid

ID of fragment containing locked row

• rowid

ID of locked row

• transid

Transaction ID

• mode

Lock request mode

• state Lock state

• detail

Whether this is first holding lock in row lock queue

• op

Operation type

• duration\_millis

Milliseconds spent waiting or holding lock

• lock\_num

ID of lock object

• waiting\_for

Waiting for lock with this ID

**Notes**

The mysql\_connection\_id column shows the MySQL connection or thread ID as shown by SHOW

PROCESSLIST.

block\_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the [threadblocks](#_bookmark8) table.

The tableid is assigned to the table by NDB; the same ID is used for this table in other ndbinfo tables, as well as in the output of ndb\_show\_tables.

The transaction ID shown in the transid column is the identifier generated by the NDB API for the transaction requesting or holding the current lock.

The mode column shows the lock mode, which is always one of S (shared lock) or X (exclusive lock). If a transaction has an exclusive lock on a given row, all other locks on that row have the same transaction ID.

The state column shows the lock state. Its value is always one of H (holding) or W (waiting). A waiting lock request waits for a lock held by a different transaction.

The detail column indicates whether this lock is the first holding lock in the affected row's lock queue, in which case it contains a \* (asterisk character); otherwise, this column is empty. This information can be used to help identify the unique entries in a list of lock requests.

The op column shows the type of operation requesting the lock. This is always one of the values READ, INSERT, UPDATE, DELETE, SCAN, or REFRESH.

The duration\_millis column shows the number of milliseconds for which this lock request has been waiting or holding the lock. This is reset to 0 when a lock is granted for a waiting request.

The lock ID (lockid column) is unique to this node and block instance.

If the lock\_state column's value is W, this lock is waiting to be granted, and the waiting\_for column shows the lock ID of the lock object this request is waiting for. Otherwise, waiting\_for is empty. waiting\_for can refer only to locks on the same row (as identified by node\_id, block\_instance, tableid, fragmentid, and rowid).

**23.6.16.54** **The** **ndbinfo** **server\_operations** **Table**

The server\_operations table contains entries for all ongoing NDB operations that the current SQL node (MySQL Server) is currently involved in. It effectively is a subset of the [cluster\_operations](#_bookmark7)

table, in which operations for other SQL and API nodes are not shown.

The server\_operations table contains the following columns:

• mysql\_connection\_id MySQL Server connection ID

• node\_id

Node ID

• block\_instance Block instance

• transid

Transaction ID

• operation\_type

Operation type (see text for possible values)

• state

Operation state (see text for possible values)

• tableid

Table ID

• fragmentid

Fragment ID

• client\_node\_id Client node ID

• client\_block\_ref Client block reference

• tc\_node\_id

Transaction coordinator node ID

• tc\_block\_no

Transaction coordinator block number

• tc\_block\_instance

Transaction coordinator block instance

**Notes**

The mysql\_connection\_id is the same as the connection or session ID shown in the output of SHOW PROCESSLIST. It is obtained from the INFORMATION\_SCHEMA table

NDB\_TRANSID\_MYSQL\_CONNECTION\_MAP.

block\_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the [threadblocks](#_bookmark8) table.

The transaction ID (transid) is a unique 64-bit number which can be obtained using the NDB API's [getTransactionId()](https://dev.mysql.com/doc/ndbapi/en/ndb-ndbtransaction.html#ndb-ndbtransaction-gettransactionid) method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The operation\_type column can take any one of the values READ, READ-SH, READ-EX, INSERT, UPDATE, DELETE, WRITE, UNLOCK, REFRESH, SCAN, SCAN-SH, SCAN-EX, or <unknown>.

The state column can have any one of the values ABORT\_QUEUED, ABORT\_STOPPED,

COMMITTED, COMMIT\_QUEUED, COMMIT\_STOPPED, COPY\_CLOSE\_STOPPED, COPY\_FIRST\_STOPPED, COPY\_STOPPED, COPY\_TUPKEY, IDLE, LOG\_ABORT\_QUEUED, LOG\_COMMIT\_QUEUED, LOG\_COMMIT\_QUEUED\_WAIT\_SIGNAL, LOG\_COMMIT\_WRITTEN, LOG\_COMMIT\_WRITTEN\_WAIT\_SIGNAL, LOG\_QUEUED, PREPARED, PREPARED\_RECEIVED\_COMMIT, SCAN\_CHECK\_STOPPED, SCAN\_CLOSE\_STOPPED, SCAN\_FIRST\_STOPPED, SCAN\_RELEASE\_STOPPED, SCAN\_STATE\_USED, SCAN\_STOPPED, SCAN\_TUPKEY, STOPPED,

TC\_NOT\_CONNECTED, WAIT\_ACC, WAIT\_ACC\_ABORT, WAIT\_AI\_AFTER\_ABORT, WAIT\_ATTR,

WAIT\_SCAN\_AI, WAIT\_TUP, WAIT\_TUPKEYINFO, WAIT\_TUP\_COMMIT, or WAIT\_TUP\_TO\_ABORT. (If the MySQL Server is running with ndbinfo\_show\_hidden enabled, you can view this list of states by selecting from the ndb$dblqh\_tcconnect\_state table, which is normally hidden.)

You can obtain the name of an NDB table from its table ID by checking the output of ndb\_show\_tables.

The fragid is the same as the partition number seen in the output of ndb\_desc --extra- partition-info (short form -p).

In client\_node\_id and client\_block\_ref, client refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The block\_instance and tc\_block\_instance column provide NDB kernel block instance numbers. You can use these to obtain information about specific threads from the [threadblocks](#_bookmark8) table.

**23.6.16.55** **The** **ndbinfo** **server\_transactions** **Table**

The server\_transactions table is subset of the [cluster\_transactions](#_bookmark9) table, but includes only those transactions in which the current SQL node (MySQL Server) is a participant, while including the relevant connection IDs.

The server\_transactions table contains the following columns:

• mysql\_connection\_id MySQL Server connection ID

• node\_id

Transaction coordinator node ID

• block\_instance

Transaction coordinator block instance

• transid

Transaction ID

• state

Operation state (see text for possible values)

• count\_operations

Number of stateful operations in the transaction

• outstanding\_operations

Operations still being executed by local data management layer (LQH blocks)

• inactive\_seconds Time spent waiting for API

• client\_node\_id Client node ID

• client\_block\_ref Client block reference

**Notes**

The mysql\_connection\_id is the same as the connection or session ID shown in the output of SHOW PROCESSLIST. It is obtained from the INFORMATION\_SCHEMA table

NDB\_TRANSID\_MYSQL\_CONNECTION\_MAP.

block\_instance refers to an instance of a kernel block. Together with the block name, this number can be used to look up a given instance in the [threadblocks](#_bookmark8) table.

The transaction ID (transid) is a unique 64-bit number which can be obtained using the NDB API's [getTransactionId()](https://dev.mysql.com/doc/ndbapi/en/ndb-ndbtransaction.html#ndb-ndbtransaction-gettransactionid) method. (Currently, the MySQL Server does not expose the NDB API transaction ID of an ongoing transaction.)

The state column can have any one of the values CS\_ABORTING, CS\_COMMITTING,

CS\_COMMIT\_SENT, CS\_COMPLETE\_SENT, CS\_COMPLETING, CS\_CONNECTED, CS\_DISCONNECTED, CS\_FAIL\_ABORTED, CS\_FAIL\_ABORTING, CS\_FAIL\_COMMITTED, CS\_FAIL\_COMMITTING, CS\_FAIL\_COMPLETED, CS\_FAIL\_PREPARED, CS\_PREPARE\_TO\_COMMIT, CS\_RECEIVING, CS\_REC\_COMMITTING, CS\_RESTART, CS\_SEND\_FIRE\_TRIG\_REQ, CS\_STARTED,

CS\_START\_COMMITTING, CS\_START\_SCAN, CS\_WAIT\_ABORT\_CONF, CS\_WAIT\_COMMIT\_CONF,

CS\_WAIT\_COMPLETE\_CONF, CS\_WAIT\_FIRE\_TRIG\_REQ. (If the MySQL Server is running with ndbinfo\_show\_hidden enabled, you can view this list of states by selecting from the ndb $dbtc\_apiconnect\_state table, which is normally hidden.)

In client\_node\_id and client\_block\_ref, client refers to an NDB Cluster API or SQL node (that is, an NDB API client or a MySQL Server attached to the cluster).

The block\_instance column provides the [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html) kernel block instance number. You can use this to obtain information about specific threads from the [threadblocks](#_bookmark8) table.

**23.6.16.56** **The** **ndbinfo** **table\_distribution\_status** **Table**

The table\_distribution\_status table provides information about the progress of table distribution for NDB tables.

The table\_distribution\_status table contains the following columns:

• node\_id Node id

• table\_id

Table ID

• tab\_copy\_status

Status of copying of table distribution data to disk; one of IDLE, SR\_PHASE1\_READ\_PAGES, SR\_PHASE2\_READ\_TABLE, SR\_PHASE3\_COPY\_TABLE, REMOVE\_NODE, LCP\_READ\_TABLE, COPY\_TAB\_REQ, COPY\_NODE\_STATE, ADD\_TABLE\_COORDINATOR (*prior* *to* *NDB* *8.0.23*: ADD\_TABLE\_MASTER), ADD\_TABLE\_PARTICIPANT (*prior* *to* *NDB* *8.0.23*: ADD\_TABLE\_SLAVE), INVALIDATE\_NODE\_LCP, ALTER\_TABLE, COPY\_TO\_SAVE, or GET\_TABINFO

• tab\_update\_status

Status of updating of table distribution data; one of IDLE, LOCAL\_CHECKPOINT,

LOCAL\_CHECKPOINT\_QUEUED, REMOVE\_NODE, COPY\_TAB\_REQ, ADD\_TABLE\_MASTER,

ADD\_TABLE\_SLAVE, INVALIDATE\_NODE\_LCP, or CALLBACK

• tab\_lcp\_status

Status of table LCP; one of ACTIVE (waiting for local checkpoint to be performed), WRITING\_TO\_FILE (checkpoint performed but not yet written to disk), or COMPLETED (checkpoint performed and persisted to disk)

• tab\_status

Table internal status; one of ACTIVE (table exists), CREATING (table is being created), or DROPPING (table is being dropped)

• tab\_storage

Table recoverability; one of NORMAL (fully recoverable with redo logging and checkpointing), NOLOGGING (recoverable from node crash, empty following cluster crash), or TEMPORARY (not recoverable)

• tab\_partitions

Number of partitions in table

• tab\_fragments

Number of fragments in table; normally same as tab\_partitions; for fully replicated tables equal to tab\_partitions \* [number of node groups]

• current\_scan\_count Current number of active scans

• scan\_count\_wait

Current number of scans waiting to be performed before ALTER TABLE can complete.

• is\_reorg\_ongoing

Whether the table is currently being reorganized (1 if true)

**23.6.16.57** **The** **ndbinfo** **table\_fragments** **Table**

The table\_fragments table provides information about the fragmentation, partitioning, distribution, and (internal) replication of NDB tables.

The table\_fragments table contains the following columns:

• node\_id

Node ID ([DIH](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbdih.html) master)

• table\_id

Table ID

• partition\_id

Partition ID

• fragment\_id

Fragment ID (same as partition ID unless table is fully replicated)

• partition\_order

Order of fragment in partition

• log\_part\_id

Log part ID of fragment

• no\_of\_replicas

Number of fragment replicas

• current\_primary Current primary node ID

• preferred\_primary Preferred primary node ID

• current\_first\_backup Current first backup node ID

• current\_second\_backup Current second backup node ID

• current\_third\_backup Current third backup node ID

• num\_alive\_replicas

Current number of live fragment replicas

• num\_dead\_replicas

Current number of dead fragment replicas

• num\_lcp\_replicas

Number of fragment replicas remaining to be checkpointed

**23.6.16.58** **The** **ndbinfo** **table\_info** **Table**

The table\_info table provides information about logging, checkpointing, distribution, and storage options in effect for individual NDB tables.

The table\_info table contains the following columns:

• table\_id

Table ID

• logged\_table

Whether table is logged (1) or not (0)

• row\_contains\_gci

Whether table rows contain GCI (1 true, 0 false)

• row\_contains\_checksum

Whether table rows contain checksum (1 true, 0 false)

• read\_backup

If backup fragment replicas are read this is 1, otherwise 0

• fully\_replicated

If table is fully replicated this is 1, otherwise 0

• storage\_type

Table storage type; one of MEMORY or DISK

• hashmap\_id

Hashmap ID

• partition\_balance

Partition balance (fragment count type) used for table; one of FOR\_RP\_BY\_NODE, FOR\_RA\_BY\_NODE, FOR\_RP\_BY\_LDM, or FOR\_RA\_BY\_LDM

• create\_gci

GCI in which table was created

**23.6.16.59** **The** **ndbinfo** **table\_replicas** **Table**

The table\_replicas table provides information about the copying, distribution, and checkpointing of NDB table fragments and fragment replicas.

The table\_replicas table contains the following columns:

• node\_id

ID of the node from which data is fetched ([DIH](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbdih.html) master)

• table\_id

Table ID

• fragment\_id Fragment ID

• initial\_gci Initial GCI for table

• replica\_node\_id

ID of node where fragment replica is stored

• is\_lcp\_ongoing

Is 1 if LCP is ongoing on this fragment, 0 otherwise

• num\_crashed\_replicas

Number of crashed fragment replica instances

• last\_max\_gci\_started

Highest GCI started in most recent LCP

• last\_max\_gci\_completed

Highest GCI completed in most recent LCP

• last\_lcp\_id

ID of most recent LCP

• prev\_lcp\_id

ID of previous LCP

• prev\_max\_gci\_started

Highest GCI started in previous LCP

• prev\_max\_gci\_completed

Highest GCI completed in previous LCP

• last\_create\_gci

Last Create GCI of last crashed fragment replica instance

• last\_replica\_gci

Last GCI of last crashed fragment replica instance

• is\_replica\_alive

1 if this fragment replica is alive, 0 otherwise

**23.6.16.60** **The** **ndbinfo** **tc\_time\_track\_stats** **Table**

The tc\_time\_track\_stats table provides time-tracking information obtained from the [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html) block (TC) instances in the data nodes, through API nodes access NDB. Each TC instance tracks latencies for a set of activities it undertakes on behalf of API nodes or other data nodes; these activities include transactions, transaction errors, key reads, key writes, unique index operations, failed key operations of any type, scans, failed scans, fragment scans, and failed fragment scans.

A set of counters is maintained for each activity, each counter covering a range of latencies less than or equal to an upper bound. At the conclusion of each activity, its latency is determined and the appropriate counter incremented. tc\_time\_track\_stats presents this information as rows, with a row for each instance of the following:

• Data node, using its ID

• TC block instance

• Other communicating data node or API node, using its ID

• Upper bound value

Each row contains a value for each activity type. This is the number of times that this activity occurred with a latency within the range specified by the row (that is, where the latency does not exceed the upper bound).

The tc\_time\_track\_stats table contains the following columns:

• node\_id Requesting node ID

• block\_number TC block number

• block\_instance

TC block instance number

• comm\_node\_id

Node ID of communicating API or data node

• upper\_bound

Upper bound of interval (in microseconds)

• scans

Based on duration of successful scans from opening to closing, tracked against the API or data nodes requesting them.

• scan\_errors

Based on duration of failed scans from opening to closing, tracked against the API or data nodes requesting them.

• scan\_fragments

Based on duration of successful fragment scans from opening to closing, tracked against the data nodes executing them

• scan\_fragment\_errors

Based on duration of failed fragment scans from opening to closing, tracked against the data nodes executing them

• transactions

Based on duration of successful transactions from beginning until sending of commit ACK, tracked against the API or data nodes requesting them. Stateless transactions are not included.

• transaction\_errors

Based on duration of failing transactions from start to point of failure, tracked against the API or data nodes requesting them.

• read\_key\_ops

Based on duration of successful primary key reads with locks. Tracked against both the API or data node requesting them and the data node executing them.

• write\_key\_ops

Based on duration of successful primary key writes, tracked against both the API or data node requesting them and the data node executing them.

• index\_key\_ops

Based on duration of successful unique index key operations, tracked against both the API or data node requesting them and the data node executing reads of base tables.

• key\_op\_errors

Based on duration of all unsuccessful key read or write operations, tracked against both the API or data node requesting them and the data node executing them.

**Notes**

The block\_instance column provides the [DBTC](https://dev.mysql.com/doc/ndb-internals/en/ndb-internals-kernel-blocks-dbtc.html) kernel block instance number. You can use this together with the block name to obtain information about specific threads from the [threadblocks](#_bookmark8) table.

**23.6.16.61** **The** **ndbinfo** **threadblocks** **Table**

The threadblocks table associates data nodes, threads, and instances of NDB kernel blocks.

ndbinfo: The NDB Cluster Information Database

The threadblocks table contains the following columns:

• node\_id

Node ID

• thr\_no

Thread ID

• block\_name Block name

• block\_instance Block instance number

**Notes**

The value of the block\_name in this table is one of the values found in the block\_name column when selecting from the [ndbinfo.blocks](#_bookmark2) table. Although the list of possible values is static for a given NDB Cluster release, the list may vary between releases.

The block\_instance column provides the kernel block instance number.

**23.6.16.62** **The** **ndbinfo** **threads** **Table**

The threads table provides information about threads running in the NDB kernel.

The threads table contains the following columns:

• node\_id

ID of the node where the thread is running

• thr\_no

Thread ID (specific to this node)

• thread\_name

Thread name (type of thread)

• thread\_description Thread (type) description

**Notes**

Sample output from a 2-node example cluster, including thread descriptions, is shown here:

mysql> **SELECT** **\*** **FROM** **threads;**

+---------+--------+-------------+------------------------------------------------------------------+

| node\_id | thr\_no | thread\_name | thread\_description |

+---------+--------+-------------+------------------------------------------------------------------+

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main

rep

ldm

recv

main

rep

ldm

recv

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main thread, schema and distribution handling

rep thread, asynch replication and proxy block

ldm thread, handling a set of data partitions

receive thread, performing receive and polling

main thread, schema and distribution handling

rep thread, asynch replication and proxy block

ldm thread, handling a set of data partitions

receive thread, performing receive and polling

0

1

2

3

0

1

2

3

5

5

5

5

6

6

6

6

|

handling

for new receives

handling

for new receives

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+---------+--------+-------------+------------------------------------------------------------------+

8 rows in set (0.01 sec)

NDB 8.0.23 introduces the possibility to set either of the ThreadConfig arguments main or rep to 0 while keeping the other at 1, in which case the thread name is main\_rep and its description is main and rep thread, schema, distribution, proxy block and asynch replication handling. It is also possible beginning with NDB 8.0.23 to set both main and rep to 0, in which case the name of the resulting thread is shown in this table as main\_rep\_recv, and its description is main, rep and recv thread, schema, distribution, proxy block and asynch replication handling and handling receive and polling for new receives.

**23.6.16.63** **The** **ndbinfo** **threadstat** **Table**

The threadstat table provides a rough snapshot of statistics for threads running in the NDB kernel. The threadstat table contains the following columns:

• node\_id

Node ID

• thr\_no

Thread ID

• thr\_nm Thread name

• c\_loop

Number of loops in main loop

• c\_exec

Number of signals executed

• c\_wait

Number of times waiting for additional input

• c\_l\_sent\_prioa

Number of priority A signals sent to own node

• c\_l\_sent\_priob

Number of priority B signals sent to own node

• c\_r\_sent\_prioa

Number of priority A signals sent to remote node

• c\_r\_sent\_priob

Number of priority B signals sent to remote node

• os\_tid

OS thread ID

• os\_now

OS time (ms)

• os\_ru\_utime

OS user CPU time (µs)

• os\_ru\_stime

OS system CPU time (µs)

• os\_ru\_minflt

OS page reclaims (soft page faults)

• os\_ru\_majflt

OS page faults (hard page faults)

• os\_ru\_nvcsw

OS voluntary context switches

• os\_ru\_nivcsw

OS involuntary context switches

**Notes**

os\_time uses the system gettimeofday() call.

The values of the os\_ru\_utime, os\_ru\_stime, os\_ru\_minflt, os\_ru\_majflt, os\_ru\_nvcsw, and os\_ru\_nivcsw columns are obtained using the system getrusage() call, or the equivalent.

Since this table contains counts taken at a given point in time, for best results it is necessary to query this table periodically and store the results in an intermediate table or tables. The MySQL Server's Event Scheduler can be employed to automate such monitoring. For more information, see Section 25.4, “Using the Event Scheduler” .

**23.6.16.64** **The** **ndbinfo** **transporters** **Table**

This table contains information about NDB transporters.

The transporters table contains the following columns:

• node\_id

This data node's unique node ID in the cluster

• remote\_node\_id

The remote data node's node ID

• status

Status of the connection

• remote\_address

Name or IP address of the remote host

• bytes\_sent

Number of bytes sent using this connection

• bytes\_received

Number of bytes received using this connection

• connect\_count

Number of times connection established on this transporter

• overloaded

1 if this transporter is currently overloaded, otherwise 0

• overload\_count

Number of times this transporter has entered overload state since connecting

• slowdown

1 if this transporter is in slowdown state, otherwise 0

• slowdown\_count

Number of times this transporter has entered slowdown state since connecting

**Notes**

For each running data node in the cluster, the transporters table displays a row showing the status of each of that node's connections with all nodes in the cluster, *including* *itself*. This information is shown in the table's *status* column, which can have any one of the following values: CONNECTING, CONNECTED, DISCONNECTING, or DISCONNECTED.

Connections to API and management nodes which are configured but not currently connected to the cluster are shown with status DISCONNECTED. Rows where the node\_id is that of a data node which is not currently connected are not shown in this table. (This is similar omission of disconnected nodes in the [ndbinfo.nodes](#_bookmark11) table.

The remote\_address is the host name or address for the node whose ID is shown in the remote\_node\_id column. The bytes\_sent from this node and bytes\_received by this node are the numbers, respectively, of bytes sent and received by the node using this connection since it was established. For nodes whose status is CONNECTING or DISCONNECTED, these columns always display 0.

Assume you have a 5-node cluster consisting of 2 data nodes, 2 SQL nodes, and 1 management node, as shown in the output of the SHOW command in the ndb\_mgm client:

ndb\_mgm> **SHOW**

Connected to Management Server at: localhost:1186

Cluster Configuration

---------------------

[ndbd(NDB)] 2 node(s)

@10.100.10.1

@10.100.10.2

[ndb\_mgmd(MGM)] 1 node(s)

id=10 @10.100.10.10 (8.0.34-ndb-8.0.34)

[mysqld(API)] 2 node(s)

(8 .0 .34-ndb-8 .0 .34)

(8.0.34-ndb-8.0.34)

(8.0.34-ndb-8.0.34, Nodegroup: 0, \*)

(8.0.34-ndb-8.0.34, Nodegroup: 0)

@10.100.10.20

@10.100.10.21

id=20

id=21

id=1

id=2

There are 10 rows in the transporters table—5 for the first data node, and 5 for the second— assuming that all data nodes are running, as shown here:

mysql> **SELECT** **node\_id,** **remote\_node\_id,** **status**

-> **FROM** **ndbinfo** **.transporters;**

+---------+----------------+---------------+

| node\_id | remote\_node\_id | status |

+---------+----------------+---------------+

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DISCONNECTED

CONNECTED

1

2

1

1

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| --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  | | 1  1  1  2  2  2  2  2 | |  |  |  |  |  |  |  | | 10  20  21  1  2  10  20  21 | |  |  |  |  |  |  |  | | CONNECTED  CONNECTED  CONNECTED  CONNECTED  DISCONNECTED  CONNECTED  CONNECTED  CONNECTED | |  |  |  |  |  |  |  | |

+---------+----------------+---------------+

10 rows in set (0.04 sec)

If you shut down one of the data nodes in this cluster using the command 2 STOP in the ndb\_mgm client, then repeat the previous query (again using the mysql client), this table now shows only 5 rows — 1 row for each connection from the remaining management node to another node, including both itself and the data node that is currently offline—and displays CONNECTING for the status of each remaining connection to the data node that is currently offline, as shown here:

mysql> **SELECT** **node\_id,** **remote\_node\_id,** **status**

-> **FROM** **ndbinfo** **.transporters;**

+---------+----------------+---------------+

| node\_id | remote\_node\_id | status |

+---------+----------------+---------------+

|

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+---------+----------------+---------------+

5 rows in set (0.02 sec)

DISCONNECTED

CONNECTING

CONNECTED

CONNECTED

CONNECTED

1

2

10

20

21

1

1

1

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The connect\_count, overloaded, overload\_count, slowdown, and slowdown\_count counters are reset on connection, and retain their values after the remote node disconnects. The bytes\_sent and bytes\_received counters are also reset on connection, and so retain their values following disconnection (until the next connection resets them).

The *overload* state referred to by the overloaded and overload\_count columns occurs

when this transporter's send buffer contains more than OVerloadLimit bytes (default is 80% of SendBufferMemory, that is, 0.8 \* 2097152 = 1677721 bytes). When a given transporter is in a state of overload, any new transaction that tries to use this transporter fails with Error 1218 (Send Buffers overloaded in NDB kernel). This affects both scans and primary key operations.

The *slowdown* state referenced by the slowdown and slowdown\_count columns of this table occurs when the transporter's send buffer contains more than 60% of the overload limit (equal to 0.6 \* 2097152 = 1258291 bytes by default). In this state, any new scan using this transporter has its batch size reduced to minimize the load on the transporter.

Common causes of send buffer slowdown or overloading include the following:

• Data size, in particular the quantity of data stored in TEXT columns or BLOB columns (or both types of columns)

• Having a data node (ndbd or ndbmtd) on the same host as an SQL node that is engaged in binary logging

• Large number of rows per transaction or transaction batch

• Configuration issues such as insufficient SendBufferMemory

• Hardware issues such as insufficient RAM or poor network connectivity See also Section 23.4.3.14, “Configuring NDB Cluster Send Buffer Parameters” .

**23.6.17** **INFORMATION\_SCHEMA** **Tables** **for** **NDB** **Cluster**

Two INFORMATION\_SCHEMA tables provide information that is of particular use when managing an NDB Cluster. The FILES table provides information about NDB Cluster Disk Data files (see

Section 23.6.11.1, “NDB Cluster Disk Data Objects”). The ndb\_transid\_mysql\_connection\_map table provides a mapping between transactions, transaction coordinators, and API nodes.

Additional statistical and other data about NDB Cluster transactions, operations, threads, blocks, and other aspects of performance can be obtained from the tables in the [ndbinfo](#_bookmark1) database. For information about these tables, see [Section 23.6.16, “ndbinfo: The NDB Cluster Information Database”](#_bookmark1) .

**23.6.18** **NDB** **Cluster** **and** **the** **Performance** **Schema**

NDB 8.0 provides information in the MySQL Performance Schema about threads and transaction memory usage; NDB 8.0.29 adds ndbcluster plugin threads, and NDB 8.0.30 adds instrumenting for transaction batch memory. These features are described in greater detail in the sections which follow.

**ndbcluster** **Plugin** **Threads**

Beginning with NDB 8.0.29, ndbcluster plugin threads are visible in the Performance Schema threads table, as shown in the following query:

mysql> **SELECT** **name,** **type,** **thread\_id,** **thread\_os\_id**

-> **FROM** **performance\_schema** **.threads**

-> **WHERE** **name** **LIKE** **'%ndbcluster%'\G**

+----------------------------------+------------+-----------+--------------+

|  |  |  |
| --- | --- | --- |
| | name | | type | | thread\_id | thread\_os\_id | |

+----------------------------------+------------+-----------+--------------+

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | thread/ndbcluster/ndb\_binlog | | | BACKGROUND | | | 30 | | | 11980 | | |
| | thread/ndbcluster/ndb\_index\_stat | | | BACKGROUND | | | 31 | | | 11981 | | |
| | thread/ndbcluster/ndb\_metadata | | | BACKGROUND | | | 32 | | | 11982 | | |

+----------------------------------+------------+-----------+--------------+

The threads table shows all three of the threads listed here:

• ndb\_binlog: Binary logging thread

• ndb\_index\_stat: Index statistics thread

• ndb\_metadata: Metadata thread

These threads are also shown by name in the setup\_threads table.

Thread names are shown in the name column of the threads and setup\_threads tables using the format *prefix*/*plugin\_name*/*thread\_name*. *prefix*, the object type as determined by the performance\_schema engine, is thread for plugin threads (see Thread Instrument Elements). The *plugin\_name* is ndbcluster. *thread\_name* is the standalone name of the thread (ndb\_binlog, ndb\_index\_stat, or ndb\_metadata).

Using the thread ID or OS thread ID for a given thread in the threads or setup\_threads table, it is possible to obtain considerable information from Performance Schema about plugin execution and resource usage. This example shows how to obtain the amount of memory allocated by the threads created by the ndbcluster plugin from the mem\_root arena by joining the threads and memory\_summary\_by\_thread\_by\_event\_name tables:

mysql> **SELECT**

-> **t** **.name,**

-> **m** **.sum\_number\_of\_bytes\_alloc,**

-> **IF(m** **.sum\_number\_of\_bytes\_alloc** **>** **0,** **"true",** **"false")** **AS** **'Has** **allocated** **memory'**

-> **FROM** **performance\_schema** **.memory\_summary\_by\_thread\_by\_event\_name** **m**

-> **JOIN** **performance\_schema** **.threads** **t**

-> **ON** **m.thread\_id** **=** **t** **.thread\_id**

-> **WHERE** **t** **.name** **LIKE** **'%ndbcluster%'**

-> **AND** **event\_name** **LIKE** **'%THD::main\_mem\_root%';**

+----------------------------------+---------------------------+----------------------+

| name | sum\_number\_of\_bytes\_alloc | Has allocated memory |

+----------------------------------+---------------------------+----------------------+

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| | thread/ndbcluster/ndb\_binlog | | | 20576 | | | true | | |
| | thread/ndbcluster/ndb\_index\_stat | | | 0 | | | false | | |
| | thread/ndbcluster/ndb\_metadata | | | 8240 | | | true | | |

+----------------------------------+---------------------------+----------------------+

**Transaction** **Memory** **Usage**

Starting with NDB 8.0.30, you can see the amount of memory used for transaction batching by querying the Performance Schema memory\_summary\_by\_thread\_by\_event\_name table, similar to what is shown here:

mysql> **SELECT** **EVENT\_NAME**

-> **FROM** **performance\_schema** **.memory\_summary\_by\_thread\_by\_event\_name**

-> **WHERE** **THREAD\_ID** **=** **PS\_CURRENT\_THREAD\_ID()**

-> **AND** **EVENT\_NAME** **LIKE** **'memory/ndbcluster/%';**

+-------------------------------------------+

| EVENT\_NAME |

+-------------------------------------------+

| memory/ndbcluster/Thd\_ndb::batch\_mem\_root |

+-------------------------------------------+

1 row in set (0.01 sec)

The ndbcluster transaction memory instrument is also visible in the Performance Schema setup\_instruments table, as shown here:

mysql> **SELECT** **\*** **from** **performance\_schema** **.setup\_instruments**

-> **WHERE** **NAME** **LIKE** **'%ndb%'\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

NAME: memory/ndbcluster/Thd\_ndb::batch\_mem\_root

ENABLED: YES

TIMED: NULL

PROPERTIES:

VOLATILITY: 0

DOCUMENTATION: Memory used for transaction batching

1 row in set (0.01 sec)

**23.6.19** **Quick** **Reference:** **NDB** **Cluster** **SQL** **Statements**

This section discusses several SQL statements that can prove useful in managing and monitoring a MySQL server that is connected to an NDB Cluster, and in some cases provide information about the cluster itself.

• SHOW ENGINE NDB STATUS, SHOW ENGINE NDBCLUSTER STATUS

The output of this statement contains information about the server's connection to the cluster, creation and usage of NDB Cluster objects, and binary logging for NDB Cluster replication.

See Section 13.7.7.15, “SHOW ENGINE Statement” , for a usage example and more detailed information.

• SHOW ENGINES

This statement can be used to determine whether or not clustering support is enabled in the MySQL server, and if so, whether it is active.

See Section 13.7.7.16, “SHOW ENGINES Statement” , for more detailed information.

**Note**

This statement does not support a LIKE clause. However, you can use LIKE to filter queries against the Information Schema ENGINES table, as discussed in the next item.

• SELECT \* FROM INFORMATION\_SCHEMA.ENGINES [WHERE ENGINE LIKE 'NDB%']

This is the equivalent of SHOW ENGINES, but uses the ENGINES table of the INFORMATION\_SCHEMA database. Unlike the case with the SHOW ENGINES statement, it is possible to filter the results using a LIKE clause, and to select specific columns to obtain information that may

be of use in scripts. For example, the following query shows whether the server was built with NDB support and, if so, whether it is enabled:

mysql> **SELECT** **ENGINE,** **SUPPORT** **FROM** **INFORMATION\_SCHEMA.ENGINES**

-> **WHERE** **ENGINE** **LIKE** **'NDB%';**

+------------+---------+

| ENGINE | SUPPORT |

+------------+---------+

|  |  |  |  |
| --- | --- | --- | --- |
| |  | | ndbcluster |  ndbinfo | | YES  YES | |  | |

+------------+---------+

If NDB support is not enabled, the preceding query returns an empty set. See Section 26.3.13, “The INFORMATION\_SCHEMA ENGINES Table” , for more information.

• SHOW VARIABLES LIKE 'NDB%'

This statement provides a list of most server system variables relating to the NDB storage engine, and their values, as shown here:

mysql> **SHOW** **VARIABLES** **LIKE** **'NDB%';**

+--------------------------------------+---------------------------------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | Variable\_name | | | Value | | |

+--------------------------------------+---------------------------------------+

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  | | --- | --- | --- | --- | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | ndb\_allow\_copying\_alter\_table  ndb\_autoincrement\_prefetch\_sz  ndb\_batch\_size  ndb\_blob\_read\_batch\_bytes  ndb\_blob\_write\_batch\_bytes  ndb\_clear\_apply\_status  ndb\_cluster\_connection\_pool  ndb\_cluster\_connection\_pool\_nodeids  ndb\_connectstring  ndb\_data\_node\_neighbour  ndb\_default\_column\_format  ndb\_deferred\_constraints  ndb\_distribution  ndb\_eventbuffer\_free\_percent  ndb\_eventbuffer\_max\_alloc  ndb\_extra\_logging  ndb\_force\_send  ndb\_fully\_replicated  ndb\_index\_stat\_enable  ndb\_index\_stat\_option | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | ON  512  32768  65536  65536  ON  1  127.0.0.1  0  FIXED  0  KEYHASH  20  0  1  ON  OFF  ON  loop\_enable=1000ms,loop\_idle=1000ms, |   loop\_busy=100ms,update\_batch=1,read\_batch=4,idle\_batch=32,check\_batch=8,  check\_delay=10m,delete\_batch=8,clean\_delay=1m,error\_batch=4,error\_delay=1m,  evict\_batch=8,evict\_delay=1m,cache\_limit=32M,cache\_lowpct=90,zero\_total=0   |  |  |  |  | | --- | --- | --- | --- | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | ndb\_join\_pushdown  ndb\_log\_apply\_status  ndb\_log\_bin  ndb\_log\_binlog\_index  ndb\_log\_empty\_epochs  ndb\_log\_empty\_update  ndb\_log\_exclusive\_reads  ndb\_log\_orig  ndb\_log\_transaction\_id  ndb\_log\_update\_as\_write  ndb\_log\_update\_minimal  ndb\_log\_updated\_only  ndb\_metadata\_check  ndb\_metadata\_check\_interval  ndb\_metadata\_sync  ndb\_mgmd\_host  ndb\_nodeid  ndb\_optimization\_delay  ndb\_optimized\_node\_selection  ndb\_read\_backup  ndb\_recv\_thread\_activation\_threshold  ndb\_recv\_thread\_cpu\_mask  ndb\_report\_thresh\_binlog\_epoch\_slip  ndb\_report\_thresh\_binlog\_mem\_usage | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | ON  OFF  OFF  ON  OFF  OFF  OFF  OFF  OFF  ON  OFF  ON  ON  60  OFF  127.0.0.1  0  10  3  ON  8  10  10 | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |

|  |  |  |  |
| --- | --- | --- | --- |
| | ndb\_row\_checksum  ndb\_schema\_dist\_lock\_wait\_timeout  ndb\_schema\_dist\_timeout  | ndb\_schema\_dist\_upgrade\_allowed  | ndb\_show\_foreign\_key\_mock\_tables  | ndb\_slave\_conflict\_role  ndb\_table\_no\_logging  ndb\_table\_temporary  | ndb\_use\_copying\_alter\_table  | ndb\_use\_exact\_count  | ndb\_use\_transactions  ndb\_version  ndb\_version\_string  | ndb\_wait\_connected  | ndb\_wait\_setup  | ndbinfo\_database  ndbinfo\_max\_bytes  ndbinfo\_max\_rows  | ndbinfo\_offline  | ndbinfo\_show\_hidden  | ndbinfo\_table\_prefix  | ndbinfo version | |  |  |  |  |  |  |  |  |  |  |  |  |  | | 1  30  120  ON  OFF  NONE  OFF  OFF  OFF  OFF  ON  524308  ndb-8.0.34  30  30  ndbinfo  0  10  OFF  OFF  ndb$  524308 | |  |  |  |  |  |  |  |  |  |  |  |  |  | |

+--------------------------------------+---------------------------------------+

See Section 5.1.8, “Server System Variables” , for more information.

• SELECT \* FROM performance\_schema.global\_variables WHERE VARIABLE\_NAME LIKE 'NDB%'

This statement is the equivalent of the SHOW VARIABLES statement described in the previous item, and provides almost identical output, as shown here:

mysql> **SELECT** **\*** **FROM** **performance\_schema** **.global\_variables**

-> **WHERE** **VARIABLE\_NAME** **LIKE** **'NDB%';**

+--------------------------------------+---------------------------------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | VARIABLE\_NAME | | | VARIABLE\_VALUE | | |

+--------------------------------------+---------------------------------------+

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| |  |  |  |  | | --- | --- | --- | --- | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | ndb\_allow\_copying\_alter\_table  ndb\_autoincrement\_prefetch\_sz  ndb\_batch\_size  ndb\_blob\_read\_batch\_bytes  ndb\_blob\_write\_batch\_bytes  ndb\_clear\_apply\_status  ndb\_cluster\_connection\_pool  ndb\_cluster\_connection\_pool\_nodeids  ndb\_connectstring  ndb\_data\_node\_neighbour  ndb\_default\_column\_format  ndb\_deferred\_constraints  ndb\_distribution  ndb\_eventbuffer\_free\_percent  ndb\_eventbuffer\_max\_alloc  ndb\_extra\_logging  ndb\_force\_send  ndb\_fully\_replicated  ndb\_index\_stat\_enable  ndb\_index\_stat\_option | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | ON  512  32768  65536  65536  ON  1  127.0.0.1  0  FIXED  0  KEYHASH  20  0  1  ON  OFF  ON  loop\_enable=1000ms,loop\_idle=1000ms, |   loop\_busy=100ms,update\_batch=1,read\_batch=4,idle\_batch=32,check\_batch=8,  check\_delay=10m,delete\_batch=8,clean\_delay=1m,error\_batch=4,error\_delay=1m,  evict\_batch=8,evict\_delay=1m,cache\_limit=32M,cache\_lowpct=90,zero\_total=0  |  ndb\_log\_apply\_status  ndb\_log\_bin  ndb\_log\_binlog\_index  ndb\_log\_empty\_epochs  ndb\_log\_empty\_update  ndb\_log\_exclusive\_reads  ndb\_log\_orig  ndb\_log\_transaction\_id  ndb\_log\_update\_as\_write  ndb\_log\_update\_minimal | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |

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ndb\_join\_pushdown

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| ndb log updated only

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ndb\_metadata\_check\_interval

ndb\_metadata\_sync

ndb\_mgmd\_host

ndb\_nodeid

ndb\_optimization\_delay

ndb\_optimized\_node\_selection

ndb\_read\_backup

ndb\_recv\_thread\_activation\_threshold

ndb\_recv\_thread\_cpu\_mask

ndb\_report\_thresh\_binlog\_epoch\_slip

ndb\_report\_thresh\_binlog\_mem\_usage

ndb\_row\_checksum

ndb\_schema\_dist\_lock\_wait\_timeout

ndb\_schema\_dist\_timeout

ndb\_schema\_dist\_upgrade\_allowed

ndb\_show\_foreign\_key\_mock\_tables

ndb\_slave\_conflict\_role

ndb\_table\_no\_logging

ndb\_table\_temporary

ndb\_use\_copying\_alter\_table

ndb\_use\_exact\_count

ndb\_use\_transactions

ndb\_version

ndb\_version\_string

ndb\_wait\_connected

ndb\_wait\_setup

ndbinfo\_database

ndbinfo\_max\_bytes

ndbinfo\_max\_rows

ndbinfo\_offline

ndbinfo\_show\_hidden

ndbinfo\_table\_prefix

ndbinfo\_version

+--------------------------------------+---------------------------------------+

ON

ON

60

OFF

127.0.0.1

0

10

3

ON

8

10

10

1

30

120

ON

OFF

NONE

OFF

OFF

OFF

OFF

ON

524308

ndb-8.0.34

30

30

ndbinfo

0

10

OFF

OFF

ndb$

524308

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ndb\_metadata\_check

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Unlike the case with the SHOW VARIABLES statement, it is possible to select individual columns. For example:

mysql> **SELECT** **VARIABLE\_VALUE**

-> **FROM** **performance\_schema** **.global\_variables**

-> **WHERE** **VARIABLE\_NAME** **=** **'ndb\_force\_send';**

+----------------+

| VARIABLE\_VALUE |

+----------------+

| ON |

+----------------+

A more useful query is shown here:

mysql> **SELECT** **VARIABLE\_NAME** **AS** **Name,** **VARIABLE\_VALUE** **AS** **Value**

> **FROM** **performance\_schema** **.global\_variables**

> **WHERE** **VARIABLE\_NAME**

> **IN** **('version',** **'ndb\_version',**

> **'ndb\_version\_string',** **'ndbinfo\_version');**

+--------------------+----------------+

| Name | Value |

+--------------------+----------------+

| ndb\_version | 524317 |

| ndb\_version\_string | ndb-8 .0 .29 |

| ndbinfo\_version | 524317 |

| version | 8 .0 .29-cluster |

+--------------------+----------------+

4 rows in set (0.00 sec)

For more information, see Section 27.12.15, “Performance Schema Status Variable Tables” , and Section 5.1.8, “Server System Variables” .

• SHOW STATUS LIKE 'NDB%'

This statement shows at a glance whether or not the MySQL server is acting as a cluster SQL node, and if so, it provides the MySQL server's cluster node ID, the host name and port for the cluster management server to which it is connected, and the number of data nodes in the cluster, as shown here:

mysql> **SHOW** **STATUS** **LIKE** **'NDB%';**

+----------------------------------------------+-------------------------------+

| Variable\_name | Value |

+----------------------------------------------+-------------------------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | Ndb\_metadata\_detected\_count  Ndb\_cluster\_node\_id  Ndb\_config\_from\_host  | Ndb\_config\_from\_port  | Ndb\_number\_of\_data\_nodes  | Ndb\_number\_of\_ready\_data\_nodes  Ndb\_connect\_count  Ndb\_execute\_count  | Ndb\_scan\_count  | Ndb\_pruned\_scan\_count  | Ndb\_schema\_locks\_count  Ndb\_api\_wait\_exec\_complete\_count\_session  Ndb\_api\_wait\_scan\_result\_count\_session  | Ndb\_api\_wait\_meta\_request\_count\_session  | Ndb\_api\_wait\_nanos\_count\_session  | Ndb\_api\_bytes\_sent\_count\_session  Ndb\_api\_bytes\_received\_count\_session  Ndb\_api\_trans\_start\_count\_session  | Ndb\_api\_trans\_commit\_count\_session  | Ndb\_api\_trans\_abort\_count\_session  | Ndb\_api\_trans\_close\_count\_session  Ndb\_api\_pk\_op\_count\_session  Ndb\_api\_uk\_op\_count\_session  | Ndb\_api\_table\_scan\_count\_session  | Ndb\_api\_range\_scan\_count\_session  | Ndb\_api\_pruned\_scan\_count\_session  Ndb\_api\_scan\_batch\_count\_session  Ndb\_api\_read\_row\_count\_session  Ndb\_api\_trans\_local\_read\_row\_count\_session  |  |  |  |  Ndb\_api\_adaptive\_send\_forced\_count\_session  Ndb\_api\_adaptive\_send\_unforced\_count\_session  Ndb\_api\_adaptive\_send\_deferred\_count\_session  Ndb\_trans\_hint\_count\_session  Ndb\_sorted\_scan\_count  | Ndb\_pushed\_queries\_defined  | Ndb\_pushed\_queries\_dropped  Ndb\_pushed\_queries\_executed  Ndb\_pushed\_reads  | Ndb\_last\_commit\_epoch\_server  | Ndb\_last\_commit\_epoch\_session  | Ndb\_system\_name  Ndb\_api\_event\_data\_count\_injector  Ndb\_api\_event\_nondata\_count\_injector  | Ndb\_api\_event\_bytes\_count\_injector  | Ndb\_api\_wait\_exec\_complete\_count\_slave  | Ndb\_api\_wait\_scan\_result\_count\_slave  Ndb\_api\_wait\_meta\_request\_count\_slave  Ndb\_api\_wait\_nanos\_count\_slave  | Ndb\_api\_bytes\_sent\_count\_slave  | Ndb\_api\_bytes\_received\_count\_slave  | Ndb\_api\_trans\_start\_count\_slave  Ndb\_api\_trans\_commit\_count\_slave  Ndb\_api\_trans\_abort\_count\_slave  | Ndb\_api\_trans\_close\_count\_slave  | Ndb\_api\_pk\_op\_count\_slave  | Ndb\_api\_uk\_op\_count\_slave  Ndb\_api\_table\_scan\_count\_slave  Ndb\_api\_range\_scan\_count\_slave  | Ndb\_api\_pruned\_scan\_count\_slave  | Ndb\_api\_scan\_batch\_count\_slave  | Ndb api read row count slave | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | 0  100  127.0.0.1  1186  2  2  0  0  0  0  0  0  0  1  163446  60  28  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  37632503447571  0  MC\_20191126162038  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0 | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |

|  |  |  |  |
| --- | --- | --- | --- |
| | Ndb\_api\_trans\_local\_read\_row\_count\_slave  Ndb\_api\_adaptive\_send\_forced\_count\_slave  Ndb\_api\_adaptive\_send\_unforced\_count\_slave  | Ndb\_api\_adaptive\_send\_deferred\_count\_slave  | Ndb\_slave\_max\_replicated\_epoch  | Ndb\_api\_wait\_exec\_complete\_count  Ndb\_api\_wait\_scan\_result\_count  Ndb\_api\_wait\_meta\_request\_count  | Ndb\_api\_wait\_nanos\_count  | Ndb\_api\_bytes\_sent\_count  | Ndb\_api\_bytes\_received\_count  Ndb\_api\_trans\_start\_count  Ndb\_api\_trans\_commit\_count  | Ndb\_api\_trans\_abort\_count  | Ndb\_api\_trans\_close\_count  | Ndb\_api\_pk\_op\_count  Ndb\_api\_uk\_op\_count  Ndb\_api\_table\_scan\_count  | Ndb\_api\_range\_scan\_count  | Ndb\_api\_pruned\_scan\_count  | Ndb\_api\_scan\_batch\_count  Ndb\_api\_read\_row\_count  Ndb\_api\_trans\_local\_read\_row\_count  | Ndb\_api\_adaptive\_send\_forced\_count  | Ndb\_api\_adaptive\_send\_unforced\_count  | Ndb\_api\_adaptive\_send\_deferred\_count  Ndb\_api\_event\_data\_count  Ndb\_api\_event\_nondata\_count  | Ndb\_api\_event\_bytes\_count  | Ndb\_metadata\_excluded\_count  | Ndb\_metadata\_synced\_count  Ndb\_conflict\_fn\_max  Ndb\_conflict\_fn\_old  | Ndb\_conflict\_fn\_max\_del\_win  | Ndb\_conflict\_fn\_epoch  | Ndb\_conflict\_fn\_epoch\_trans  Ndb\_conflict\_fn\_epoch2  Ndb\_conflict\_fn\_epoch2\_trans  | Ndb\_conflict\_trans\_row\_conflict\_count  | Ndb\_conflict\_trans\_row\_reject\_count  | Ndb\_conflict\_trans\_reject\_count  Ndb\_conflict\_trans\_detect\_iter\_count  Ndb\_conflict\_trans\_conflict\_commit\_count  | Ndb\_conflict\_epoch\_delete\_delete\_count  | Ndb\_conflict\_reflected\_op\_prepare\_count  | Ndb\_conflict\_reflected\_op\_discard\_count  Ndb\_conflict\_refresh\_op\_count  Ndb\_conflict\_last\_conflict\_epoch  | Ndb\_conflict\_last\_stable\_epoch  | Ndb\_index\_stat\_status | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | 0  0  0  0  0  4  7  172  1083548094028  4640  109356  4  1  1  4  2  0  1  1  0  1  3  2  1  5  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  allow:1,enable:1,busy:0, | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |

loop:1000,list:(new:0,update:0,read:0,idle:0,check:0,delete:0,error:0,total:0),

analyze:(queue:0,wait:0),stats:(nostats:0,wait:0),total:(analyze:(all:0,error:0),

query:(all:0,nostats:0,error:0),event:(act:0,skip:0,miss:0),cache:(refresh:0,

clean:0,pinned:0,drop:0,evict:0)),cache:(query:0,clean:0,drop:0,evict:0,

usedpct:0.00,highpct:0.00) |

| Ndb\_index\_stat\_cache\_query | 0 |

| Ndb\_index\_stat\_cache\_clean | 0 |

+----------------------------------------------+-------------------------------+

If the MySQL server was built with NDB support, but it is not currently connected to a cluster, every row in the output of this statement contains a zero or an empty string for the Value column.

See also Section 13.7.7.37, “SHOW STATUS Statement” .

• SELECT \* FROM performance\_schema.global\_status WHERE VARIABLE\_NAME LIKE 'NDB%'

This statement provides similar output to the SHOW STATUS statement discussed in the previous item. Unlike the case with SHOW STATUS, it is possible using SELECT statements to extract values in SQL for use in scripts for monitoring and automation purposes.

For more information, see Section 27.12.15, “Performance Schema Status Variable Tables” .

• SELECT \* FROM INFORMATION\_SCHEMA.PLUGINS WHERE PLUGIN\_NAME LIKE 'NDB%'

This statement displays information from the Information Schema PLUGINS table about plugins associated with NDB Cluster, such as version, author, and license, as shown here:

mysql> **SELECT** **\*** **FROM** **INFORMATION\_SCHEMA.PLUGINS**

> **WHERE** **PLUGIN\_NAME** **LIKE** **'NDB%'\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

PLUGIN\_NAME: ndbcluster

PLUGIN\_VERSION: 1.0

PLUGIN\_STATUS: ACTIVE

PLUGIN\_TYPE: STORAGE ENGINE

PLUGIN\_TYPE\_VERSION: 80032.0

PLUGIN\_LIBRARY: NULL

PLUGIN\_LIBRARY\_VERSION: NULL

PLUGIN\_AUTHOR: Oracle Corporation

PLUGIN\_DESCRIPTION: Clustered, fault-tolerant tables

PLUGIN\_LICENSE: GPL

LOAD\_OPTION: ON

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 2. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

PLUGIN\_NAME: ndbinfo

PLUGIN\_VERSION: 0.1

PLUGIN\_STATUS: ACTIVE

PLUGIN\_TYPE: STORAGE ENGINE

PLUGIN\_TYPE\_VERSION: 80032.0

PLUGIN\_LIBRARY: NULL

PLUGIN\_LIBRARY\_VERSION: NULL

PLUGIN\_AUTHOR: Oracle Corporation

PLUGIN\_DESCRIPTION: MySQL Cluster system information storage engine

PLUGIN\_LICENSE: GPL

LOAD\_OPTION: ON

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 3. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

PLUGIN\_NAME: ndb\_transid\_mysql\_connection\_map

PLUGIN\_VERSION: 0.1

PLUGIN\_STATUS: ACTIVE

PLUGIN\_TYPE: INFORMATION SCHEMA

PLUGIN\_TYPE\_VERSION: 80032.0

PLUGIN\_LIBRARY: NULL

PLUGIN\_LIBRARY\_VERSION: NULL

PLUGIN\_AUTHOR: Oracle Corporation

PLUGIN\_DESCRIPTION: Map between MySQL connection ID and NDB transaction ID

PLUGIN\_LICENSE: GPL

LOAD\_OPTION: ON

You can also use the SHOW PLUGINS statement to display this information, but the output from that statement cannot easily be filtered. See also [The MySQL Plugin API](https://dev.mysql.com/doc/extending-mysql/8.0/en/plugin-api.html), which describes where and how the information in the PLUGINS table is obtained.

You can also query the tables in the [ndbinfo](#_bookmark1) information database for real-time data about many NDB Cluster operations. See [Section 23.6.16, “ndbinfo: The NDB Cluster Information Database”](#_bookmark1) .

**23.6.20** **NDB** **Cluster** **Security** **Issues**

This section discusses security considerations to take into account when setting up and running NDB

Cluster.

Topics covered in this section include the following:

• NDB Cluster and network security issues



• Configuration issues relating to running NDB Cluster securely

• NDB Cluster and the MySQL privilege system

• MySQL standard security procedures as applicable to NDB Cluster

**23.6.20.1** **NDB** **Cluster** **Security** **and** **Networking** **Issues**

In this section, we discuss basic network security issues as they relate to NDB Cluster. It is extremely important to remember that NDB Cluster “out of the box” is not secure; you or your network administrator must take the proper steps to ensure that your cluster cannot be compromised over the network.

Cluster communication protocols are inherently insecure, and no encryption or similar security measures are used in communications between nodes in the cluster. Because network speed and latency have a direct impact on the cluster's efficiency, it is also not advisable to employ SSL or other encryption to network connections between nodes, as such schemes cause slow communications.

It is also true that no authentication is used for controlling API node access to an NDB Cluster. As with encryption, the overhead of imposing authentication requirements would have an adverse impact on Cluster performance.

In addition, there is no checking of the source IP address for either of the following when accessing the cluster:

• SQL or API nodes using “free slots” created by empty [mysqld] or [api] sections in the config.ini file

This means that, if there are any empty [mysqld] or [api] sections in the config.ini file, then any API nodes (including SQL nodes) that know the management server's host name (or IP address) and port can connect to the cluster and access its data without restriction. (See [Section 23.6.20.2,](#_bookmark27) [“NDB Cluster and MySQL Privileges”](#_bookmark27) , for more information about this and related issues.)

**Note**

You can exercise some control over SQL and API node access to the cluster by specifying a HostName parameter for all [mysqld] and [api] sections in the config.ini file. However, this also means that, should you wish to connect an API node to the cluster from a previously unused host, you need to add an [api] section containing its host name to the config.ini file.

More information is available elsewhere in this chapter about the HostName parameter. Also see Section 23.4.1, “Quick Test Setup of NDB Cluster” , for configuration examples using HostName with API nodes.

• Any ndb\_mgm client

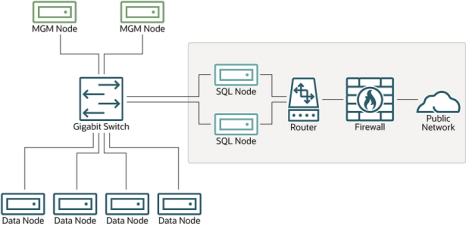
This means that any cluster management client that is given the management server's host name (or IP address) and port (if not the standard port) can connect to the cluster and execute any management client command. This includes commands such as ALL STOP and SHUTDOWN.

For these reasons, it is necessary to protect the cluster on the network level. The safest network configuration for Cluster is one which isolates connections between Cluster nodes from any other network communications. This can be accomplished by any of the following methods:

1. Keeping Cluster nodes on a network that is physically separate from any public networks. This option is the most dependable; however, it is the most expensive to implement.

We show an example of an NDB Cluster setup using such a physically segregated network here:

**Figure** **23.7** **NDB** **Cluster** **with** **Hardware** **Firewall**



This setup has two networks, one private (solid box) for the Cluster management servers and data nodes, and one public (dotted box) where the SQL nodes reside. (We show the management and data nodes connected using a gigabit switch since this provides the best performance.) Both networks are protected from the outside by a hardware firewall, sometimes also known as a *network-based* *firewall*.

This network setup is safest because no packets can reach the cluster's management or data nodes from outside the network—and none of the cluster's internal communications can reach the outside—without going through the SQL nodes, as long as the SQL nodes do not permit any packets to be forwarded. This means, of course, that all SQL nodes must be secured against hacking attempts.

**Important**

With regard to potential security vulnerabilities, an SQL node is no different from any other MySQL server. See Section 6.1.3, “Making MySQL Secure Against Attackers” , for a description of techniques you can use to secure MySQL servers.

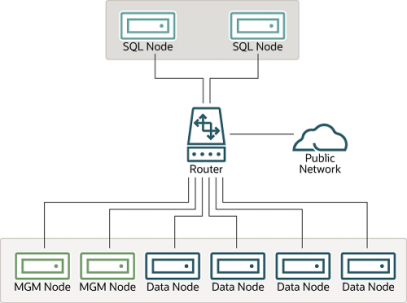
2. Using one or more software firewalls (also known as *host-based* *firewalls*) to control which packets pass through to the cluster from portions of the network that do not require access to it. In this type

of setup, a software firewall must be installed on every host in the cluster which might otherwise be accessible from outside the local network.

The host-based option is the least expensive to implement, but relies purely on software to provide protection and so is the most difficult to keep secure.

This type of network setup for NDB Cluster is illustrated here:

**Figure** **23.8** **NDB** **Cluster** **with** **Software** **Firewalls**



Using this type of network setup means that there are two zones of NDB Cluster hosts. Each cluster host must be able to communicate with all of the other machines in the cluster, but only those hosting SQL nodes (dotted box) can be permitted to have any contact with the outside, while those in the zone containing the data nodes and management nodes (solid box) must be isolated from any machines that are not part of the cluster. Applications using the cluster and user of those applications must *not* be permitted to have direct access to the management and data node hosts.

To accomplish this, you must set up software firewalls that limit the traffic to the type or types shown in the following table, according to the type of node that is running on each cluster host computer:

**Table** **23.68** **Node** **types** **in** **a** **host-based** **firewall** **cluster** **configuration**

|  |  |
| --- | --- |
| **Node** **Type** | **Permitted** **Traffic** |
| SQL or API node | • It originates from the IP address of a management or data node (using any TCP or UDP port).  • It originates from within the network in which the cluster resides and is on the port that your application is using. |
| Data node or Management node | • It originates from the IP address of a management or data node (using any TCP or UDP port). |



|  |  |
| --- | --- |
| **Node** **Type** | **Permitted** **Traffic** |
|  | • It originates from the IP address of an SQL or API node. |

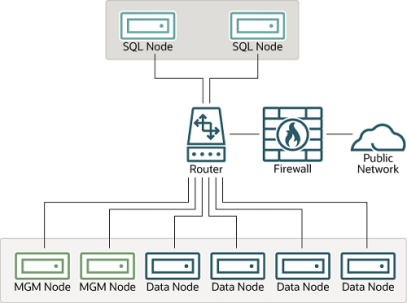
Any traffic other than that shown in the table for a given node type should be denied.

The specifics of configuring a firewall vary from firewall application to firewall application, and are beyond the scope of this Manual. iptables is a very common and reliable firewall application, which is often used with APF as a front end to make configuration easier. You can (and should) consult the documentation for the software firewall that you employ, should you choose to implement an NDB Cluster network setup of this type, or of a “mixed” type as discussed under the next item.

3. It is also possible to employ a combination of the first two methods, using both hardware and software to secure the cluster—that is, using both network-based and host-based firewalls. This is between the first two schemes in terms of both security level and cost. This type of network setup keeps the cluster behind the hardware firewall, but permits incoming packets to travel beyond the router connecting all cluster hosts to reach the SQL nodes.

One possible network deployment of an NDB Cluster using hardware and software firewalls in combination is shown here:

**Figure** **23.9** **NDB** **Cluster** **with** **a** **Combination** **of** **Hardware** **and** **Software** **Firewalls**



In this case, you can set the rules in the hardware firewall to deny any external traffic except to SQL nodes and API nodes, and then permit traffic to them only on the ports required by your application.

Whatever network configuration you use, remember that your objective from the viewpoint of keeping the cluster secure remains the same—to prevent any unessential traffic from reaching the cluster while ensuring the most efficient communication between the nodes in the cluster.

Because NDB Cluster requires large numbers of ports to be open for communications between nodes, the recommended option is to use a segregated network. This represents the simplest way to prevent unwanted traffic from reaching the cluster.

**Note**

If you wish to administer an NDB Cluster remotely (that is, from outside the local network), the recommended way to do this is to use ssh or another secure

login shell to access an SQL node host. From this host, you can then run the management client to access the management server safely, from within the cluster's own local network.

Even though it is possible to do so in theory, it is *not* recommended to use ndb\_mgm to manage a Cluster directly from outside the local network on which the Cluster is running. Since neither authentication nor encryption takes place between the management client and the management server, this represents an extremely insecure means of managing the cluster, and is almost certain to be compromised sooner or later.

**23.6.20.2** **NDB** **Cluster** **and** **MySQL** **Privileges**

In this section, we discuss how the MySQL privilege system works in relation to NDB Cluster and the implications of this for keeping an NDB Cluster secure.

Standard MySQL privileges apply to NDB Cluster tables. This includes all MySQL privilege types (SELECT privilege, UPDATE privilege, DELETE privilege, and so on) granted on the database, table, and column level. As with any other MySQL Server, user and privilege information is stored in the mysql system database. The SQL statements used to grant and revoke privileges on NDB tables, databases containing such tables, and columns within such tables are identical in all respects with the GRANT and REVOKE statements used in connection with database objects involving any (other) MySQL storage engine. The same thing is true with respect to the CREATE USER and DROP USER statements.

It is important to keep in mind that, by default, the MySQL grant tables use the InnoDB storage engine. Because of this, those tables are not normally duplicated or shared among MySQL servers acting as SQL nodes in an NDB Cluster. In other words, changes in users and their privileges do not automatically propagate between SQL nodes by default. If you wish, you can enable synchronization of MySQL users and privileges across NDB Cluster SQL nodes; see Section 23.6.13, “Privilege Synchronization and NDB\_STORED\_USER” , for details.

Conversely, because there is no way in MySQL to deny privileges (privileges can either be revoked or not granted in the first place, but not denied as such), there is no special protection for NDB tables on one SQL node from users that have privileges on another SQL node; this is true even if you are not using automatic distribution of user privileges. The definitive example of this is the MySQL root account, which can perform any action on any database object. In combination with empty [mysqld] or [api] sections of the config.ini file, this account can be especially dangerous. To understand why, consider the following scenario:

• The config.ini file contains at least one empty [mysqld] or [api] section. This means that the NDB Cluster management server performs no checking of the host from which a MySQL Server (or other API node) accesses the NDB Cluster.

• There is no firewall, or the firewall fails to protect against access to the NDB Cluster from hosts external to the network.

• The host name or IP address of the NDB Cluster management server is known or can be determined from outside the network.

If these conditions are true, then anyone, anywhere can start a MySQL Server with --ndbcluster --ndb-connectstring=*management\_host* and access this NDB Cluster. Using the MySQL root account, this person can then perform the following actions:

• Execute metadata statements such as SHOW DATABASES statement (to obtain a list of all NDB databases on the server) or SHOW TABLES FROM *some\_ndb\_database* statement to obtain a list of all NDB tables in a given database

• Run any legal MySQL statements on any of the discovered tables, such as:

• SELECT \* FROM *some\_table* or TABLE *some\_table* to read all the data from any table

• DELETE FROM *some\_table* or TRUNCATE TABLE to delete all the data from a table

• DESCRIBE *some\_table* or SHOW CREATE TABLE *some\_table* to determine the table schema

• UPDATE *some\_table* SET *column1* = *some\_value* to fill a table column with “garbage” data; this could actually cause much greater damage than simply deleting all the data

More insidious variations might include statements like these:

|  |  |
| --- | --- |
| UPDATE *some\_* | *table* SET *an\_int\_column* = *an\_int\_column* + 1 |
| or |  |
| UPDATE *some\_* | *table* SET *a\_varchar\_column* = REVERSE(*a\_varchar\_column*) |

Such malicious statements are limited only by the imagination of the attacker.

The only tables that would be safe from this sort of mayhem would be those tables that were created using storage engines other than NDB, and so not visible to a “rogue” SQL node.

A user who can log in as root can also access the INFORMATION\_SCHEMA database and its tables, and so obtain information about databases, tables, stored routines, scheduled events, and any other database objects for which metadata is stored in INFORMATION\_SCHEMA.

It is also a very good idea to use different passwords for the root accounts on different NDB Cluster SQL nodes unless you are using shared privileges.

In sum, you cannot have a safe NDB Cluster if it is directly accessible from outside your local network.

**Important**

*Never* *leave* *the* *MySQL* *root* *account* *password* *empty*. This is just as true when running MySQL as an NDB Cluster SQL node as it is when running it as a standalone (non-Cluster) MySQL Server, and should be done as part of the MySQL installation process before configuring the MySQL Server as an SQL node in an NDB Cluster.

If you need to synchronize mysql system tables between SQL nodes, you can use standard MySQL replication to do so, or employ a script to copy table entries between the MySQL servers. Users and their privileges can be shared and kept in synch using the NDB\_STORED\_USER privilege.

**Summary.** The most important points to remember regarding the MySQL privilege system with regard to NDB Cluster are listed here:

1. Users and privileges established on one SQL node do not automatically exist or take effect on other SQL nodes in the cluster. Conversely, removing a user or privilege on one SQL node in the cluster does not remove the user or privilege from any other SQL nodes.

2. You can share MySQL users and privileges among SQL nodes using NDB\_STORED\_USER.

3. Once a MySQL user is granted privileges on an NDB table from one SQL node in an NDB Cluster, that user can “see” any data in that table regardless of the SQL node from which the data originated, even if that user is not shared.

**23.6.20.3** **NDB** **Cluster** **and** **MySQL** **Security** **Procedures**

In this section, we discuss MySQL standard security procedures as they apply to running NDB Cluster.

In general, any standard procedure for running MySQL securely also applies to running a MySQL Server as part of an NDB Cluster. First and foremost, you should always run a MySQL Server as the mysql operating system user; this is no different from running MySQL in a standard (non-Cluster)



environment. The mysql system account should be uniquely and clearly defined. Fortunately, this is the default behavior for a new MySQL installation. You can verify that the mysqld process is running as the mysql operating system user by using the system command such as the one shown here:

$> **ps** **aux** **|** **grep** **mysql**

root 10467 0.0 0.1 3616 1380 pts/3 S 11:53 0:00 \

/bin/sh ./mysqld\_safe --ndbcluster --ndb-connectstring=localhost:1186

mysql 10512 0.2 2.5 58528 26636 pts/3 Sl 11:53 0:00 \

/usr/local/mysql/libexec/mysqld --basedir=/usr/local/mysql \

--datadir=/usr/local/mysql/var --user=mysql --ndbcluster \

--ndb-connectstring=localhost:1186 --pid-file=/usr/local/mysql/var/mothra .pid \

--log-error=/usr/local/mysql/var/mothra .err

jon 10579 0.0 0.0 2736 688 pts/0 S+ 11:54 0:00 grep mysql

If the mysqld process is running as any other user than mysql, you should immediately shut it down and restart it as the mysql user. If this user does not exist on the system, the mysql user account should be created, and this user should be part of the mysql user group; in this case, you should also make sure that the MySQL data directory on this system (as set using the --datadir option for mysqld) is owned by the mysql user, and that the SQL node's my.cnf file includes user=mysql in the [mysqld] section. Alternatively, you can start the MySQL server process with --user=mysql on the command line, but it is preferable to use the my.cnf option, since you might forget to use the command-line option and so have mysqld running as another user unintentionally. The mysqld\_safe startup script forces MySQL to run as the mysql user.

**Important**

Never run mysqld as the system root user. Doing so means that potentially any file on the system can be read by MySQL, and thus—should MySQL be compromised—by an attacker.

As mentioned in the previous section (see [Section 23.6.20.2, “NDB Cluster and MySQL Privileges”](#_bookmark27)), you should always set a root password for the MySQL Server as soon as you have it running. You should also delete the anonymous user account that is installed by default. You can accomplish these tasks using the following statements:

$> **mysql** **-u** **root**

mysql> **UPDATE** **mysql** **.user**

->

->

mysql> **DELETE** **FROM** **mysql** **.user**

-> **WHERE** **User='';**

mysql> **FLUSH** **PRIVILEGES;**

**SET** **Password=PASSWORD('*secure\_password*')**

**WHERE** **User='root';**

Be very careful when executing the DELETE statement not to omit the WHERE clause, or you risk deleting *all* MySQL users. Be sure to run the FLUSH PRIVILEGES statement as soon as you have modified the mysql.user table, so that the changes take immediate effect. Without FLUSH PRIVILEGES, the changes do not take effect until the next time that the server is restarted.

**Note**

Many of the NDB Cluster utilities such as ndb\_show\_tables, ndb\_desc, and ndb\_select\_all also work without authentication and can reveal table names, schemas, and data. By default these are installed on Unix-style systems with the permissions wxr-xr-x (755), which means they can be executed by any user that can access the mysql/bin directory.

See Section 23.5, “NDB Cluster Programs” , for more information about these utilities.

**23.7** **NDB** **Cluster** **Replication**

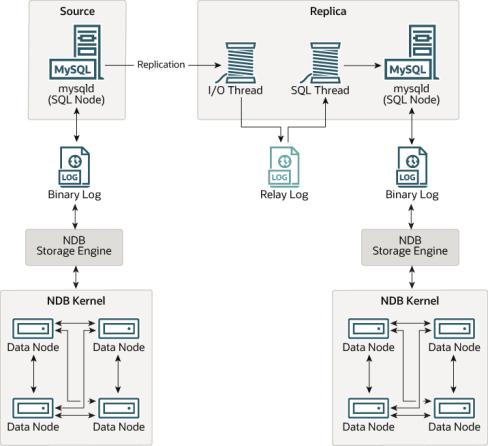
NDB Cluster supports *asynchronous* *replication*, more usually referred to simply as “replication” . This section explains how to set up and manage a configuration in which one group of computers operating as an NDB Cluster replicates to a second computer or group of computers. We assume some familiarity on the part of the reader with standard MySQL replication as discussed elsewhere in this Manual. (See Chapter 17, *Replication*).

**Note**

NDB Cluster does not support replication using GTIDs; semisynchronous replication and group replication are also not supported by the NDB storage engine.

Normal (non-clustered) replication involves a source server and a replica server, the source being so named because operations and data to be replicated originate with it, and the replica being the recipient of these. In NDB Cluster, replication is conceptually very similar but can be more complex in practice, as it may be extended to cover a number of different configurations including replicating between two complete clusters. Although an NDB Cluster itself depends on the NDB storage engine for clustering functionality, it is not necessary to use NDB as the storage engine for the replica's copies of the replicated tables (see [Replication from NDB to other storage engines](#_bookmark29)). However, for maximum availability, it is possible (and preferable) to replicate from one NDB Cluster to another, and it is this scenario that we discuss, as shown in the following figure:

**Figure** **23.10** **NDB** **Cluster-to-Cluster** **Replication** **Layout**



In this scenario, the replication process is one in which successive states of a source cluster are logged and saved to a replica cluster. This process is accomplished by a special thread known as the NDB binary log injector thread, which runs on each MySQL server and produces a binary log (binlog). This thread ensures that all changes in the cluster producing the binary log—and not just those changes that are effected through the MySQL Server—are inserted into the binary log with the correct serialization order. We refer to the MySQL source and replica servers as replication servers or replication nodes, and the data flow or line of communication between them as a *replication* *channel*.

For information about performing point-in-time recovery with NDB Cluster and NDB Cluster Replication, see [Section 23.7.9.2, “Point-In-Time Recovery Using NDB Cluster Replication”](#_bookmark30) .

**NDB** **API** **replica** **status** **variables.** NDB API counters can provide enhanced monitoring capabilities on replica clusters. These counters are implemented as NDB statistics \_slave status variables, as seen in the output of SHOW STATUS, or in the results of queries against the Performance Schema session\_status or global\_status table in a mysql client session connected to a MySQL Server that is acting as a replica in NDB Cluster Replication. By comparing the values of these status variables before and after the execution of statements affecting replicated NDB tables, you can observe the corresponding actions taken on the NDB API level by the replica, which can be useful when monitoring or troubleshooting NDB Cluster Replication. Section 23.6.15, “NDB API Statistics Counters and Variables” , provides additional information.

**Replication** **from** **NDB** **to** **non-NDB** **tables.** It is possible to replicate NDB tables from an NDB Cluster acting as the replication source to tables using other MySQL storage engines such as InnoDB or MyISAM on a replica mysqld. This is subject to a number of conditions; see [Replication from NDB](#_bookmark29) [to other storage engines](#_bookmark29), and [Replication from NDB to a nontransactional storage engine](#_bookmark31), for more information.

**23.7.1** **NDB** **Cluster** **Replication:** **Abbreviations** **and** **Symbols**

Throughout this section, we use the following abbreviations or symbols for referring to the source and replica clusters, and to processes and commands run on the clusters or cluster nodes:

**Table** **23.69** **Abbreviations** **used** **throughout** **this** **section** **referring** **to** **source** **and** **replica** **clusters,** **and** **to** **processes** **and** **commands** **run** **on** **cluster** **nodes**

|  |  |
| --- | --- |
| **Symbol** **or** **Abbreviation** | **Description** **(Refers** **to...)** |
| *S* | The cluster serving as the (primary) replication source |
| *R* | The cluster acting as the (primary) replica |
| shell*S*> | Shell command to be issued on the source cluster |
| mysql*S*> | MySQL client command issued on a single MySQL server running as an SQL node on the source cluster |
| mysql*S\**> | MySQL client command to be issued on all SQL nodes participating in the replication source cluster |
| shell*R*> | Shell command to be issued on the replica cluster |
| mysql*R*> | MySQL client command issued on a single MySQL server running as an SQL node on the replica cluster |
| mysql*R\**> | MySQL client command to be issued on all SQL nodes participating in the replica cluster |
| *C* | Primary replication channel |
| *C'* | Secondary replication channel |
| *S'* | Secondary replication source |
| *R'* | Secondary replica |

**23.7.2** **General** **Requirements** **for** **NDB** **Cluster** **Replication**

A replication channel requires two MySQL servers acting as replication servers (one each for the source and replica). For example, this means that in the case of a replication setup with two replication channels (to provide an extra channel for redundancy), there should be a total of four replication nodes, two per cluster.

Replication of an NDB Cluster as described in this section and those following is dependent on row- based replication. This means that the replication source MySQL server must be running with -- binlog-format=ROW or --binlog-format=MIXED, as described in [Section 23.7.6, “Starting NDB](#_bookmark33) [Cluster Replication (Single Replication Channel)”](#_bookmark33) . For general information about row-based replication, see Section 17.2.1, “Replication Formats” .

**Important**

If you attempt to use NDB Cluster Replication with --binlog- format=STATEMENT, replication fails to work properly because the ndb\_binlog\_index table on the source cluster and the epoch column of the ndb\_apply\_status table on the replica cluster are not updated (see [Section 23.7.4, “NDB Cluster Replication Schema and Tables”](#_bookmark34)). Instead, only updates on the MySQL server acting as the replication source propagate to the replica, and no updates from any other SQL nodes in the source cluster are replicated.

The default value for the --binlog-format option is MIXED.

Each MySQL server used for replication in either cluster must be uniquely identified among all the MySQL replication servers participating in either cluster (you cannot have replication servers on both the source and replica clusters sharing the same ID). This can be done by starting each SQL node using the --server-id=*id* option, where *id* is a unique integer. Although it is not strictly necessary, we assume for purposes of this discussion that all NDB Cluster binaries are of the same release version.

It is generally true in MySQL Replication that both MySQL servers (mysqld processes) involved must be compatible with one another with respect to both the version of the replication protocol used and the SQL feature sets which they support (see Section 17.5.2, “Replication Compatibility Between MySQL Versions” ). It is due to such differences between the binaries in the NDB Cluster and MySQL Server 8.0 distributions that NDB Cluster Replication has the additional requirement that both mysqld binaries come from an NDB Cluster distribution. The simplest and easiest way to assure that the mysqld servers are compatible is to use the same NDB Cluster distribution for all source and replica mysqld binaries.

We assume that the replica server or cluster is dedicated to replication of the source cluster, and that no other data is being stored on it.

All NDB tables being replicated must be created using a MySQL server and client. Tables and other database objects created using the NDB API (with, for example, [Dictionary::createTable()](https://dev.mysql.com/doc/ndbapi/en/ndb-dictionary.html#ndb-dictionary-createtable)) are not visible to a MySQL server and so are not replicated. Updates by NDB API applications to existing tables that were created using a MySQL server can be replicated.

**Note**

It is possible to replicate an NDB Cluster using statement-based replication. However, in this case, the following restrictions apply:

• All updates to data rows on the cluster acting as the source must be directed to a single MySQL server.

• It is not possible to replicate a cluster using multiple simultaneous MySQL replication processes.

• Only changes made at the SQL level are replicated.

These are in addition to the other limitations of statement-based replication as opposed to row-based replication; see Section 17.2.1.1, “Advantages and Disadvantages of Statement-Based and Row-Based Replication” , for more specific information concerning the differences between the two replication formats.



**23.7.3** **Known** **Issues** **in** **NDB** **Cluster** **Replication**

This section discusses known problems or issues when using replication with NDB Cluster.

**Loss** **of** **connection** **between** **source** **and** **replica.** A loss of connection can occur either between the source cluster SQL node and the replica cluster SQL node, or between the source SQL node and the data nodes of the source cluster. In the latter case, this can occur not only as a result of loss of physical connection (for example, a broken network cable), but due to the overflow of data node event buffers; if the SQL node is too slow to respond, it may be dropped by the cluster (this is controllable to some degree by adjusting the MaxBufferedEpochs and TimeBetweenEpochs configuration parameters). If this occurs, *it* *is* *entirely* *possible* *for* *new* *data* *to* *be* *inserted* *into* *the* *source* *cluster* *without* *being* *recorded* *in* *the* *source* *SQL* *node's* *binary* *log*. For this reason, to guarantee high availability, it is extremely important to maintain a backup replication channel, to monitor the primary channel, and to fail over to the secondary replication channel when necessary to keep the replica cluster synchronized with the source. NDB Cluster is not designed to perform such monitoring on its own; for this, an external application is required.

The source SQL node issues a “gap” event when connecting or reconnecting to the source cluster. (A gap event is a type of “incident event,” which indicates an incident that occurs that affects the contents of the database but that cannot easily be represented as a set of changes. Examples of incidents are server failures, database resynchronization, some software updates, and some hardware changes.) When the replica encounters a gap in the replication log, it stops with an error message. This message is available in the output of SHOW REPLICA STATUS (prior to NDB 8.0.22, use SHOW SLAVE STATUS), and indicates that the SQL thread has stopped due to an incident registered in the replication stream, and that manual intervention is required. See [Section 23.7.8, “Implementing Failover with NDB](#_bookmark35) [Cluster Replication”](#_bookmark35) , for more information about what to do in such circumstances.

**Important**

Because NDB Cluster is not designed on its own to monitor replication status or provide failover, if high availability is a requirement for the replica server or cluster, then you must set up multiple replication lines, monitor the source mysqld on the primary replication line, and be prepared fail over to a secondary line if and as necessary. This must be done manually, or possibly by means of a third-party application. For information about implementing this type of setup, see [Section 23.7.7, “Using Two Replication Channels for NDB Cluster](#_bookmark36) [Replication”](#_bookmark36) , and [Section 23.7.8, “Implementing Failover NDB Cluster](#_bookmark35)with [Replication”](#_bookmark35) .

If you are replicating from a standalone MySQL server to an NDB Cluster, one channel is usually sufficient.

**Circular** **replication.** NDB Cluster Replication supports circular replication, as shown in the next

example. The replication setup involves three NDB Clusters numbered 1, 2, and 3, in which Cluster 1 acts as the replication source for Cluster 2, Cluster 2 acts as the source for Cluster 3, and Cluster 3 acts as the source for Cluster 1, thus completing the circle. Each NDB Cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

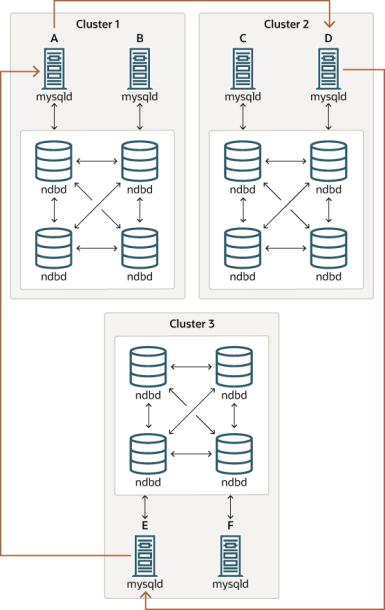
Circular replication using these clusters is supported as long as the following conditions are met:

• The SQL nodes on all source and replica clusters are the same.

• All SQL nodes acting as sources and replicas are started with the system variable log\_replica\_updates (NDB 8.0.26 and later) or log\_slave\_updates (prior to NDB 8.0.26) enabled.

This type of circular replication setup is shown in the following diagram:

**Figure** **23.11** **NDB** **Cluster** **Circular** **Replication** **With** **All** **Sources** **As** **Replicas**

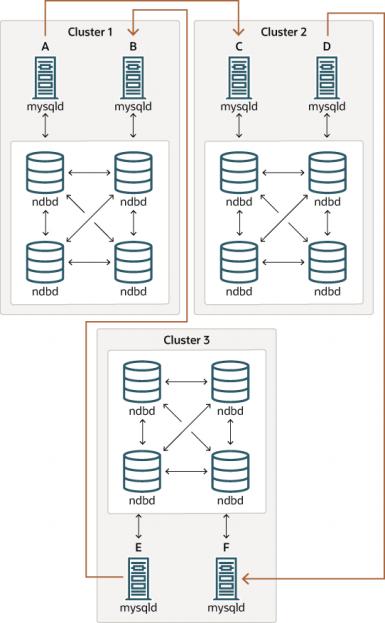


In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the curved arrows in the diagram) directly connects all SQL nodes used as sources and replicas.

It should also be possible to set up circular replication in which not all source SQL nodes are also replicas, as shown here:



**Figure** **23.12** **NDB** **Cluster** **Circular** **Replication** **Where** **Not** **All** **Sources** **Are** **Replicas**



In this case, different SQL nodes in each cluster are used as sources and replicas. However, you must *not* start any of the SQL nodes with the log\_replica\_updates or log\_slave\_updates system variable enabled. This type of circular replication scheme for NDB Cluster, in which the line of replication (again indicated by the curved arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

**Note**

The NDB storage engine uses *idempotent* *execution* *mode*, which suppresses duplicate-key and other errors that otherwise break circular replication of NDB Cluster. This is equivalent to setting the global value of the system variable replica\_exec\_mode or slave\_exec\_mode to IDEMPOTENT, although this is not necessary in NDB Cluster replication, since NDB Cluster sets this variable automatically and ignores any attempts to set it explicitly.

**NDB** **Cluster** **replication** **and** **primary** **keys.** In the event of a node failure, errors in replication of NDB tables without primary keys can still occur, due to the possibility of duplicate rows being inserted in such cases. For this reason, it is highly recommended that all NDB tables being replicated have explicit primary keys.

**NDB** **Cluster** **Replication** **and** **Unique** **Keys.** In older versions of NDB Cluster, operations

that updated values of unique key columns of NDB tables could result in duplicate-key errors when replicated. This issue is solved for replication between NDB tables by deferring unique key checks until after all table row updates have been performed.

Deferring constraints in this way is currently supported only by NDB. Thus, updates of unique keys when replicating from NDB to a different storage engine such as InnoDB or MyISAM are still not supported.

The problem encountered when replicating without deferred checking of unique key updates can be illustrated using NDB table such as t, is created and populated on the source (and transmitted to a replica that does not support deferred unique key updates) as shown here:

CREATE TABLE t (

p INT PRIMARY KEY,

c INT,

UNIQUE KEY u (c)

) ENGINE NDB;

INSERT INTO t

VALUES (1,1), (2,2), (3,3), (4,4), (5,5);

The following UPDATE statement on t succeeds on the source, since the rows affected are processed in the order determined by the ORDER BY option, performed over the entire table:

UPDATE t SET c = c - 1 ORDER BY p;

The same statement fails with a duplicate key error or other constraint violation on the replica, because the ordering of the row updates is performed for one partition at a time, rather than for the table as a whole.

**Note**

Every NDB table is implicitly partitioned by key when it is created. See [Section 24.2.5, “KEY Partitioning”](#_bookmark37) , for more information.

**GTIDs** **not** **supported.** Replication using global transaction IDs is not compatible with the NDB storage engine, and is not supported. Enabling GTIDs is likely to cause NDB Cluster Replication to fail.

**Multithreaded** **replicas.** NDB Cluster does not support multithreaded replicas. This is because the replica may not be able to separate transactions occurring in one database from those in another if they are written within the same epoch. In addition, every transaction handled by the NDB storage engine involves at least two databases—the target database and the mysql system database—due to the requirement for updating the mysql.ndb\_apply\_status table (see [Section 23.7.4, “NDB](#_bookmark34) [Cluster Replication Schema and Tables”](#_bookmark34)). This in turn breaks the requirement for multithreading that the transaction is specific to a given database.

Prior to NDB 8.0.26, setting any system variables relating to multithreaded replicas

such as replica\_parallel\_workers or slave\_parallel\_workers, and replica\_checkpoint\_group or slave\_checkpoint\_group (or the equivalent mysqld startup options) was completely ignored, and had no effect.

In NDB 8.0.27 through NDB 8.0.32, replica\_parallel\_workers must be set to 0. In these versions, if this is set to any other value on startup, NDB changes it to 0, and writes a message to the mysqld server log file. This restriction is lifted in NDB 8.0.33.

**Restarting** **with** **--initial.** Restarting the cluster with the --initial option causes the sequence of GCI and epoch numbers to start over from 0. (This is generally true of NDB Cluster and not



limited to replication scenarios involving Cluster.) The MySQL servers involved in replication should in this case be restarted. After this, you should use the RESET MASTER and RESET REPLICA (prior to NDB 8.0.22, use RESET SLAVE) statements to clear the invalid ndb\_binlog\_index and ndb\_apply\_status tables, respectively.

**Replication** **from** **NDB** **to** **other** **storage** **engines.** It is possible to replicate an NDB table on the source to a table using a different storage engine on the replica, taking into account the restrictions listed here:

• Multi-source and circular replication are not supported (tables on both the source and the replica must use the NDB storage engine for this to work).

• Using a storage engine which does not perform binary logging for tables on the replica requires special handling.

• Use of a nontransactional storage engine for tables on the replica also requires special handling.

• The source mysqld must be started with --ndb-log-update-as-write=0 or --ndb-log- update-as-write=OFF.

The next few paragraphs provide additional information about each of the issues just described.

**Multiple** **sources** **not** **supported** **when** **replicating** **NDB** **to** **other** **storage** **engines.** For replication from NDB to a different storage engine, the relationship between the two databases must be one-to- one. This means that bidirectional or circular replication is not supported between NDB Cluster and other storage engines.

In addition, it is not possible to configure more than one replication channel when replicating between NDB and a different storage engine. (An NDB Cluster database *can* simultaneously replicate to multiple NDB Cluster databases.) If the source uses NDB tables, it is still possible to have more than one MySQL Server maintain a binary log of all changes, but for the replica to change sources (fail over), the new source-replica relationship must be explicitly defined on the replica.

**Replicating** **NDB** **tables** **to** **a** **storage** **engine** **that** **does** **not** **perform** **binary** **logging.** If you attempt to replicate from an NDB Cluster to a replica that uses a storage engine that does not handle its own binary logging, the replication process aborts with the error Binary logging not possible ... Statement cannot be written atomically since more than one engine involved and at least one engine is self-logging (Error 1595). It is possible to work around this issue in one of the following ways:

• **Turn** **off** **binary** **logging** **on** **the** **replica.** This can be accomplished by setting sql\_log\_bin =

0.

• **Change** **the** **storage** **engine** **used** **for** **the** **mysql.ndb\_apply\_status** **table.** Causing this table to use an engine that does not handle its own binary logging can also eliminate the conflict.

This can be done by issuing a statement such as ALTER TABLE mysql.ndb\_apply\_status ENGINE=MyISAM on the replica. It is safe to do this when using a storage engine other than NDB on the replica, since you do not need to worry about keeping multiple replicas synchronized.

• **Filter** **out** **changes** **to** **the** **mysql.ndb\_apply\_status** **table** **on** **the** **replica.** This can be done by starting the replica with --replicate-ignore-table=mysql.ndb\_apply\_status. If you need for other tables to be ignored by replication, you might wish to use an appropriate --replicate- wild-ignore-table option instead.

**Important**

You should *not* disable replication or binary logging of

mysql.ndb\_apply\_status or change the storage engine used for this table when replicating from one NDB Cluster to another. See [Replication and binary](#_bookmark38) [log filtering rules with replication between NDB Clusters](#_bookmark38), for details.

**Replication** **from** **NDB** **to** **a** **nontransactional** **storage** **engine.** When replicating from NDB to a nontransactional storage engine such as MyISAM, you may encounter unnecessary duplicate key errors when replicating INSERT ... ON DUPLICATE KEY UPDATE statements. You can suppress these by using --ndb-log-update-as-write=0, which forces updates to be logged as writes, rather than as updates.

**Replication** **and** **binary** **log** **filtering** **rules** **with** **replication** **between** **NDB** **Clusters.** If you are using any of the options --replicate-do-\*, --replicate-ignore-\*, --binlog-do-db, or -- binlog-ignore-db to filter databases or tables being replicated, you must take care not to block replication or binary logging of the mysql.ndb\_apply\_status, which is required for replication between NDB Clusters to operate properly. In particular, you must keep in mind the following:

1. Using --replicate-do-db=*db\_name* (and no other --replicate-do-\* or --replicate- ignore-\* options) means that *only* tables in database *db\_name* are replicated. In this case, you should also use --replicate-do-db=mysql, --binlog-do-db=mysql, or --replicate- do-table=mysql.ndb\_apply\_status to ensure that mysql.ndb\_apply\_status is populated on replicas.

Using --binlog-do-db=*db\_name* (and no other --binlog-do-db options) means that changes *only* to tables in database *db\_name* are written to the binary log. In this case, you should also use --replicate-do-db=mysql, --binlog-do-db=mysql, or --replicate-do- table=mysql.ndb\_apply\_status to ensure that mysql.ndb\_apply\_status is populated on replicas.

2. Using --replicate-ignore-db=mysql means that no tables in the mysql

database are replicated. In this case, you should also use --replicate-do- table=mysql.ndb\_apply\_status to ensure that mysql.ndb\_apply\_status is replicated.

Using --binlog-ignore-db=mysql means that no changes to tables in the mysql database are written to the binary log. In this case, you should also use --replicate-do- table=mysql.ndb\_apply\_status to ensure that mysql.ndb\_apply\_status is replicated.

You should also remember that each replication rule requires the following:

1. Its own --replicate-do-\* or --replicate-ignore-\* option, and that multiple rules

cannot be expressed in a single replication filtering option. For information about these rules, see Section 17. 1.6, “Replication and Binary Logging Options and Variables” .

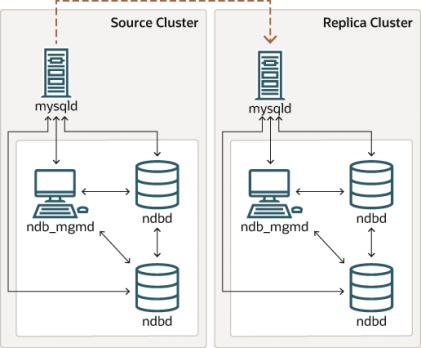
2. Its own --binlog-do-db or --binlog-ignore-db option, and that multiple rules cannot be expressed in a single binary log filtering option. For information about these rules, see Section 5.4.4, “The Binary Log” .

If you are replicating an NDB Cluster to a replica that uses a storage engine other than NDB, the considerations just given previously may not apply, as discussed elsewhere in this section.

**NDB** **Cluster** **Replication** **and** **IPv6.** Beginning with NDB 8.0.22, all types of NDB Cluster nodes support IPv6; this includes management nodes, data nodes, and API or SQL nodes.

Prior to NDB 8.0.22, the NDB API and MGM API (and thus data nodes and management nodes) do not support IPv6, although MySQL Servers—including those acting as SQL nodes in an NDB Cluster —can use IPv6 to contact other MySQL Servers. In versions of NDB Cluster prior to 8.0.22, you can replicate between clusters using IPv6 to connect the SQL nodes acting as source and replica as shown by the dotted arrow in the following diagram:

**Figure** **23.13** **Replication** **Between** **SQL** **Nodes** **Connected** **Using** **IPv6**



Prior to NDB 8.0.22, all connections originating *within* the NDB Cluster —represented in the preceding diagram by solid arrows—must use IPv4. In other words, all NDB Cluster data nodes, management servers, and management clients must be accessible from one another using IPv4. In addition, SQL nodes must use IPv4 to communicate with the cluster. In NDB 8.0.22 and later, these restrictions no longer apply; in addition, any applications written using the NDB and MGM APIs can be written and deployed assuming an IPv6-only environment.

**Attribute** **promotion** **and** **demotion.** NDB Cluster Replication includes support for attribute promotion and demotion. The implementation of the latter distinguishes between lossy and non-lossy type conversions, and their use on the replica can be controlled by setting the global value of the system variable replica\_type\_conversions (NDB 8.0.26 and later) or slave\_type\_conversions (prior to NDB 8.0.26).

For more information about attribute promotion and demotion in NDB Cluster, see Row-based replication: attribute promotion and demotion.

NDB, unlike InnoDB or MyISAM, does not write changes to virtual columns to the binary log; however, this has no detrimental effects on NDB Cluster Replication or replication between NDB and other storage engines. Changes to stored generated columns are logged.

**23.7.4** **NDB** **Cluster** **Replication** **Schema** **and** **Tables**

• [ndb\_apply\_status Table](#_bookmark39)

• [ndb\_binlog\_index Table](#_bookmark40)

• [ndb\_replication Table](#_bookmark41)

Replication in NDB Cluster makes use of a number of dedicated tables in the mysql database on each MySQL Server instance acting as an SQL node in both the cluster being replicated and in the replica. This is true regardless of whether the replica is a single server or a cluster.

The ndb\_binlog\_index and ndb\_apply\_status tables are created in the mysql database. They should not be explicitly replicated by the user. User intervention is normally not required to create or maintain either of these tables, since both are maintained by the NDB binary log (binlog) injector thread.

This keeps the source mysqld process updated to changes performed by the NDB storage engine. The NDB *binlog* *injector* *thread* receives events directly from the NDB storage engine. The NDB injector is responsible for capturing all the data events within the cluster, and ensures that all events which change, insert, or delete data are recorded in the ndb\_binlog\_index table. The replica I/O (receiver) thread transfers the events from the source's binary log to the replica's relay log.

The ndb\_replication table must be created manually. This table can be updated by the user to perform filtering by database or table. See [ndb\_replication Table](#_bookmark41), for more information. ndb\_replication is also used in NDB Replication conflict detection and resolution for conflict resolution control; see [Conflict Resolution Control](#_bookmark42).

Even though ndb\_binlog\_index and ndb\_apply\_status are created and maintained automatically, it is advisable to check for the existence and integrity of these tables as an initial step in preparing an NDB Cluster for replication. It is possible to view event data recorded in the binary log by querying the mysql.ndb\_binlog\_index table directly on the source. This can be also be accomplished using the SHOW BINLOG EVENTS statement on either the source or replica SQL node. (See Section 13.7.7.2, “SHOW BINLOG EVENTS Statement” .)

You can also obtain useful information from the output of SHOW ENGINE NDB STATUS.

**Note**

When performing schema changes on NDB tables, applications should wait until the ALTER TABLE statement has returned in the MySQL client connection that issued the statement before attempting to use the updated definition of the table.

**ndb\_apply\_status** **Table**

ndb\_apply\_status is used to keep a record of the operations that have been replicated from the source to the replica. If the ndb\_apply\_status table does not exist on the replica, ndb\_restore re- creates it.

Unlike the case with ndb\_binlog\_index, the data in this table is not specific to any one SQL node in the (replica) cluster, and so ndb\_apply\_status can use the NDBCLUSTER storage engine, as shown here:

CREATE TABLE `ndb\_apply\_status` (

`server\_id` INT(10) UNSIGNED NOT NULL,

`epoch` BIGINT(20) UNSIGNED NOT NULL,

`log\_name` VARCHAR(255) CHARACTER SET latin1 COLLATE latin1\_bin NOT NULL,

`start\_pos` BIGINT(20) UNSIGNED NOT NULL,

`end\_pos` BIGINT(20) UNSIGNED NOT NULL,

PRIMARY KEY (`server\_id`) USING HASH

) ENGINE=NDBCLUSTER DEFAULT CHARSET=latin1;

The ndb\_apply\_status table is populated only on replicas, which means that, on the source, this table never contains any rows; thus, there is no need to allot any DataMemory to ndb\_apply\_status there.

Because this table is populated from data originating on the source, it should be allowed to replicate; any replication filtering or binary log filtering rules that inadvertently prevent the replica from updating ndb\_apply\_status, or that prevent the source from writing into the binary log may prevent replication between clusters from operating properly. For more information about potential problems arising from such filtering rules, see [Replication and binary log filtering rules with replication between](#_bookmark38) [NDB Clusters](#_bookmark38).

It is possible to delete this table, but this is not recommended. Deleting it puts all SQL nodes in read-only mode; in NDB 8.0.24 and later, NDB detects that this table has been dropped, and re-creates it, after which it is possible once again to perform updates. Dropping and re-creating

ndb\_apply\_status creates a gap event in the binary log; the gap event causes replica SQL nodes to



stop applying changes from the source until the replication channel is restarted. Prior to NDB 8.0.24, it was necessary in such cases to restart all SQL nodes to bring them out of read-only mode, and then to re-create ndb\_apply\_status manually.

0 in the epoch column of this table indicates a transaction originating from a storage engine other than NDB.

ndb\_apply\_status is used to record which epoch transactions have been replicated and applied to a replica cluster from an upstream source. This information is captured in an NDB online backup, but (by design) it is not restored by ndb\_restore. In some cases, it can be helpful to restore this information for use in new setups; beginning with NDB 8.0.29, you can do this by invoking ndb\_restore with the --with-apply-status option. See the description of the option for more information.

**ndb\_binlog\_index** **Table**

NDB Cluster Replication uses the ndb\_binlog\_index table for storing the binary log's indexing data. Since this table is local to each MySQL server and does not participate in clustering, it uses the InnoDB storage engine. This means that it must be created separately on each mysqld participating in the source cluster. (The binary log itself contains updates from all MySQL servers in the cluster.) This table is defined as follows:

CREATE TABLE `ndb\_binlog\_index` (

`Position` BIGINT(20) UNSIGNED NOT NULL,

`File` VARCHAR(255) NOT NULL,

`epoch` BIGINT(20) UNSIGNED NOT NULL,

`inserts` INT(10) UNSIGNED NOT NULL,

`updates` INT(10) UNSIGNED NOT NULL,

`deletes` INT(10) UNSIGNED NOT NULL,

`schemaops` INT(10) UNSIGNED NOT NULL,

`orig\_server\_id` INT(10) UNSIGNED NOT NULL,

`orig\_epoch` BIGINT(20) UNSIGNED NOT NULL,

`gci` INT(10) UNSIGNED NOT NULL,

`next\_position` bigint(20) unsigned NOT NULL,

`next\_file` varchar(255) NOT NULL,

PRIMARY KEY (`epoch`,`orig\_server\_id`,`orig\_epoch`)

) ENGINE=InnoDB DEFAULT CHARSET=latin1;

**Note**

If you are upgrading from an older release (prior to NDB 7.5.2), perform the MySQL upgrade procedure and ensure that the system tables are upgraded by starting the MySQL server with the --upgrade=FORCE option. The system table upgrade causes an ALTER TABLE ... ENGINE=INNODB statement to be executed for this table. Use of the MyISAM storage engine for this table continues to be supported for backward compatibility.

ndb\_binlog\_index may require additional disk space after being converted to InnoDB. If this becomes an issue, you may be able to conserve space by using an InnoDB tablespace for this table, changing its ROW\_FORMAT to COMPRESSED, or both. For more information, see Section 13.1.21, “CREATE TABLESPACE Statement” , and Section 13.1.20, “CREATE TABLE Statement” , as well as Section 15.6.3, “Tablespaces” .

The size of the ndb\_binlog\_index table is dependent on the number of epochs per binary log file and the number of binary log files. The number of epochs per binary log file normally depends on the amount of binary log generated per epoch and the size of the binary log file, with smaller epochs resulting in more epochs per file. You should be aware that empty epochs produce inserts to the ndb\_binlog\_index table, even when the --ndb-log-empty-epochs option is OFF, meaning that the number of entries per file depends on the length of time that the file is in use; this relationship can be represented by the formula shown here:

[number of epochs per file] = [time spent per file] / TimeBetweenEpochs

A busy NDB Cluster writes to the binary log regularly and presumably rotates binary log files more quickly than a quiet one. This means that a “quiet” NDB Cluster with --ndb-log-empty-epochs=ON can actually have a much higher number of ndb\_binlog\_index rows per file than one with a great deal of activity.

When mysqld is started with the --ndb-log-orig option, the orig\_server\_id and orig\_epoch columns store, respectively, the ID of the server on which the event originated and the epoch in which the event took place on the originating server, which is useful in NDB Cluster replication setups employing multiple sources. The SELECT statement used to find the closest binary log position to the highest applied epoch on the replica in a multi-source setup (see [Section 23.7.10, “NDB Cluster](#_bookmark43) [Replication: Bidirectional and Circular Replication”](#_bookmark43)) employs these two columns, which are not indexed. This can lead to performance issues when trying to fail over, since the query must perform a table scan, especially when the source has been running with --ndb-log-empty-epochs=ON. You can improve multi-source failover times by adding an index to these columns, as shown here:

ALTER TABLE mysql.ndb\_binlog\_index

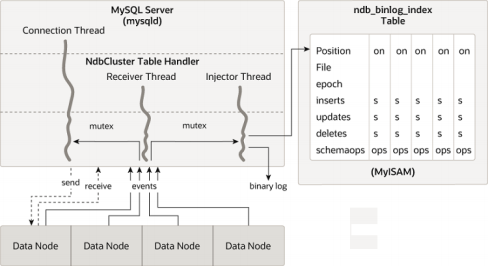
ADD INDEX orig\_lookup USING BTREE (orig\_server\_id, orig\_epoch);

Adding this index provides no benefit when replicating from a single source to a single replica, since the query used to get the binary log position in such cases makes no use of orig\_server\_id or orig\_epoch.

See [Section 23.7.8, “Implementing Failover with NDB Cluster Replication”](#_bookmark35) , for more information about using the next\_position and next\_file columns.

The following figure shows the relationship of the NDB Cluster replication source server, its binary log injector thread, and the mysql.ndb\_binlog\_index table.

**Figure** **23.14** **The** **Replication** **Source** **Cluster**



**ndb\_replication** **Table**

The ndb\_replication table is used to control binary logging and conflict resolution, and acts on a per-table basis. Each row in this table corresponds to a table being replicated, determines how to log changes to the table and, if a conflict resolution function is specified, and determines how to resolve conflicts for that table.

Unlike the ndb\_apply\_status and ndb\_replication tables, the ndb\_replication table must be created manually, using the SQL statement shown here:

CREATE TABLE mysql.ndb\_replication (

db VARBINARY(63),

table\_name VARBINARY(63),

server\_id INT UNSIGNED,

binlog\_type INT UNSIGNED,

conflict\_fn VARBINARY(128),

PRIMARY KEY USING HASH (db, table\_name, server\_id)

) ENGINE=NDB

PARTITION BY KEY(db,table\_name);

The columns of this table are listed here, with descriptions:

• db column

The name of the database containing the table to be replicated.

You may employ either or both of the wildcards \_ and % as part of the database name. (See [Matching with wildcards](#_bookmark44), later in this section.)

• table\_name column

The name of the table to be replicated.

The table name may include either or both of the wildcards \_ and %. See [Matching with wildcards](#_bookmark44), later in this section.

• server\_id column

The unique server ID of the MySQL instance (SQL node) where the table resides.

0 in this column acts like a wildcard equivalent to %, and matches any server ID. (See [Matching with](#_bookmark44) [wildcards](#_bookmark44), later in this section.)

• binlog\_type column

The type of binary logging to be employed. See text for values and descriptions.

• conflict\_fn column

The conflict resolution function to be applied; one of [NDB$OLD()](#_bookmark45), [NDB$MAX()](#_bookmark46), [NDB](#_bookmark47) [$MAX\_DELETE\_WIN()](#_bookmark47), [NDB$EPOCH()](#_bookmark48), [NDB$EPOCH\_TRANS()](#_bookmark49), [NDB$EPOCH2()](#_bookmark50), [NDB](#_bookmark51) [$EPOCH2\_TRANS()](#_bookmark51); NULL indicates that conflict resolution is not used for this table. NDB 8.0.30 and later supports two additional conflict resolution functions [NDB$MAX\_INS()](#_bookmark52) and [NDB](#_bookmark53) [$MAX\_DEL\_WIN\_INS()](#_bookmark53).

See [Conflict Resolution Functions](#_bookmark54), for more information about these functions and their uses in NDB Replication conflict resolution.

Some conflict resolution functions (NDB$OLD(), NDB$EPOCH(), NDB$EPOCH\_TRANS()) require the use of one or more user-created exceptions tables. See [Conflict Resolution Exceptions Table](#_bookmark55).

To enable conflict resolution with NDB Replication, it is necessary to create and populate this table with control information on the SQL node or nodes on which the conflict should be resolved. Depending on the conflict resolution type and method to be employed, this may be the source, the replica, or both servers. In a simple source-replica setup where data can also be changed locally on the replica this is typically the replica. In a more complex replication scheme, such as bidirectional replication, this is usually all of the sources involved. See [Section 23.7.12, “NDB Cluster Replication Conflict Resolution”](#_bookmark56) , for more information.

The ndb\_replication table allows table-level control over binary logging outside the scope of conflict resolution, in which case conflict\_fn is specified as NULL, while the remaining column values are used to control binary logging for a given table or set of tables matching a wildcard expression. By setting the proper value for the binlog\_type column, you can make logging for a given table or tables use a desired binary log format, or disabling binary logging altogether. Possible values for this column, with values and descriptions, are shown in the following table:

**Table** **23.70** **binlog\_type** **values,** **with** **values** **and** **descriptions**

|  |  |
| --- | --- |
| **Value** | **Description** |
| 0 | Use server default |
| 1 | Do not log this table in the binary log (same effect as sql\_log\_bin = 0, but applies to one or more specified tables only) |
| 2 | Log updated attributes only; log these as WRITE\_ROW events |
| 3 | Log full row, even if not updated (MySQL server default behavior) |
| 6 | Use updated attributes, even if values are unchanged |
| 7 | Log full row, even if no values are changed; log updates as UPDATE\_ROW events |
| 8 | Log update as UPDATE\_ROW; log only primary key columns in before image, and only updated columns in after image (same effect as --ndb-log-update- minimal, but applies to one or more specified tables only) |
| 9 | Log update as UPDATE\_ROW; log only primary key columns in before image, and all columns other than primary key columns in after image |

**Note**

binlog\_type values 4 and 5 are not used, and so are omitted from the table just shown, as well as from the next table.

Several binlog\_type values are equivalent to various combinations of the mysqld logging options --ndb-log-updated-only, --ndb-log-update-as-write, and --ndb-log-update- minimal, as shown in the following table:

**Table** **23.71** **binlog\_type** **values** **with** **equivalent** **combinations** **of** **NDB** **logging** **options**

|  |  |  |  |
| --- | --- | --- | --- |
| **Value** | **--ndb-log-updated-only**  **Value** | **--ndb-log-update-as-** **write** **Value** | **--ndb-log-update-**  **minimal** **Value** |
| 0 | -- | -- | -- |
| 1 | -- | -- | -- |
| 2 | ON | ON | OFF |
| 3 | OFF | ON | OFF |
| 6 | ON | OFF | OFF |
| 7 | OFF | OFF | OFF |
| 8 | ON | OFF | ON |
| 9 | OFF | OFF | ON |

Binary logging can be set to different formats for different tables by inserting rows into the ndb\_replication table using the appropriate db, table\_name, and binlog\_type column values. The internal integer value shown in the preceding table should be used when setting the binary logging format. The following two statements set binary logging to logging of full rows ( value 3) for table test.a, and to logging of updates only ( value 2) for table test.b:

# Table test.a: Log full rows

INSERT INTO mysql.ndb\_replication VALUES("test", "a", 0, 3, NULL);

# Table test.b: log updates only

INSERT INTO mysql.ndb\_replication VALUES("test", "b", 0, 2, NULL);

To disable logging for one or more tables, use 1 for binlog\_type, as shown here:

# Disable binary logging for table test.t1

INSERT INTO mysql.ndb\_replication VALUES("test", "t1", 0, 1, NULL);

# Disable binary logging for any table in 'test' whose name begins with 't'

INSERT INTO mysql.ndb\_replication VALUES("test", "t%", 0, 1, NULL);

Disabling logging for a given table is the equivalent of setting sql\_log\_bin = 0, except that it applies to one or more tables individually. If an SQL node is not performing binary logging for a given table, it is not sent the row change events for those tables. This means that it is not receiving all changes and discarding some, but rather it is not subscribing to these changes.

Disabling logging can be useful for a number of reasons, including those listed here:

• Not sending changes across the network generally saves bandwidth, buffering, and CPU resources.

• Not logging changes to tables with very frequent updates but whose value is not great is a good fit for transient data (such as session data) that may be relatively unimportant in the event of a complete failure of the cluster.

• Using a session variable (or sql\_log\_bin) and application code, it is also possible to log (or not to log) certain SQL statements or types of SQL statements; for example, it may be desirable in some cases not to record DDL statements on one or more tables.

• Splitting replication streams into two (or more) binary logs can be done for reasons of performance, a need to replicate different databases to different places, use of different binary logging types for different databases, and so on.

**Matching** **with** **wildcards.** In order not to make it necessary to insert a row in the ndb\_replication table for each and every combination of database, table, and SQL node in your replication setup, NDB supports wildcard matching on the this table's db, table\_name, and server\_id columns. Database and table names used in, respectively, db and table\_name may contain either or both of the following wildcards:

• \_ (underscore character): matches zero or more characters

• % (percent sign): matches a single character

(These are the same wildcards as supported by the MySQL LIKE operator.)

The server\_id column supports 0 as a wildcard equivalent to \_ (matches anything). This is used in the examples shown previously.

A given row in the ndb\_replication table can use wildcards to match any of the database name, table name, and server ID in any combination. Where there are multiple potential matches in the table, the best match is chosen, according to the table shown here, where *W* represents a wildcard match, *E* an exact match, and the greater the value in the *Quality* column, the better the match:

**Table** **23.72** **Weights** **of** **different** **combinations** **of** **wildcard** **and** **exact** **matches** **on** **columns** **in** **the** **mysql.ndb\_replication** **table**

|  |  |  |  |
| --- | --- | --- | --- |
| **db** | **table\_name** | **server\_id** | **Quality** |
| W | W | W | 1 |
| W | W | E | 2 |
| W | E | W | 3 |



|  |  |  |  |
| --- | --- | --- | --- |
| **db** | **table\_name** | **server\_id** | **Quality** |
| W | E | E | 4 |
| E | W | W | 5 |
| E | W | E | 6 |
| E | E | W | 7 |
| E | E | E | 8 |

Thus, an exact match on database name, table name, and server ID is considered best (strongest), while the weakest (worst) match is a wildcard match on all three columns. Only the strength of the match is considered when choosing which rule to apply; the order in which the rows occur in the table has no effect on this determination.

**Logging** **Full** **or** **Partial** **Rows.** There are two basic methods of logging rows, as determined by the setting of the --ndb-log-updated-only option for mysqld:

• Log complete rows (option set to ON)

• Log only column data that has been updated—that is, column data whose value has been set, regardless of whether or not this value was actually changed. This is the default behavior (option set to OFF).

It is usually sufficient—and more efficient—to log updated columns only; however, if you need to log full rows, you can do so by setting --ndb-log-updated-only to 0 or OFF.

**Logging** **Changed** **Data** **as** **Updates.** The setting of the MySQL Server's --ndb-log-update- as-write option determines whether logging is performed with or without the “before” image.

Because conflict resolution for updates and delete operations is done in the MySQL Server's update handler, it is necessary to control the logging performed by the replication source such that updates are updates and not writes; that is, such that updates are treated as changes in existing rows rather than the writing of new rows, even though these replace existing rows.

This option is turned on by default; in other words, updates are treated as writes. That is, updates are by default written as write\_row events in the binary log, rather than as update\_row events.

To disable the option, start the source mysqld with --ndb-log-update-as-write=0 or --ndb- log-update-as-write=OFF. You must do this when replicating from NDB tables to tables using a different storage engine; see [Replication from NDB to other storage engines](#_bookmark29), and [Replication from](#_bookmark31) [NDB to a nontransactional storage engine](#_bookmark31), for more information.

**Important**

(*NDB* *8.0.30* *and* *later*:) For insert conflict resolution using NDB$MAX\_INS() or NDB$MAX\_DEL\_WIN\_INS(), an SQL node (that is, a mysqld process) can record row updates on the source cluster as WRITE\_ROW events with the -- ndb-log-update-as-write option enabled for idempotency and optimal size. This works for these algorithms since they both map a WRITE\_ROW event to an insert or update depending on whether the row already exists, and the required metadata (the “after” image for the timestamp column) is present in the “WRITE\_ROW” event.

**23.7.5** **Preparing** **the** **NDB** **Cluster** **for** **Replication**

Preparing the NDB Cluster for replication consists of the following steps:

1. Check all MySQL servers for version compatibility (see [Section 23.7.2, “General Requirements for](#_bookmark32) [NDB Cluster Replication”](#_bookmark32)).

2. Create a replication account on the source Cluster with the appropriate privileges, using the following two SQL statements:

mysql*S*> **CREATE** **USER** **'*replica\_user*'@'*replica\_host*** **'**

-> **IDENTIFIED** **BY** **'*replica\_password*';**

mysql*S*> **GRANT** **REPLICATION** **SLAVE** **ON** **\*** **.\***

-> **TO** **'*replica\_user*'@'*replica\_host*** **';**

In the previous statement, *replica\_user* is the replication account user name, *replica\_host* is the host name or IP address of the replica, and *replica\_password* is the password to assign to this account.

For example, to create a replica user account with the name myreplica, logging in from the host named replica-host, and using the password 53cr37, use the following CREATE USER and GRANT statements:

mysql*S*> **CREATE** **USER** **'myreplica'@'replica-host'**

-> **IDENTIFIED** **BY** **'53cr37';**

mysql*S*> **GRANT** **REPLICATION** **SLAVE** **ON** **\*** **.\***

-> **TO** **'myreplica'@'replica-host';**

For security reasons, it is preferable to use a unique user account—not employed for any other purpose—for the replication account.

3. Set up the replica to use the source. Using the mysql client, this can be accomplished with the CHANGE REPLICATION SOURCE TO statement (beginning with NDB 8.0.23) or CHANGE MASTER TO statement (prior to NDB 8.0.23):

mysql*R*> **CHANGE** **MASTER** **TO**

-> **MASTER\_HOST='*source\_host*** **',**

-> **MASTER\_PORT=*source\_port*** **,**

-> **MASTER\_USER='*replica\_user*',**

-> **MASTER\_PASSWORD='*replica\_password*';**

Beginning with NDB 8.0.23, you can also use the following statement:

mysql*R*> **CHANGE** **REPLICATION** **SOURCE** **TO**

-> **SOURCE\_HOST='*source\_host*** **',**

-> **SOURCE\_PORT=*source\_port*** **,**

-> **SOURCE\_USER='*replica\_user*',**

-> **SOURCE\_PASSWORD='*replica\_password*';**

In the previous statement, *source\_host* is the host name or IP address of the replication source, *source\_port* is the port for the replica to use when connecting to the source, *replica\_user* is the user name set up for the replica on the source, and *replica\_password* is the password set for that user account in the previous step.

For example, to tell the replica to use the MySQL server whose host name is rep-source with the replication account created in the previous step, use the following statement:

mysql*R*> **CHANGE** **MASTER** **TO**

-> **MASTER\_HOST='rep-source',**

-> **MASTER\_PORT=3306,**

-> **MASTER\_USER='myreplica',**

-> **MASTER\_PASSWORD='53cr37';**

Beginning with NDB 8.0.23, you can also use the following statement:

mysql*R*> **CHANGE** **REPLICATION** **SOURCE** **TO**

-> **SOURCE\_HOST='rep-source',**

-> **SOURCE\_PORT=3306,**

-> **SOURCE\_USER='myreplica',**

-> **SOURCE\_PASSWORD='53cr37';**

For a complete list of options that can be used with this statement, see Section 13.4.2.1, “CHANGE

MASTER TO Statement” .

To provide replication backup capability, you also need to add an --ndb-connectstring option to the replica's my.cnf file prior to starting the replication process. See [Section 23.7.9, “NDB](#_bookmark58) [Cluster Backups With NDB Cluster Replication”](#_bookmark58) , for details.

For additional options that can be set in my.cnf for replicas, see Section 17.1.6, “Replication and Binary Logging Options and Variables” .

4. If the source cluster is already in use, you can create a backup of the source and load this onto the replica to cut down on the amount of time required for the replica to synchronize itself with the source. If the replica is also running NDB Cluster, this can be accomplished using the backup and restore procedure described in [Section 23.7.9, “NDB Cluster Backups With NDB Cluster](#_bookmark58) [Replication”](#_bookmark58) .

ndb-connectstring=*management\_host* [:*port*]

In the event that you are *not* using NDB Cluster on the replica, you can create a backup with this command on the source:

shell*S*> **mysqldump** **--master-data=1**

Then import the resulting data dump onto the replica by copying the dump file over to it. After this, you can use the mysql client to import the data from the dumpfile into the replica database as shown here, where *dump\_file* is the name of the file that was generated using mysqldump on the source, and *db\_name* is the name of the database to be replicated:

shell*R*> **mysql** **-u** **root** **-p** ***db\_name*** **<** ***dump\_file***

For a complete list of options to use with mysqldump, see Section 4.5.4, “mysqldump — A Database Backup Program” .

**Note**

If you copy the data to the replica in this fashion, make sure that you stop the replica from trying to connect to the source to begin replicating before all the data has been loaded. You can do this by starting the replica with the --skip-slave-start option on the command line, by including skip- slave-start in the replica's my.cnf file, or beginning with NDB 8.0.24, by setting the skip\_slave\_start system variable. Beginning with NDB 8.0.26, use --skip-replica-start or skip\_replica\_start instead. Once the data loading has completed, follow the additional steps outlined in the next two sections.

5. Ensure that each MySQL server acting as a replication source is assigned a unique server ID, and has binary logging enabled, using the row-based format. (See Section 17.2.1, “Replication Formats” .) In addition, we strongly recommend enabling the replica\_allow\_batching system variable (NDB 8.0.26 and later; prior to NDB 8.0.26, use slave\_allow\_batching). Beginning with NDB 8.0.30, this is enabled by default.

If you are using a release of NDB Cluster prior to NDB 8.0.30, you should also consider increasing the values used with the --ndb-batch-size and --ndb-blob-write-batch-bytes options as well. In NDB 8.0.30 and later, use --ndb-replica-batch-size to set the batch size used for writes on the replica instead of --ndb-batch-size, and --ndb-replica-blob-write- batch-bytes rather than --ndb-blob-write-batch-bytes to determine the batch size used by the replication applier for writing blob data. All of these options can be set either in the source server's my.cnf file, or on the command line when starting the source mysqld process. See [Section 23.7.6, “Starting NDB Cluster Replication (Single Replication Channel)”](#_bookmark33) , for more information.



**23.7.6** **Starting** **NDB** **Cluster** **Replication** **(Single** **Replication** **Channel)**

This section outlines the procedure for starting NDB Cluster replication using a single replication channel.

1. Start the MySQL replication source server by issuing this command, where *id* is this server's unique ID (see [Section 23.7.2, “General Requirements for NDB Cluster Replication”](#_bookmark32)):

shell*S*> **mysqld** **--ndbcluster** **--server-id=*id*** **\**

**--log-bin** **--ndb-log-bin** **&**

This starts the server's mysqld process with binary logging enabled using the proper logging format. It is also necessary in NDB 8.0 to enable logging of updates to NDB tables explicitly, using the --ndb-log-bin option; this is a change from previous versions of NDB Cluster, in which this option was enabled by default.

**Note**

You can also start the source with --binlog-format=MIXED, in which case row-based replication is used automatically when replicating between clusters. Statement-based binary logging is not supported for NDB Cluster Replication (see [Section 23.7.2, “General Requirements for NDB Cluster](#_bookmark32) [Replication”](#_bookmark32)).

2. Start the MySQL replica server as shown here:

shell*R*> **mysqld** **--ndbcluster** **--server-id=*id*** **&**

In the command just shown, *id* is the replica server's unique ID. It is not necessary to enable logging on the replica.

**Note**

Unless you want replication to begin immediately, delay the start of the replication threads until the appropriate START REPLICA statement has been issued, as explained in Step 4 below. You can do this by starting the replica with the --skip-slave-start option on the command line, by including skip-slave-start in the replica's my.cnf file, or in NDB 8.0.24 and later, by setting the skip\_slave\_start system variable. In NDB 8.0.26 and later, use --skip-replica-start and skip\_replica\_start.

3. It is necessary to synchronize the replica server with the source server's replication binary log. If binary logging has not previously been running on the source, run the following statement on the replica:

mysql*R*> **CHANGE** **MASTER** **TO**

-> **MASTER\_LOG\_FILE='',**

-> **MASTER\_LOG\_POS=4;**

Beginning with NDB 8.0.23, you can also use the following statement:

mysql*R*> **CHANGE** **REPLICATION** **SOURCE** **TO**

-> **SOURCE\_LOG\_FILE='',**

-> **SOURCE\_LOG\_POS=4;**

This instructs the replica to begin reading the source server's binary log from the log's starting point.

Otherwise—that is, if you are loading data from the source using a backup—see [Section 23.7.8,](#_bookmark35) [“Implementing Failover with NDB Cluster Replication”](#_bookmark35) , for information on how to obtain the correct values to use for SOURCE\_LOG\_FILE | MASTER\_LOG\_FILE and SOURCE\_LOG\_POS | MASTER\_LOG\_POS in such cases.

4. Finally, instruct the replica to begin applying replication by issuing this command from the mysql client on the replica:

mysql*R*> **START** **SLAVE;**

In NDB 8.0.22 and later, you can also use the following statement:

mysql*R*> **START** **REPLICA;**

This also initiates the transmission of data and changes from the source to the replica.

It is also possible to use two replication channels, in a manner similar to the procedure described in the next section; the differences between this and using a single replication channel are covered in [Section 23.7.7, “Using Two Replication Channels for NDB Cluster Replication”](#_bookmark36) .

It is also possible to improve cluster replication performance by enabling *batched* *updates*. This can be accomplished by setting the system variable replica\_allow\_batching (NDB 8.0.26 and later) or slave\_allow\_batching (prior to NDB 8.0.26) on the replicas' mysqld processes. Normally, updates are applied as soon as they are received. However, the use of batching causes updates to be applied in batches of 32 KB each; this can result in higher throughput and less CPU usage, particularly where individual updates are relatively small.

**Note**

Batching works on a per-epoch basis; updates belonging to more than one transaction can be sent as part of the same batch.

All outstanding updates are applied when the end of an epoch is reached, even if the updates total less than 32 KB.

Batching can be turned on and off at runtime. To activate it at runtime, you can use either of these two statements:

SET GLOBAL slave\_allow\_batching = 1;

SET GLOBAL slave\_allow\_batching = ON;

Beginning with NDB 8.0.26, you can (and should) use one of the following statements:

SET GLOBAL replica\_allow\_batching = 1;

SET GLOBAL replica\_allow\_batching = ON;

If a particular batch causes problems (such as a statement whose effects do not appear to be replicated correctly), batching can be deactivated using either of the following statements:

SET GLOBAL slave\_allow\_batching = 0;

SET GLOBAL slave\_allow\_batching = OFF;

Beginning with NDB 8.0.26, you can (and should) use one of the following statements instead:

SET GLOBAL replica\_allow\_batching = 0;

SET GLOBAL replica\_allow\_batching = OFF;

You can check whether batching is currently being used by means of an appropriate SHOW VARIABLES statement, like this one:

mysql> **SHOW** **VARIABLES** **LIKE** **'slave%';**

In ŃDB 8.0.26 and later, use the following statement:

mysql> **SHOW** **VARIABLES** **LIKE** **'replica%';**

**23.7.7** **Using** **Two** **Replication** **Channels** **for** **NDB** **Cluster** **Replication**



**--log-bin** **&**

**--log-bin** **&**

**--skip-slave-start** **&**

**--skip-slave-start** **&**

In a more complete example scenario, we envision two replication channels to provide redundancy and thereby guard against possible failure of a single replication channel. This requires a total of four replication servers, two source servers on the source cluster and two replica servers on the replica cluster. For purposes of the discussion that follows, we assume that unique identifiers are assigned as shown here:

**Table** **23.73** **NDB** **Cluster** **replication** **servers** **described** **in** **the** **text**

|  |  |
| --- | --- |
| **Server** **ID** | **Description** |
| 1 | Source - primary replication channel (*S*) |
| 2 | Source - secondary replication channel (*S'*) |
| 3 | Replica - primary replication channel (*R*) |
| 4 | replica - secondary replication channel (*R'*) |

Setting up replication with two channels is not radically different from setting up a single replication channel. First, the mysqld processes for the primary and secondary replication source servers must be started, followed by those for the primary and secondary replicas. The replication processes can be initiated by issuing the START REPLICA statement on each of the replicas. The commands and the order in which they need to be issued are shown here:

1. Start the primary replication source:

shell*S*> **mysqld** **--ndbcluster** **--server-id=1** **\**

2. Start the secondary replication source:

shell*S'*> **mysqld** **--ndbcluster** **--server-id=2** **\**

3. Start the primary replica server:

shell*R*> **mysqld** **--ndbcluster** **--server-id=3** **\**

4. Start the secondary replica server:

shell*R'*> **mysqld** **--ndbcluster** **--server-id=4** **\**

5. Finally, initiate replication on the primary channel by executing the START REPLICA statement on the primary replica as shown here:

mysql*R*> **START** **SLAVE;**

Beginning with NDB 8.0.22, you can also use the following statement:

mysql*R*> **START** **REPLICA;**

**Warning**

Only the primary channel must be started at this point. The secondary replication channel needs to be started only in the event that the primary replication channel fails, as described in [Section 23.7.8, “Implementing](#_bookmark35) [Failover with NDB Cluster Replication”](#_bookmark35) . Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replicas.

As mentioned previously, it is not necessary to enable binary logging on the replicas.

**23.7.8** **Implementing** **Failover** **with** **NDB** **Cluster** **Replication**

In the event that the primary Cluster replication process fails, it is possible to switch over to the secondary replication channel. The following procedure describes the steps required to accomplish this.

1. Obtain the time of the most recent global checkpoint (GCP). That is, you need to determine the most recent epoch from the ndb\_apply\_status table on the replica cluster, which can be found using the following query:

mysql*R'*> **SELECT** **@latest:=MAX(epoch)**

-> **FROM** **mysql** **.ndb\_apply\_status;**

In a circular replication topology, with a source and a replica running on each host, when you are using ndb\_log\_apply\_status=1, NDB Cluster epochs are written in the replicas' binary logs. This means that the ndb\_apply\_status table contains information for the replica on this host as well as for any other host which acts as a replica of the replication source server running on this host.

In this case, you need to determine the latest epoch on this replica to the exclusion of

any epochs from any other replicas in this replica's binary log that were not listed in the IGNORE\_SERVER\_IDS options of the CHANGE REPLICATION SOURCE TO | CHANGE MASTER TO statement used to set up this replica. The reason for excluding such epochs is that rows in the mysql.ndb\_apply\_status table whose server IDs have a match in the IGNORE\_SERVER\_IDS list from the CHANGE REPLICATION SOURCE TO | CHANGE MASTER TO statement used to prepare this replicas's source are also considered to be from local servers, in addition to those having the replica's own server ID. You can retrieve this list as Replicate\_Ignore\_Server\_Ids from the output of SHOW REPLICA STATUS. We assume that you have obtained this list and are substituting it for *ignore\_server\_ids* in the query shown here, which like the previous version of the query, selects the greatest epoch into a variable named @latest:

mysql*R'*> **SELECT** **@latest:=MAX(epoch)**

->

**FROM** **mysql.ndb\_apply\_status**

->

**WHERE** **server\_id** **NOT** **IN** **(*ignore\_server\_ids*);**

In some cases, it may be simpler or more efficient (or both) to use a list of the server IDs to be included and server\_id IN *server\_id\_list* in the WHERE condition of the preceding query.

2. Using the information obtained from the query shown in Step 1, obtain the corresponding records from the ndb\_binlog\_index table on the source cluster.

You can use the following query to obtain the needed records from the ndb\_binlog\_index table on the source:

mysql*S'*> **SELECT**

->

**@file:=SUBSTRING\_INDEX(next\_file,** **'/',** **-1),**

->

**@pos:=next\_position**

-> **FROM** **mysql** **.ndb\_binlog\_index**

-> **WHERE** **epoch** **=** **@latest;**

These are the records saved on the source since the failure of the primary replication channel. We have employed a user variable @latest here to represent the value obtained in Step 1. Of course, it is not possible for one mysqld instance to access user variables set on another server instance directly. These values must be “plugged in” to the second query manually or by an application.

**Important**

You must ensure that the replica mysqld is started with --slave-skip- errors=ddl\_exist\_errors before executing START REPLICA. Otherwise, replication may stop with duplicate DDL errors.

3. Now it is possible to synchronize the secondary channel by running the following query on the secondary replica server:

mysql*R'*> **CHANGE** **MASTER** **TO**



|  |  |
| --- | --- |
| ->  -> | **MASTER\_LOG\_FILE='@file',**  **MASTER\_LOG\_POS=@pos;** |

In NDB 8.0.23 and later, you can also use the statement shown here:

mysql*R'*> **CHANGE** **REPLICATION** **SOURCE** **TO**

|  |  |
| --- | --- |
| ->  -> | **SOURCE\_LOG\_FILE='@file',**  **SOURCE\_LOG\_POS=@pos;** |

Again we have employed user variables (in this case @file and @pos) to represent the values obtained in Step 2 and applied in Step 3; in practice these values must be inserted manually or using an application that can access both of the servers involved.

**Note**

@file is a string value such as '/var/log/mysql/replication- source-bin.00001', and so must be quoted when used in SQL or application code. However, the value represented by @pos must *not* be quoted. Although MySQL normally attempts to convert strings to numbers, this case is an exception.

4. You can now initiate replication on the secondary channel by issuing the appropriate command on the secondary replica mysqld:

mysql*R'*> **START** **SLAVE;**

In NDB 8.0.22 or later, you can also use the following statement:

mysql*R'*> **START** **REPLICA;**

Once the secondary replication channel is active, you can investigate the failure of the primary and effect repairs. The precise actions required to do this depend upon the reasons for which the primary channel failed.

**Warning**

The secondary replication channel is to be started only if and when the primary replication channel has failed. Running multiple replication channels simultaneously can result in unwanted duplicate records being created on the replicas.

If the failure is limited to a single server, it should in theory be possible to replicate from *S* to *R'*, or from *S'* to *R*.

**23.7.9** **NDB** **Cluster** **Backups** **With** **NDB** **Cluster** **Replication**

This section discusses making backups and restoring from them using NDB Cluster replication. We assume that the replication servers have already been configured as covered previously (see [Section 23.7.5, “Preparing the NDB Cluster for Replication”](#_bookmark57) , and the sections immediately following). This having been done, the procedure for making a backup and then restoring from it is as follows:

1. There are two different methods by which the backup may be started.

• **Method** **A.** This method requires that the cluster backup process was previously enabled on the source server, prior to starting the replication process. This can be done by including the following line in a [mysql\_cluster] section in the my.cnf file, where *management\_host* is the IP address or host name of the NDB management server for the source cluster, and *port* is the management server's port number:

ndb-connectstring=*management\_host* [:*port*]

**Note**

The port number needs to be specified only if the default port (1186) is not being used. See Section 23.3.3, “Initial Configuration of NDB Cluster” , for more information about ports and port allocation in NDB Cluster.

In this case, the backup can be started by executing this statement on the replication source: shell*S*> **ndb\_mgm** **-e** **"START** **BACKUP"**

• **Method** **B.** If the my.cnf file does not specify where to find the management host, you can start the backup process by passing this information to the NDB management client as part of the START BACKUP command. This can be done as shown here, where *management\_host* and *port* are the host name and port number of the management server:

shell*S*> **ndb\_mgm** ***management\_host*:*port*** **-e** **"START** **BACKUP"**

In our scenario as outlined earlier (see [Section 23.7.5, “Preparing the NDB Cluster for](#_bookmark57)

[Replication”](#_bookmark57)), this would be executed as follows: shell*S*> **ndb\_mgm** **rep-source:1186** **-e** **"START** **BACKUP"**

2. Copy the cluster backup files to the replica that is being brought on line. Each system running an ndbd process for the source cluster has cluster backup files located on it, and *all* of these files must be copied to the replica to ensure a successful restore. The backup files can be copied into any directory on the computer where the replica's management host resides, as long as the MySQL and NDB binaries have read permissions in that directory. In this case, we assume that these files have been copied into the directory /var/BACKUPS/BACKUP-1.

While it is not necessary that the replica cluster have the same number of data nodes as the source, it is highly recommended this number be the same. It *is* necessary that the replication process is prevented from starting when the replica server starts. You can do this by starting the replica with the --skip-slave-start option on the command line, by including skip-slave- start in the replica's my.cnf file, or in NDB 8.0.24 or later, by setting the skip\_slave\_start system variable.

3. Create any databases on the replica cluster that are present on the source cluster and that are to be replicated.

**Important**

A CREATE DATABASE (or CREATE SCHEMA) statement corresponding to each database to be replicated must be executed on each SQL node in the replica cluster.

4. Reset the replica cluster using this statement in the mysql client: mysql*R*> **RESET** **SLAVE;** In NDB 8.0.22 or later, you can also use this statement: mysql*R*> **RESET** **REPLICA;**

5. You can now start the cluster restoration process on the replica using the ndb\_restore command for each backup file in turn. For the first of these, it is necessary to include the -m option to restore the cluster metadata, as shown here:

shell*R*> **ndb\_restore** **-c** ***replica\_host*:*port*** **-n** ***node-id*** **\**



**FROM** **mysql.ndb\_apply\_status;**

**-b** ***backup-id*** **-m** **-r** ***dir***

*dir* is the path to the directory where the backup files have been placed on the replica. For the ndb\_restore commands corresponding to the remaining backup files, the -m option should *not* be used.

For restoring from a source cluster with four data nodes (as shown in the figure in [Section 23.7,](#_bookmark28) [“NDB Cluster Replication”](#_bookmark28)) where the backup files have been copied to the directory /var/ BACKUPS/BACKUP-1, the proper sequence of commands to be executed on the replica might look like this:

shell*R*> **ndb\_restore** **-c** **replica-host:1186** **-n** **2** **-b** **1** **-m** **\**

**-r** **./var/BACKUPS/BACKUP-1**

shell*R*> **ndb\_restore** **-c** **replica-host:1186** **-n** **3** **-b** **1** **\**

**-r** **./var/BACKUPS/BACKUP-1**

shell*R*> **ndb\_restore** **-c** **replica-host:1186** **-n** **4** **-b** **1** **\**

**-r** **./var/BACKUPS/BACKUP-1**

shell*R*> **ndb\_restore** **-c** **replica-host:1186** **-n** **5** **-b** **1** **-e** **\**

**-r** **./var/BACKUPS/BACKUP-1**

**Important**

The -e (or --restore-epoch) option in the final invocation of ndb\_restore in this example is required to make sure that the epoch is written to the replica's mysql.ndb\_apply\_status table. Without this information, the replica cannot synchronize properly with the source. (See Section 23.5.23, “ndb\_restore — Restore an NDB Cluster Backup” .)

6. Now you need to obtain the most recent epoch from the ndb\_apply\_status table on the replica (as discussed in [Section 23.7.8, “Implementing Failover with NDB Cluster Replication”](#_bookmark35)):

mysql*R*> **SELECT** **@latest:=MAX(epoch)**

7. Using @latest as the epoch value obtained in the previous step, you can obtain the correct starting position @pos in the correct binary log file @file from the mysql.ndb\_binlog\_index table on the source. The query shown here gets these from the Position and File columns from the last epoch applied before the logical restore position:

mysql*S*> **SELECT**

->

**@file:=SUBSTRING\_INDEX(File,** **'/',** **-1),**

**@pos:=Position**

->

-> **FROM** **mysql** **.ndb\_binlog\_index**

-> **WHERE** **epoch** **>** **@latest**

-> **ORDER** **BY** **epoch** **ASC** **LIMIT** **1;**

In the event that there is currently no replication traffic, you can get similar information by running SHOW MASTER STATUS on the source and using the value shown in the Position column of the output for the file whose name has the suffix with the greatest value for all files shown in the File column. In this case, you must determine which file this is and supply the name in the next step manually or by parsing the output with a script.

8. Using the values obtained in the previous step, you can now issue the appropriate in the replica's mysql client. In NDB 8.0.23 and later, use the following CHANGE REPLICATION SOURCE TO statement:

mysql*R*> **CHANGE** **REPLICATION** **SOURCE** **TO**

->

**SOURCE\_LOG\_FILE='@file',**

**SOURCE\_LOG\_POS=@pos;**

->

Prior to NDB 8.0.23, you can must use the CHANGE MASTER TO statement shown here:

mysql*R*> **CHANGE** **MASTER** **TO**

->

->

**MASTER\_LOG\_FILE='@file',**

**MASTER\_LOG\_POS=@pos;**

9. Now that the replica knows from what point in which binary log file to start reading data from the source, you can cause the replica to begin replicating with this statement:

mysql*R*> **START** **SLAVE;**

Beginning with NDB 8.0.22, you can also use the following statement:

mysql*R*> **START** **REPLICA;**

To perform a backup and restore on a second replication channel, it is necessary only to repeat these steps, substituting the host names and IDs of the secondary source and replica for those of the primary source and replica servers where appropriate, and running the preceding statements on them.

For additional information on performing Cluster backups and restoring Cluster from backups, see Section 23.6.8, “Online Backup of NDB Cluster” .

**23.7.9.1** **NDB** **Cluster** **Replication:** **Automating** **Synchronization** **of** **the** **Replica** **to** **the**

**Source** **Binary** **Log**

It is possible to automate much of the process described in the previous section (see [Section 23.7.9,](#_bookmark58) [“NDB Cluster Backups With NDB Cluster Replication”](#_bookmark58)). The following Perl script reset-replica.pl serves as an example of how you can do this.

#!/user/bin/perl -w

# file: reset-replica.pl

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# it under the terms of the GNU General Public License as published by

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# This program is distributed in the hope that it will be useful,

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# along with this program; if not, write to:

# Free Software Foundation, Inc .

# 59 Temple Place, Suite 330

# Boston, MA 02111-1307 USA

#

# Version 1.1

######################## Includes ###############################

use DBI;

######################## Globals ################################

my $m\_host='';

my $m\_port='';

my $m\_user='';

my $m\_pass='';

my $s\_host='';

my $s\_port='';

my $s\_user='';

my $s\_pass='';

my $dbhM='';

my $dbhS='';

####################### Sub Prototypes ##########################

sub CollectCommandPromptInfo;

sub ConnectToDatabases;

sub DisconnectFromDatabases;

sub GetReplicaEpoch;

sub GetSourceInfo;

sub UpdateReplica;

######################## Program Main ###########################

CollectCommandPromptInfo;

ConnectToDatabases;

GetReplicaEpoch;

GetSourceInfo;

UpdateReplica;

DisconnectFromDatabases;

################## Collect Command Prompt Info ##################

sub CollectCommandPromptInfo

{

### Check that user has supplied correct number of command line args

die "Usage:\n

reset-replica >source MySQL host< >source MySQL port< \n

>source user< >source pass< >replica MySQL host< \n

>replica MySQL port< >replica user< >replica pass< \n

All 8 arguments must be passed . Use BLANK for NULL passwords\n"

unless @ARGV == 8;

$m\_host = $ARGV[0];

$m\_port = $ARGV[1];

$m\_user = $ARGV[2];

$m\_pass = $ARGV[3];

$s\_host = $ARGV[4];

$s\_port = $ARGV[5];

$s\_user = $ARGV[6];

$s\_pass = $ARGV[7];

if ($m\_pass eq "BLANK") { $m\_pass = '';}

if ($s\_pass eq "BLANK") { $s\_pass = '';}

}

############### Make connections to both databases #############

sub ConnectToDatabases

{

### Connect to both source and replica cluster databases

### Connect to source

$dbhM

= DBI->connect(

"dbi:mysql:database=mysql;host=$m\_host;port=$m\_port",

"$m\_user", "$m\_pass")

or die "Can't connect to source cluster MySQL process!

Error: $DBI::errstr\n";

### Connect to replica

$dbhS

= DBI->connect(

"dbi:mysql:database=mysql;host=$s\_host",

"$s\_user", "$s\_pass")

or die "Can't connect to replica cluster MySQL process!

Error: $DBI::errstr\n";

}

################ Disconnect from both databases ################

sub DisconnectFromDatabases

{

### Disconnect from source

$dbhM->disconnect

or warn " Disconnection failed: $DBI::errstr\n";

### Disconnect from replica

$dbhS->disconnect

or warn " Disconnection failed: $DBI::errstr\n";

}

###################### Find the last good GCI ##################

sub GetReplicaEpoch

{

$sth = $dbhS->prepare("SELECT MAX(epoch)

FROM mysql .ndb\_apply\_status;")

or die "Error while preparing to select epoch from replica: ",

$dbhS->errstr;

$sth->execute

or die "Selecting epoch from replica error: ", $sth->errstr;

$sth->bind\_col (1, \$epoch);

$sth->fetch;

print "\tReplica epoch = $epoch\n";

$sth->finish;

}

####### Find the position of the last GCI in the binary log ########

sub GetSourceInfo

{

$sth = $dbhM->prepare("SELECT

SUBSTRING\_INDEX(File, '/', -1), Position

FROM mysql .ndb\_binlog\_index

WHERE epoch > $epoch

ORDER BY epoch ASC LIMIT 1;")

or die "Prepare to select from source error: ", $dbhM->errstr;

$sth->execute

or die "Selecting from source error: ", $sth->errstr;

$sth->bind\_col (1, \$binlog);

$sth->bind\_col (2, \$binpos);

$sth->fetch;

print "\tSource binary log file = $binlog\n";

print "\tSource binary log position = $binpos\n";

$sth->finish;

}

########## Set the replica to process from that location #########

sub UpdateReplica

{

$sth = $dbhS->prepare("CHANGE MASTER TO

MASTER\_LOG\_FILE='$binlog',

MASTER\_LOG\_POS=$binpos;")

or die "Prepare to CHANGE MASTER error: ", $dbhS->errstr;

$sth->execute

or die "CHANGE MASTER on replica error: ", $sth->errstr;

$sth->finish;

print "\tReplica has been updated . You may now start the replica .\n";

}

# end reset-replica.pl

**23.7.9.2** **Point-In-Time** **Recovery** **Using** **NDB** **Cluster** **Replication**

*Point-in-time* recovery—that is, recovery of data changes made since a given point in time— is performed after restoring a full backup that returns the server to its state when the backup was made. Performing point-in-time recovery of NDB Cluster tables with NDB Cluster and NDB Cluster Replication can be accomplished using a native NDB data backup (taken by issuing CREATE BACKUP in the ndb\_mgm client) and restoring the ndb\_binlog\_index table (from a dump made using mysqldump).

To perform point-in-time recovery of NDB Cluster, it is necessary to follow the steps shown here:



1. Back up all NDB databases in the cluster, using the START BACKUP command in the ndb\_mgm client (see Section 23.6.8, “Online Backup of NDB Cluster” ).

2. At some later point, prior to restoring the cluster, make a backup of the

mysql.ndb\_binlog\_index table. It is probably simplest to use mysqldump for this task. Also back up the binary log files at this time.

This backup should be updated regularly—perhaps even hourly—depending on your needs.

3. (*Catastrophic* *failure* *or* *error* *occurs*.)

4. Locate the last known good backup.

5. Clear the data node file systems (using ndbd --initial or ndbmtd --initial).

**Note**

Beginning with NDB 8.0.21, Disk Data tablespace and log files are removed by --initial. Previously, it was necessary to delete these manually.

6. Use DROP TABLE or TRUNCATE TABLE with the mysql.ndb\_binlog\_index table.

7. Execute ndb\_restore, restoring all data. You must include the --restore-epoch option when you run ndb\_restore, so that the ndb\_apply\_status table is populated correctly. (See Section 23.5.23, “ndb\_restore — Restore an NDB Cluster Backup” , for more information.)

8. Restore the ndb\_binlog\_index table from the output of mysqldump and restore the binary log files from backup, if necessary.

9. Find the epoch applied most recently—that is, the maximum epoch column value in the ndb\_apply\_status table—as the user variable @LATEST\_EPOCH (emphasized):

SELECT *@LATEST\_EPOCH*:=MAX(epoch)

FROM mysql.ndb\_apply\_status;

10. Find the latest binary log file (@FIRST\_FILE) and position (Position column value) within this file that correspond to @LATEST\_EPOCH in the ndb\_binlog\_index table:

SELECT Position, *@FIRST\_FILE*:=File

FROM mysql.ndb\_binlog\_index

WHERE epoch > *@LATEST\_EPOCH* ORDER BY epoch ASC LIMIT 1;

11. Using mysqlbinlog, replay the binary log events from the given file and position up to the point of the failure. (See Section 4.6.9, “mysqlbinlog — Utility for Processing Binary Log Files” .)

See also Section 7.5, “Point-in-Time (Incremental) Recovery” , for more information about the binary log, replication, and incremental recovery.

**23.7.10** **NDB** **Cluster** **Replication:** **Bidirectional** **and** **Circular** **Replication**

It is possible to use NDB Cluster for bidirectional replication between two clusters, as well as for circular replication between any number of clusters.

**Circular** **replication** **example.** In the next few paragraphs we consider the example of a replication setup involving three NDB Clusters numbered 1, 2, and 3, in which Cluster 1 acts as the replication source for Cluster 2, Cluster 2 acts as the source for Cluster 3, and Cluster 3 acts as the source for Cluster 1. Each cluster has two SQL nodes, with SQL nodes A and B belonging to Cluster 1, SQL nodes C and D belonging to Cluster 2, and SQL nodes E and F belonging to Cluster 3.

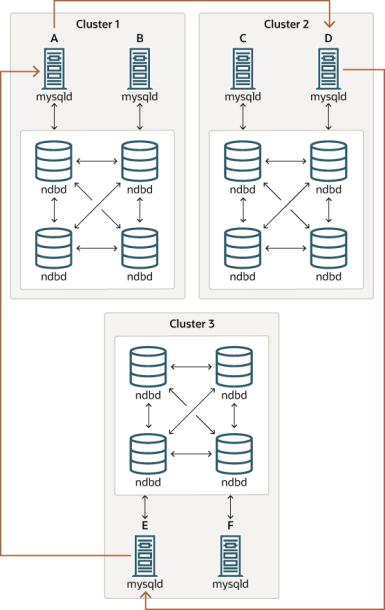
Circular replication using these clusters is supported as long as the following conditions are met:

• The SQL nodes on all sources and replicas are the same.

• All SQL nodes acting as sources and replicas are started with the system variable log\_replica\_updates (beginning with NDB 8.0.26) or log\_slave\_updates (NDB 8.0.26 and earlier) enabled.

This type of circular replication setup is shown in the following diagram:

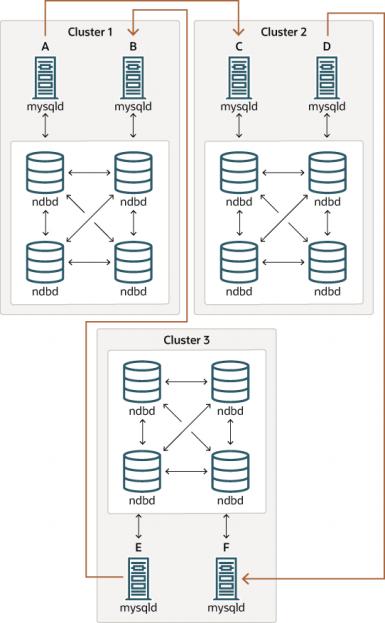
**Figure** **23.15** **NDB** **Cluster** **Circular** **Replication** **with** **All** **Sources** **As** **Replicas**



In this scenario, SQL node A in Cluster 1 replicates to SQL node C in Cluster 2; SQL node C replicates to SQL node E in Cluster 3; SQL node E replicates to SQL node A. In other words, the replication line (indicated by the curved arrows in the diagram) directly connects all SQL nodes used as replication sources and replicas.

It is also possible to set up circular replication in such a way that not all source SQL nodes are also replicas, as shown here:

**Figure** **23.16** **NDB** **Cluster** **Circular** **Replication** **Where** **Not** **All** **Sources** **Are** **Replicas**

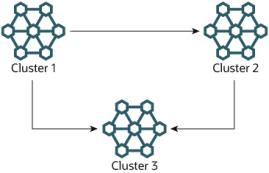


In this case, different SQL nodes in each cluster are used as replication sources and replicas. You must *not* start any of the SQL nodes with the system variable log\_replica\_updates (NDB 8.0.26 and later) or log\_slave\_updates (prior to NDB 8.0.26) enabled. This type of circular replication scheme for NDB Cluster, in which the line of replication (again indicated by the curved arrows in the diagram) is discontinuous, should be possible, but it should be noted that it has not yet been thoroughly tested and must therefore still be considered experimental.

**Using** **NDB-native** **backup** **and** **restore** **to** **initialize** **a** **replica** **cluster.** When setting up circular replication, it is possible to initialize the replica cluster by using the management client START BACKUP command on one NDB Cluster to create a backup and then applying this backup on another NDB Cluster using ndb\_restore. This does not automatically create binary logs on the second NDB Cluster's SQL node acting as the replica; in order to cause the binary logs to be created, you must issue a SHOW TABLES statement on that SQL node; this should be done prior to running START REPLICA. This is a known issue.

**Multi-source** **failover** **example.** In this section, we discuss failover in a multi-source NDB Cluster replication setup with three NDB Clusters having server IDs 1, 2, and 3. In this scenario, Cluster 1 replicates to Clusters 2 and 3; Cluster 2 also replicates to Cluster 3. This relationship is shown here:

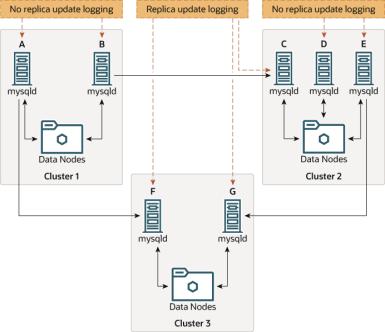
**Figure** **23.17** **NDB** **Cluster** **Multi-Master** **Replication** **With** **3** **Sources**



In other words, data replicates from Cluster 1 to Cluster 3 through 2 different routes: directly, and by way of Cluster 2.

Not all MySQL servers taking part in multi-source replication must act as both source and replica, and a given NDB Cluster might use different SQL nodes for different replication channels. Such a case is shown here:

**Figure** **23.18** **NDB** **Cluster** **Multi-Source** **Replication,** **With** **MySQL** **Servers**



MySQL servers acting as replicas must be run with the system variable log\_replica\_updates (beginning with NDB 8.0.26) or log\_slave\_updates (NDB 8.0.26 and earlier) enabled. Which mysqld processes require this option is also shown in the preceding diagram.

**Note**

Using the log\_replica\_updates or log\_slave\_updates system variable has no effect on servers not being run as replicas.

The need for failover arises when one of the replicating clusters goes down. In this example, we consider the case where Cluster 1 is lost to service, and so Cluster 3 loses 2 sources of updates from



Cluster 1. Because replication between NDB Clusters is asynchronous, there is no guarantee that Cluster 3's updates originating directly from Cluster 1 are more recent than those received through Cluster 2. You can handle this by ensuring that Cluster 3 catches up to Cluster 2 with regard to updates from Cluster 1. In terms of MySQL servers, this means that you need to replicate any outstanding updates from MySQL server C to server F.

On server C, perform the following queries:

mysqlC> SELECT @latest:=MAX(epoch)

|  |  |
| --- | --- |
| ->  -> | FROM mysql.ndb\_apply\_status  WHERE server\_id=1; |

mysqlC> SELECT

|  |  |
| --- | --- |
| ->  ->  ->  ->  ->  -> | @file:=SUBSTRING\_INDEX(File, '/', -1),  @pos:=Position  FROM mysql.ndb\_binlog\_index  WHERE orig\_epoch >= @latest  AND orig\_server\_id = 1  ORDER BY epoch ASC LIMIT 1; |

**Note**

You can improve the performance of this query, and thus likely speed up failover times significantly, by adding the appropriate index to the ndb\_binlog\_index table. See [Section 23.7.4, “NDB Cluster Replication](#_bookmark34) [Schema and Tables”](#_bookmark34) , for more information.

Copy over the values for *@file* and *@pos* manually from server C to server F (or have your application perform the equivalent). Then, on server F, execute the following CHANGE REPLICATION SOURCE TO statement (NDB 8.0.23 and later) or CHANGE MASTER TO statement (prior to NDB 8.0.23):

mysqlF> CHANGE MASTER TO

|  |  |
| --- | --- |
| ->  ->  -> | MASTER\_HOST = 'serverC' MASTER\_LOG\_FILE='@file', MASTER\_LOG\_POS=@pos; |

Beginning with NDB 8.0.23, you can also use the following statement:

mysqlF> CHANGE REPLICATION SOURCE TO

SOURCE\_HOST = 'serverC'

SOURCE\_LOG\_FILE='@file',

SOURCE\_LOG\_POS=@pos;

->

->

->

Once this has been done, you can issue a START REPLICA statement on MySQL server F; this causes any missing updates originating from server B to be replicated to server F.

The CHANGE REPLICATION SOURCE TO | CHANGE MASTER TO statement also supports an IGNORE\_SERVER\_IDS option which takes a comma-separated list of server IDs and causes events originating from the corresponding servers to be ignored. For more information, see Section 13.4.2.1, “CHANGE MASTER TO Statement” , and Section 13.7.7.36, “SHOW SLAVE | REPLICA STATUS Statement” . For information about how this option interacts with the ndb\_log\_apply\_status variable, see [Section 23.7.8, “Implementing Failover with NDB Cluster Replication”](#_bookmark35) .

**23.7.11** **NDB** **Cluster** **Replication** **Using** **the** **Multithreaded** **Applier**

• [Requirements](#_bookmark59)

• [MTA Configuration: Source](#_bookmark60)

• [MTA Configuration: Replica](#_bookmark61)

• [Transaction Dependency and Writeset Handling](#_bookmark62)

• [Writeset Tracking Memory Usage](#_bookmark63)

• [Known Limitations](#_bookmark64)

Beginning with NDB 8.0.33, NDB replication supports the use of the generic MySQL Server Multithreaded Applier mechanism (MTA), which allows independent binary log transactions to be applied in parallel on a replica, increasing peak replication throughput.

**Requirements**

The MySQL Server MTA implementation delegates the processing of separate binary log transactions to a pool of worker threads (whose size is configurable), and coordinates the worker threads to ensure that transaction dependencies encoded in the binary log are respected, and that commit ordering is maintained if required (see Section 17.2.3, “Replication Threads” ). To use this functionality with NDB Cluster, it is necessary that the following three conditions be met:

1. *Binary* *log* *transaction* *dependencies* *are* *determined* *at* *the* *source*.

For this to be true, the binlog\_transaction\_dependency\_tracking server system variable must be set to WRITESET on the source. This is supported by NDB 8.0.33 and later. (The default is COMMIT\_ORDER.)

Writeset maintenance work in NDB is performed by the MySQL binary log injector thread as part of preparing and committing each epoch transaction to the binary log. This requires extra resources, and may reduce peak throughput.

2. *Transaction* *dependencies* *are* *encoded* *into* *the* *binary* *log*.

NDB 8.0.33 and later supports the --ndb-log-transaction-dependency startup option for mysqld; set this option to ON to enable writing of NDB transaction dependencies into the binary log.

3. *The* *replica* *is* *configured* *to* *use* *multiple* *worker* *threads*.

NDB 8.0.33 and later supports setting replica\_parallel\_workers to nonzero values to control the number of worker threads on the replica. The default is 4.

**MTA** **Configuration:** **Source**

Source mysqld configuration for the NDB MTA must include the following explicit settings:

• binlog\_transaction\_dependency\_tracking must be set to WRITESET.

• The replication source mysqld must be started with --ndb-log-transaction-dependency=ON.

If set, replica\_parallel\_type must be LOGICAL\_CLOCK (the default value; DATABASE is not supported).

In addition, it is recommended that you set the amount of memory used to track binary log transaction writesets on the source (binlog\_transaction\_dependency\_history\_size) to *E* \* *P*, where *E* is the average epoch size (as the number of operations per epoch) and *P* is the maximum expected parallelism. See [Writeset Tracking Memory Usage](#_bookmark63), for more information.

**MTA** **Configuration:** **Replica**

Replica mysqld configuration for the NDB MTA requires that replica\_parallel\_workers is

greater than 1. The recommended starting value when first enabling MTA is 4, which is the default. In addition, replica\_preserve\_commit\_order must be ON. This is also the default value.

**Transaction** **Dependency** **and** **Writeset** **Handling**

Transaction dependencies are detected using analysis of each transaction's writeset, that is, the set of rows (table, key values) written by the transaction. Where two transactions modify the same

row they are considered to be dependent, and must be applied in order (in other words, serially) to avoid deadlocks or incorrect results. Where a table has secondary unique keys, these values are also added to the transaction's writeset to detect the case where there are transaction dependencies implied by different transactions affecting the same unique key value, and so requiring ordering. Where dependencies cannot be efficiently determined, mysqld falls back to considering transactions dependent for reasons of safety.

Transaction dependencies are encoded in the binary log by the source mysqld. Dependencies are encoded in an ANONYMOUS\_GTID event using a scheme called 'Logical clock'. (See Section 17.1.4.1, “Replication Mode Concepts” .)

The writeset implementation employed by MySQL (and NDB Cluster) uses hash-based conflict detection based on matching 64-bit row hashes of relevant table and index values. This detects reliably when the same key is seen twice, but can also produce false positives if different table and index values hash to the same 64-bit value; this may result in artificial dependencies which can reduce the available parallelism.

Transaction dependencies are forced by any of the following:

• DDL statements

• Binary log rotation or encountering binary log file boundaries

• Writeset history size limitations

• Writes which reference parent foreign keys in the target table

More specifically, transactions which perform inserts, updates, and deletes on foreign key *parent* tables are serialized relative to all preceding and following transactions, and not just to those transactions affecting tables involved in a constraint relationship. Conversely, transactions performing inserts, updates and deletes on foreign key *child* tables (referencing) are not especially serialized with regard to one another.

The MySQL MTA implementation attempts to apply independent binary log transactions in parallel. NDB records all changes occurring in all user transactions committing in an epoch (TimeBetweenEpochs, default 100 milliseconds), in one binary log transaction, referred to as an epoch transaction. Therefore, for two consecutive epoch transactions to be independent, and possible to apply in parallel, it is required that no row is modified in both epochs. If any single row is modified in both epochs, then they are dependent, and are applied serially, which can limit the expolitable parallelism available.

Epoch transactions are considered independent based on the set of rows modified on the source cluster in the epoch, but not including the generated mysql.ndb\_apply\_status WRITE\_ROW events that convey epoch metadata. This avoids every epoch transaction being trivially dependent on the preceding epoch, but does require that the binlog is applied at the replica with the commit order preserved. This also implies that an NDB binary log with writeset dependencies is not suitable for use by a replica database using a different MySQL storage engine.

It may be possible or desirable to modify application transaction behavior to avoid patterns of repeated modifications to the same rows, in separate transactions over a short time period, to increase exploitable apply parallelism.

**Writeset** **Tracking** **Memory** **Usage**

The amount of memory used to track binary log transaction writesets can be set using the binlog\_transaction\_dependency\_history\_size server system variable, which defaults to 25000 row hashes.

If an average binary log transaction modifies *N* rows, then to be able to identify

independent (parallelizable) transactions up to a parallelism level of *P*, we need binlog\_transaction\_dependency\_history\_size to be at least *N* \* *P*. (The maximum is 1000000.)

The finite size of the history results in a finite maximum dependency length that can be reliably determined, giving a finite parallelism that can be expressed. Any row not found in the history may be dependent on the last transaction purged from the history.

Writeset history does not act like a sliding window over the last *N*transactions; rather, it is a finite buffer which is allowed to fill up completely, then its contents entirely discarded when it becomes full. This means that the history size follows a sawtooth pattern over time, and therefore the maximum detectable dependency length also follows a sawtooth pattern over time, such that independent transactions may still be marked as dependent if the writeset history buffer has been reset between their being processed.

In this scheme, each transaction in a binary log file is annotated with a sequence\_number (1, 2, 3, ...), and as well as the sequence number of the most recent binary log transaction that it depends on, to which we refer as last\_committed.

Within a given binary log file, the first transaction has sequence\_number 1 and last\_committed 0.

Where a binary log transaction depends on its immediate predecessor, its application is serialized. If the dependency is on an earlier transaction then it may be possible to apply the transaction in parallel with the preceding independent transactions.

The content of ANONYMOUS\_GTID events, including sequence\_number and last\_committed (and thus the transaction dependencies), can be seen using mysqlbinlog.

The ANONYMOUS\_GTID events generated on the source are handled separately from the compressed transaction payload with bulk BEGIN, TABLE\_MAP\*, WRITE\_ROW\*, UPDATE\_ROW\*, DELETE\_ROW\*, and COMMIT events, allowing dependencies to be determined prior to decompression. This means that the replica coordinator thread can delegate transaction payload decompression to a worker thread, providing automatic parallel decompression of independent transactions on the replica.

**Known** **Limitations**

**Secondary** **unique** **columns.** Tables with secondary unique columns (that is, unique keys other than the primary key) have all columns sent to the source so that unique-key related conflicts can be detected.

Where the current binary logging mode does not include all columns, but only changed columns (-- ndb-log-updated-only=OFF, --ndb-log-update-minimal=ON, --ndb-log-update-as- write=OFF), this can increase the volume of data sent from data nodes to SQL nodes.

The impact depends on both the rate of modification (update or delete) of rows in such tables and the volume of data in columns which are not actually modified.

**Replicating** **NDB** **to** **to** **InnoDB.** NDB binary log injector transaction dependency tracking intentionally ignores the inter-transaction dependencies created by generated

mysql.ndb\_apply\_status metadata events, which are handled separately as part of the commit of the epoch transaction on the replica applier. For replication to InnoDB, there is no special handling; this may result in reduced performance or other issues when using an InnoDB multithreaded applier to consume an NDB MTA binary log.

**23.7.12** **NDB** **Cluster** **Replication** **Conflict** **Resolution**

• [Requirements](#_bookmark65)

• [Source Column Control](#_bookmark66)

• [Conflict Resolution Control](#_bookmark42)

• [Conflict Resolution Functions](#_bookmark54)

• [Conflict Resolution Exceptions Table](#_bookmark55)



• [Conflict Detection Status Variables](#_bookmark67)

• [Examples](#_bookmark68)

When using a replication setup involving multiple sources (including circular replication), it is possible that different sources may try to update the same row on the replica with different data. Conflict resolution in NDB Cluster Replication provides a means of resolving such conflicts by permitting a user- defined resolution column to be used to determine whether or not an update on a given source should be applied on the replica.

Some types of conflict resolution supported by NDB Cluster (NDB$OLD(), NDB$MAX(), and NDB$MAX\_DELETE\_WIN(); additionally, in NDB 8.0.30 and later, NDB$MAX\_INS() and NDB $MAX\_DEL\_WIN\_INS()) implement this user-defined column as a “timestamp” column (although its type cannot be TIMESTAMP, as explained later in this section). These types of conflict resolution are always applied a row-by-row basis rather than a transactional basis. The epoch-based conflict resolution functions NDB$EPOCH() and NDB$EPOCH\_TRANS() compare the order in which epochs are replicated (and thus these functions are transactional). Different methods can be used to compare resolution column values on the replica when conflicts occur, as explained later in this section; the method used can be set to act on a single table, database, or server, or on a set of one or more tables using pattern matching. See [Matching with wildcards](#_bookmark44), for information about using pattern matches in the db, table\_name, and server\_id columns of the mysql.ndb\_replication table.

You should also keep in mind that it is the application's responsibility to ensure that the resolution column is correctly populated with relevant values, so that the resolution function can make the appropriate choice when determining whether to apply an update.

**Requirements**

Preparations for conflict resolution must be made on both the source and the replica. These tasks are described in the following list:

• On the source writing the binary logs, you must determine which columns are sent (all columns or only those that have been updated). This is done for the MySQL Server as a whole by applying the mysqld startup option --ndb-log-updated-only (described later in this section), or on one or more specific tables by placing the proper entries in the mysql.ndb\_replication table (see [ndb\_replication Table](#_bookmark41)).

**Note**

If you are replicating tables with very large columns (such as TEXT or BLOB columns), --ndb-log-updated-only can also be useful for reducing the size of the binary logs and avoiding possible replication failures due to exceeding max\_allowed\_packet.

See Section 17.5.1.20, “Replication and max\_allowed\_packet” , for more information about this issue.

• On the replica, you must determine which type of conflict resolution to apply (“latest timestamp wins” , “same timestamp wins” , “primary wins” , “primary wins, complete transaction” , or none). This is done using the mysql.ndb\_replication system table, and applies to one or more specific tables (see [ndb\_replication Table](#_bookmark41)).

• NDB Cluster also supports read conflict detection, that is, detecting conflicts between reads of a given row in one cluster and updates or deletes of the same row in another cluster. This requires exclusive read locks obtained by setting ndb\_log\_exclusive\_reads equal to 1 on the replica. All rows read by a conflicting read are logged in the exceptions table. For more information, see [Read](#_bookmark69) [conflict detection and resolution](#_bookmark69).

• Prior to NDB 8.0.30, NDB applied WRITE\_ROW events strictly as inserts, requiring that there was not already any such row; that is, an incoming write was always rejected if the row already existed.

(This is still the case when using any conflict resolution function other than NDB$MAX\_INS() or NDB $MAX\_DEL\_WIN\_INS().)

Beginning with NDB 8.0.30, when using NDB$MAX\_INS() or NDB$MAX\_DEL\_WIN\_INS(), NDB can apply WRITE\_ROW events idempotently, mapping such an event to an insert when the incoming row does not already exist, or to an update if it does.

When using the functions NDB$OLD(), NDB$MAX(), and NDB$MAX\_DELETE\_WIN() for timestamp- based conflict resolution (as well as NDB$MAX\_INS() and NDB$MAX\_DEL\_WIN\_INS(), beginning with NDB 8.0.30), we often refer to the column used for determining updates as a “timestamp” column. However, the data type of this column is never TIMESTAMP; instead, its data type should be INT ( INTEGER) or BIGINT. The “timestamp” column should also be UNSIGNED and NOT NULL.

The NDB$EPOCH() and NDB$EPOCH\_TRANS() functions discussed later in this section work by comparing the relative order of replication epochs applied on a primary and secondary NDB Cluster, and do not make use of timestamps.

**Source** **Column** **Control**

We can see update operations in terms of “before” and “after” images—that is, the states of the table before and after the update is applied. Normally, when updating a table with a primary key, the “before” image is not of great interest; however, when we need to determine on a per-update basis whether or not to use the updated values on a replica, we need to make sure that both images are written to the source's binary log. This is done with the --ndb-log-update-as-write option for mysqld, as described later in this section.

**Important**

Whether logging of complete rows or of updated columns only is done is decided when the MySQL server is started, and cannot be changed online; you must either restart mysqld, or start a new mysqld instance with different logging options.

**Conflict** **Resolution** **Control**

Conflict resolution is usually enabled on the server where conflicts can occur. Like logging method selection, it is enabled by entries in the mysql.ndb\_replication table.

NBT\_UPDATED\_ONLY\_MINIMAL and NBT\_UPDATED\_FULL\_MINIMAL can be used with NDB $EPOCH(), NDB$EPOCH2(), and NDB$EPOCH\_TRANS(), because these do not require “before” values of columns which are not primary keys. Conflict resolution algorithms requiring the old values, such as NDB$MAX() and NDB$OLD(), do not work correctly with these binlog\_type values.

**Conflict** **Resolution** **Functions**

This section provides detailed information about the functions which can be used for conflict detection and resolution with NDB Replication.

• [NDB$OLD()](#_bookmark45)

• [NDB$MAX()](#_bookmark46)

• [NDB$MAX\_DELETE\_WIN()](#_bookmark47)

• [NDB$MAX\_INS()](#_bookmark52)

• [NDB$MAX\_DEL\_WIN\_INS()](#_bookmark53)

• [NDB$EPOCH()](#_bookmark48)

• [NDB$EPOCH\_TRANS()](#_bookmark49)



• [NDB$EPOCH2()](#_bookmark50)

• [NDB$EPOCH2\_TRANS()](#_bookmark51)

**NDB$OLD()**

If the value of *column\_name* is the same on both the source and the replica, then the update is applied; otherwise, the update is not applied on the replica and an exception is written to the log. This is illustrated by the following pseudocode:

if (*source\_old\_column\_value* == *replica\_current\_column\_value*)

apply\_update();

else

log\_exception();

This function can be used for “same value wins” conflict resolution. This type of conflict resolution ensures that updates are not applied on the replica from the wrong source.

**Important**

The column value from the source's “before” image is used by this function.

**NDB$MAX()**

For an update or delete operation, if the “timestamp” column value for a given row coming from the source is higher than that on the replica, it is applied; otherwise it is not applied on the replica. This is illustrated by the following pseudocode:

if (*source\_new\_column\_value* > *replica\_current\_column\_value*)

apply\_update();

This function can be used for “greatest timestamp wins” conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was most recently updated is the version that persists.

This function has no effects on conflicts between write operations, other than that a write operation with the same primary key as a previous write is always rejected; it is accepted and applied only if no write operation using the same primary key already exists. Beginning with NDB 8.0.30, you can use [NDB](#_bookmark52) [$MAX\_INS()](#_bookmark52) to handle conflict resolution between writes.

**Important**

The column value from the sources's “after” image is used by this function.

**NDB$MAX\_DELETE\_WIN()**

This is a variation on NDB$MAX(). Due to the fact that no timestamp is available for a delete operation, a delete using NDB$MAX() is in fact processed as NDB$OLD, but for some use cases, this is not optimal. For NDB$MAX\_DELETE\_WIN(), if the “timestamp” column value for a given row adding or updating an existing row coming from the source is higher than that on the replica, it is applied. However, delete operations are treated as always having the higher value. This is illustrated by the following pseudocode:

if ( (*source\_new\_column\_value* > *replica\_current\_column\_value*)

||

*operation* *.type* == "delete")

apply\_update();

This function can be used for “greatest timestamp, delete wins” conflict resolution. This type of conflict resolution ensures that, in the event of a conflict, the version of the row that was deleted or (otherwise) most recently updated is the version that persists.

**Note**

As with NDB$MAX(), the column value from the source's “after” image is the value used by this function.

**NDB$MAX\_INS()**

This function provides support for resolution of conflicting write operations. Such conflicts are handled by “NDB$MAX\_INS()” as follows:

1. If there is no conflicting write, apply this one (this is the same as NDB$MAX()).

2. Otherwise, apply “greatest timestamp wins” conflict resolution, as follows:

a. If the timestamp for the incoming write is greater than that of the conflicting write, apply the incoming operation.

b. If the timestamp for the incoming write is *not* greater, reject the incoming write operation.

When handling an insert operation, NDB$MAX\_INS() compares timestamps from the source and replica as illustrated by the following pseudocode:

if (source\_new\_column\_value > replica\_current\_column\_value)

apply\_insert();

else

log\_exception();

For an update operation, the updated timestamp column value from the source is compared with the replica's timestamp column value, as shown here:

if (source\_new\_column\_value > replica\_current\_column\_value)

apply\_update();

else

log\_exception();

This is the same as performed by [NDB$MAX()](#_bookmark46).

For delete operations, the handling is also the same as that performed by NDB$MAX() (and thus the same as NDB$OLD()), and is done like this:

if (source\_new\_column\_value == replica\_current\_column\_value)

apply\_delete();

else

log\_exception();

NDB$MAX\_INS() was added in NDB 8.0.30.

**NDB$MAX\_DEL\_WIN\_INS()**

This function provides support for resolution of conflicting write operations, along with “delete wins” resolution like that of [NDB$MAX\_DELETE\_WIN()](#_bookmark47). Write conflicts are handled by NDB $MAX\_DEL\_WIN\_INS() as shown here:

1. If there is no conflicting write, apply this one (this is the same as NDB$MAX\_DELETE\_WIN()).

2. Otherwise, apply “greatest timestamp wins” conflict resolution, as follows:

a. If the timestamp for the incoming write is greater than that of the conflicting write, apply the incoming operation.

b. If the timestamp for the incoming write is *not* greater, reject the incoming write operation.

Handling of insert operations as performed by NDB$MAX\_DEL\_WIN\_INS() can be represented in pseudocode as shown here:

if (source\_new\_column\_value > replica\_current\_column\_value)

apply\_insert();

else

log\_exception();

For update operations, the source's updated timestamp column value is compared with replica's timestamp column value, like this (again using pseudocode):

if (source\_new\_column\_value > replica\_current\_column\_value)

apply\_update();

else

log\_exception();

Deletes are handled using a “delete always wins” strategy (the same as NDB$MAX\_DELETE\_WIN()); a DELETE is always applied without any regard to any timestamp values, as illustrated by this pseudocode:

if (operation.type == "delete")

apply\_delete();

For conflicts between update and delete operations, this function behaves identically to NDB $MAX\_DELETE\_WIN().

NDB$MAX\_DEL\_WIN\_INS() was added in NDB 8.0.30.

**NDB$EPOCH()**

The NDB$EPOCH() function tracks the order in which replicated epochs are applied on a replica cluster relative to changes originating on the replica. This relative ordering is used to determine whether changes originating on the replica are concurrent with any changes that originate locally, and are therefore potentially in conflict.

Most of what follows in the description of NDB$EPOCH() also applies to NDB$EPOCH\_TRANS(). Any exceptions are noted in the text.

NDB$EPOCH() is asymmetric, operating on one NDB Cluster in a bidirectional replication configuration (sometimes referred to as “active-active” replication). We refer here to cluster on which it operates as the primary, and the other as the secondary. The replica on the primary is responsible for detecting and handling conflicts, while the replica on the secondary is not involved in any conflict detection or handling.

When the replica on the primary detects conflicts, it injects events into its own binary log to compensate for these; this ensures that the secondary NDB Cluster eventually realigns itself with the primary and so keeps the primary and secondary from diverging. This compensation and realignment mechanism requires that the primary NDB Cluster always wins any conflicts with the secondary—that is, that the primary's changes are always used rather than those from the secondary in event of a conflict. This “primary always wins” rule has the following implications:

• Operations that change data, once committed on the primary, are fully persistent and are not undone or rolled back by conflict detection and resolution.

• Data read from the primary is fully consistent. Any changes committed on the Primary (locally or from the replica) are not reverted later.

• Operations that change data on the secondary may later be reverted if the primary determines that they are in conflict.

• Individual rows read on the secondary are self-consistent at all times, each row always reflecting either a state committed by the secondary, or one committed by the primary.

• Sets of rows read on the secondary may not necessarily be consistent at a given single point in time. For NDB$EPOCH\_TRANS(), this is a transient state; for NDB$EPOCH(), it can be a persistent state.

• Assuming a period of sufficient length without any conflicts, all data on the secondary NDB Cluster (eventually) becomes consistent with the primary's data.

NDB$EPOCH() and NDB$EPOCH\_TRANS() do not require any user schema modifications, or application changes to provide conflict detection. However, careful thought must be given to the schema used, and the access patterns used, to verify that the complete system behaves within specified limits.

Each of the NDB$EPOCH() and NDB$EPOCH\_TRANS() functions can take an optional parameter; this is the number of bits to use to represent the lower 32 bits of the epoch, and should be set to no less than the value calculated as shown here:

CEIL( LOG2( TimeBetweenGlobalCheckpoints / TimeBetweenEpochs ), 1)

For the default values of these configuration parameters (2000 and 100 milliseconds, respectively), this gives a value of 5 bits, so the default value (6) should be sufficient, unless other values are used for TimeBetweenGlobalCheckpoints, TimeBetweenEpochs, or both. A value that is too small can result in false positives, while one that is too large could lead to excessive wasted space in the database.

Both NDB$EPOCH() and NDB$EPOCH\_TRANS() insert entries for conflicting rows into the relevant exceptions tables, provided that these tables have been defined according to the same exceptions table schema rules as described elsewhere in this section (see [NDB$OLD()](#_bookmark45)). You must create any exceptions table before creating the data table with which it is to be used.

As with the other conflict detection functions discussed in this section, NDB$EPOCH() and NDB $EPOCH\_TRANS() are activated by including relevant entries in the mysql.ndb\_replication table (see [ndb\_replication Table](#_bookmark41)). The roles of the primary and secondary NDB Clusters in this scenario are fully determined by mysql.ndb\_replication table entries.

Because the conflict detection algorithms employed by NDB$EPOCH() and NDB$EPOCH\_TRANS() are asymmetric, you must use different values for the server\_id entries of the primary and secondary replicas.

A conflict between DELETE operations alone is not sufficient to trigger a conflict using NDB$EPOCH() or NDB$EPOCH\_TRANS(), and the relative placement within epochs does not matter.

**Limitations** **on** **NDB$EPOCH()**

The following limitations currently apply when using NDB$EPOCH() to perform conflict detection:

• Conflicts are detected using NDB Cluster epoch boundaries, with granularity proportional to TimeBetweenEpochs (default: 100 milliseconds). The minimum conflict window is the minimum

time during which concurrent updates to the same data on both clusters always report a conflict. This is always a nonzero length of time, and is roughly proportional to 2 \* (latency + queueing + TimeBetweenEpochs). This implies that—assuming the default for TimeBetweenEpochs and ignoring any latency between clusters (as well as any queuing delays)—the minimum conflict window size is approximately 200 milliseconds. This minimum window should be considered when looking at expected application “race” patterns.

• Additional storage is required for tables using the NDB$EPOCH() and NDB$EPOCH\_TRANS() functions; from 1 to 32 bits extra space per row is required, depending on the value passed to the function.

• Conflicts between delete operations may result in divergence between the primary and secondary. When a row is deleted on both clusters concurrently, the conflict can be detected, but is not recorded, since the row is deleted. This means that further conflicts during the propagation of any subsequent realignment operations are not detected, which can lead to divergence.

Deletes should be externally serialized, or routed to one cluster only. Alternatively, a separate row should be updated transactionally with such deletes and any inserts that follow them, so that conflicts can be tracked across row deletes. This may require changes in applications.

• Only two NDB Clusters in a bidirectional “active-active” configuration are currently supported when using NDB$EPOCH() or NDB$EPOCH\_TRANS() for conflict detection.

• Tables having BLOB or TEXT columns are not currently supported with NDB$EPOCH() or NDB $EPOCH\_TRANS().

**NDB$EPOCH\_TRANS()**

NDB$EPOCH\_TRANS() extends the NDB$EPOCH() function. Conflicts are detected and handled in the same way using the “primary wins all” rule (see [NDB$EPOCH()](#_bookmark48)) but with the extra condition that any other rows updated in the same transaction in which the conflict occurred are also regarded as being in conflict. In other words, where NDB$EPOCH() realigns individual conflicting rows on the secondary, NDB$EPOCH\_TRANS() realigns conflicting transactions.

In addition, any transactions which are detectably dependent on a conflicting transaction are also regarded as being in conflict, these dependencies being determined by the contents of the secondary cluster's binary log. Since the binary log contains only data modification operations (inserts, updates, and deletes), only overlapping data modifications are used to determine dependencies between transactions.

NDB$EPOCH\_TRANS() is subject to the same conditions and limitations as NDB$EPOCH(), and in addition requires that all transaction IDs are recorded in the secondary's binary log, using --ndb-log- transaction-id set to ON. This adds a variable amount of overhead (up to 13 bytes per row).

The deprecated log\_bin\_use\_v1\_row\_events system variable, which defaults to OFF, must *not* be set to ON with NDB$EPOCH\_TRANS().

See [NDB$EPOCH()](#_bookmark48).

**NDB$EPOCH2()**

The NDB$EPOCH2() function is similar to NDB$EPOCH(), except that NDB$EPOCH2() provides for delete-delete handling with a bidirectional replication topology. In this scenario, primary and secondary roles are assigned to the two sources by setting the ndb\_slave\_conflict\_role system variable to the appropriate value on each source (usually one each of PRIMARY, SECONDARY). When this is done, modifications made by the secondary are reflected by the primary back to the secondary which then conditionally applies them.

**NDB$EPOCH2\_TRANS()**

NDB$EPOCH2\_TRANS() extends the NDB$EPOCH2() function. Conflicts are detected and handled in the same way, and assigning primary and secondary roles to the replicating clusters, but with the extra condition that any other rows updated in the same transaction in which the conflict occurred are also regarded as being in conflict. That is, NDB$EPOCH2() realigns individual conflicting rows on the secondary, while NDB$EPOCH\_TRANS() realigns conflicting transactions.

Where NDB$EPOCH() and NDB$EPOCH\_TRANS() use metadata that is specified per row, per last modified epoch, to determine on the primary whether an incoming replicated row change from the secondary is concurrent with a locally committed change; concurrent changes are regarded as conflicting, with subsequent exceptions table updates and realignment of the secondary. A problem arises when a row is deleted on the primary so there is no longer any last-modified epoch available to determine whether any replicated operations conflict, which means that conflicting delete operations are not detected. This can result in divergence, an example being a delete on one cluster which is concurrent with a delete and insert on the other; this why delete operations can be routed to only one cluster when using NDB$EPOCH() and NDB$EPOCH\_TRANS().

NDB$EPOCH2() bypasses the issue just described—storing information about deleted rows on the PRIMARY—by ignoring any delete-delete conflict, and by avoiding any potential resultant divergence as well. This is accomplished by reflecting any operation successfully applied on and replicated from the secondary back to the secondary. On its return to the secondary, it can be used to reapply an operation on the secondary which was deleted by an operation originating from the primary.

When using NDB$EPOCH2(), you should keep in mind that the secondary applies the delete from the primary, removing the new row until it is restored by a reflected operation. In theory, the subsequent

insert or update on the secondary conflicts with the delete from the primary, but in this case, we choose to ignore this and allow the secondary to “win” , in the interest of preventing divergence between the clusters. In other words, after a delete, the primary does not detect conflicts, and instead adopts the secondary's following changes immediately. Because of this, the secondary's state can revisit multiple previous committed states as it progresses to a final (stable) state, and some of these may be visible.

You should also be aware that reflecting all operations from the secondary back to the primary increases the size of the primary's logbinary log, as well as demands on bandwidth, CPU usage, and disk I/O.

Application of reflected operations on the secondary depends on the state of the target row on the secondary. Whether or not reflected changes are applied on the secondary can be tracked by checking the Ndb\_conflict\_reflected\_op\_prepare\_count and Ndb\_conflict\_reflected\_op\_discard\_count status variables. The number of changes applied is simply the difference between these two values (note that Ndb\_conflict\_reflected\_op\_prepare\_count is always greater than or equal to Ndb\_conflict\_reflected\_op\_discard\_count).

Events are applied if and only if both of the following conditions are true:

• The existence of the row—that is, whether or not it exists— is in accordance with the type of event. For delete and update operations, the row must already exist. For insert operations, the row must *not* exist.

• The row was last modified by the primary. It is possible that the modification was accomplished through the execution of a reflected operation.

If both of these conditions are not met, the reflected operation is discarded by the secondary.

**Conflict** **Resolution** **Exceptions** **Table**

To use the NDB$OLD() conflict resolution function, it is also necessary to create an exceptions table corresponding to each NDB table for which this type of conflict resolution is to be employed. This is also true when using NDB$EPOCH() or NDB$EPOCH\_TRANS(). The name of this table is that of the table for which conflict resolution is to be applied, with the string $EX appended. (For example, if the name of the original table is mytable, the name of the corresponding exceptions table name should be mytable$EX.) The syntax for creating the exceptions table is as shown here:

CREATE TABLE *original\_table*$EX (

[NDB$]server\_id INT UNSIGNED,

[NDB$]source\_server\_id INT UNSIGNED,

[NDB$]source\_epoch BIGINT UNSIGNED,

[NDB$]count INT UNSIGNED,

[NDB$OP\_TYPE ENUM('WRITE\_ROW','UPDATE\_ROW', 'DELETE\_ROW',

'REFRESH\_ROW', 'READ\_ROW') NOT NULL,]

[NDB$CFT\_CAUSE ENUM('ROW\_DOES\_NOT\_EXIST', 'ROW\_ALREADY\_EXISTS',

'DATA\_IN\_CONFLICT', 'TRANS\_IN\_CONFLICT') NOT NULL,]

[NDB$ORIG\_TRANSID BIGINT UNSIGNED NOT NULL,]

*original\_table\_pk\_columns*,

[*orig\_table\_column* |*orig\_table\_column*$OLD |*orig\_table\_column*$NEW,]

[*additional\_columns*,]

PRIMARY KEY([NDB$]server\_id, [NDB$]source\_server\_id, [NDB$]source\_epoch, [NDB$]count)

) ENGINE=NDB;

The first four columns are required. The names of the first four columns and the columns matching the original table's primary key columns are not critical; however, we suggest for reasons of clarity and consistency, that you use the names shown here for the server\_id, source\_server\_id, source\_epoch, and count columns, and that you use the same names as in the original table for the columns matching those in the original table's primary key.

If the exceptions table uses one or more of the optional columns NDB$OP\_TYPE, NDB$CFT\_CAUSE, or NDB$ORIG\_TRANSID discussed later in this section, then each of the required columns must also be named using the prefix NDB$. If desired, you can use the NDB$ prefix to name the required columns even if you do not define any optional columns, but in this case, all four of the required columns must be named using the prefix.

Following these columns, the columns making up the original table's primary key should be copied in the order in which they are used to define the primary key of the original table. The data types for the columns duplicating the primary key columns of the original table should be the same as (or larger than) those of the original columns. A subset of the primary key columns may be used.

The exceptions table must use the NDB storage engine. (An example that uses NDB$OLD() with an exceptions table is shown later in this section.)

Additional columns may optionally be defined following the copied primary key columns, but not before any of them; any such extra columns cannot be NOT NULL. NDB Cluster supports three additional, predefined optional columns NDB$OP\_TYPE, NDB$CFT\_CAUSE, and NDB$ORIG\_TRANSID, which are described in the next few paragraphs.

NDB$OP\_TYPE: This column can be used to obtain the type of operation causing the conflict. If you use this column, define it as shown here:

NDB$OP\_TYPE ENUM('WRITE\_ROW', 'UPDATE\_ROW', 'DELETE\_ROW',

'REFRESH\_ROW', 'READ\_ROW') NOT NULL

The WRITE\_ROW, UPDATE\_ROW, and DELETE\_ROW operation types represent user-initiated operations. REFRESH\_ROW operations are operations generated by conflict resolution in compensating transactions sent back to the originating cluster from the cluster that detected the conflict. READ\_ROW operations are user-initiated read tracking operations defined with exclusive row locks.

NDB$CFT\_CAUSE: You can define an optional column NDB$CFT\_CAUSE which provides the cause of the registered conflict. This column, if used, is defined as shown here:

NDB$CFT\_CAUSE ENUM('ROW\_DOES\_NOT\_EXIST', 'ROW\_ALREADY\_EXISTS',

'DATA\_IN\_CONFLICT', 'TRANS\_IN\_CONFLICT') NOT NULL

ROW\_DOES\_NOT\_EXIST can be reported as the cause for UPDATE\_ROW and WRITE\_ROW operations; ROW\_ALREADY\_EXISTS can be reported for WRITE\_ROW events. DATA\_IN\_CONFLICT is reported when a row-based conflict function detects a conflict; TRANS\_IN\_CONFLICT is reported when a transactional conflict function rejects all of the operations belonging to a complete transaction.

NDB$ORIG\_TRANSID: The NDB$ORIG\_TRANSID column, if used, contains the ID of the originating transaction. This column should be defined as follows:

NDB$ORIG\_TRANSID BIGINT UNSIGNED NOT NULL

NDB$ORIG\_TRANSID is a 64-bit value generated by NDB. This value can be used to correlate multiple exceptions table entries belonging to the same conflicting transaction from the same or different exceptions tables.

Additional reference columns which are not part of the original table's primary key can be named *colname*$OLD or *colname*$NEW. *colname*$OLD references old values in update and delete operations—that is, operations containing DELETE\_ROW events. *colname*$NEW can be used to reference new values in insert and update operations— in other words, operations using WRITE\_ROW events, UPDATE\_ROW events, or both types of events. Where a conflicting operation does not supply a value for a given reference column that is not a primary key, the exceptions table row contains either NULL, or a defined default value for that column.

 **Important**

  The mysql.ndb\_replication table is read when a data table is set up

for replication, so the row corresponding to a table to be replicated must be

 inserted into mysql.ndb\_replication *before* the table to be replicated is

created.

**Conflict** **Detection** **Status** **Variables**

Several status variables can be used to monitor conflict detection. You can see how many rows have been found in conflict by NDB$EPOCH() since this replica was last restarted from the current value of the Ndb\_conflict\_fn\_epoch system status variable.

Ndb\_conflict\_fn\_epoch\_trans provides the number of rows that have been

found directly in conflict by NDB$EPOCH\_TRANS(). Ndb\_conflict\_fn\_epoch2 and Ndb\_conflict\_fn\_epoch2\_trans show the number of rows found in conflict by NDB$EPOCH2() and NDB$EPOCH2\_TRANS(), respectively. The number of rows actually realigned, including those affected due to their membership in or dependency on the same transactions as other conflicting rows, is given by Ndb\_conflict\_trans\_row\_reject\_count.

Another server status variable Ndb\_conflict\_fn\_max provides a count of the number of times that a row was not applied on the current SQL node due to “greatest timestamp wins” conflict resolution since the last time that mysqld was started. Ndb\_conflict\_fn\_max\_del\_win provides a count of the number of times that conflict resolution based on the outcome of NDB$MAX\_DELETE\_WIN() has been applied.

NDB 8.0.30 and later provides Ndb\_conflict\_fn\_max\_ins for tracking the number of

times that “greater timestamp wins” handling has been applied to write operations (using NDB $MAX\_INS()); a count of the number of times that “same timestamp wins” handling of writes has been applied (as implemented by NDB$MAX\_DEL\_WIN\_INS()), is provided by the status variable Ndb\_conflict\_fn\_max\_del\_win\_ins.

The number of times that a row was not applied as the result of “same timestamp wins” conflict resolution on a given mysqld since the last time it was restarted is given by the global status variable Ndb\_conflict\_fn\_old. In addition to incrementing Ndb\_conflict\_fn\_old, the primary key of the row that was not used is inserted into an *exceptions* *table*, as explained elsewhere in this section.

See also NDB Cluster Status Variables.

**Examples**

The following examples assume that you have already a working NDB Cluster replication setup, as described in [Section 23.7.5, “Preparing the NDB Cluster for Replication”](#_bookmark57) , and [Section 23.7.6, “Starting](#_bookmark33) [NDB Cluster Replication (Single Replication Channel)”](#_bookmark33) .

**NDB$MAX()** **example.** Suppose you wish to enable “greatest timestamp wins” conflict resolution on table test.t1, using column mycol as the “timestamp” . This can be done using the following steps:

1. Make sure that you have started the source mysqld with --ndb-log-update-as-write=OFF.

2. On the source, perform this INSERT statement:

INSERT INTO mysql.ndb\_replication

VALUES ('test', 't1', 0, NULL, 'NDB$MAX(mycol)');

**Note**

If the ndb\_replication table does not already exist, you must create it. See [ndb\_replication Table](#_bookmark41).

Inserting a 0 into the server\_id column indicates that all SQL nodes accessing this table should use conflict resolution. If you want to use conflict resolution on a specific mysqld only, use the actual server ID.

Inserting NULL into the binlog\_type column has the same effect as inserting 0 (NBT\_DEFAULT); the server default is used.



3. Create the test.t1 table:

CREATE TABLE test.t1 (

*columns*

mycol INT UNSIGNED,

*columns*

) ENGINE=NDB;

Now, when updates are performed on this table, conflict resolution is applied, and the version of the row having the greatest value for mycol is written to the replica.

**Note**

Other binlog\_type options such as NBT\_UPDATED\_ONLY\_USE\_UPDATE ( 6) should be used to control logging on the source using the ndb\_replication table rather than by using command-line options.

**NDB$OLD()** **example.** Suppose an NDB table such as the one defined here is being replicated, and you wish to enable “same timestamp wins” conflict resolution for updates to this table:

CREATE TABLE test.t2 (

a INT UNSIGNED NOT NULL,

b CHAR(25) NOT NULL,

*columns*,

mycol INT UNSIGNED NOT NULL,

*columns*,

PRIMARY KEY pk (a, b)

) ENGINE=NDB;

The following steps are required, in the order shown:

1. First—and *prior* to creating test.t2—you must insert a row into the [mysql.ndb\_replication](#_bookmark41) table, as shown here:

INSERT INTO mysql.ndb\_replication

VALUES ('test', 't2', 0, 0, 'NDB$OLD(mycol)');

Possible values for the binlog\_type column are shown earlier in this section; in this case, we use 0 to specify that the server default logging behavior be used. The value 'NDB$OLD(mycol)' should be inserted into the conflict\_fn column.

2. Create an appropriate exceptions table for test.t2. The table creation statement shown here includes all required columns; any additional columns must be declared following these columns, and before the definition of the table's primary key.

CREATE TABLE test.t2$EX (

server\_id INT UNSIGNED,

source\_server\_id INT UNSIGNED,

source\_epoch BIGINT UNSIGNED,

count INT UNSIGNED,

INT UNSIGNED NOT NULL,

[*additional\_columns*,]

PRIMARY KEY(server\_id, source\_server\_id, source\_epoch, count)

) ENGINE=NDB;

CHAR(25) NOT NULL,

We can include additional columns for information about the type, cause, and originating transaction ID for a given conflict. We are also not required to supply matching columns for all primary key columns in the original table. This means you can create the exceptions table like this:

CREATE TABLE test.t2$EX (

NDB$server\_id INT UNSIGNED,

NDB$source\_server\_id INT UNSIGNED,

NDB$source\_epoch BIGINT UNSIGNED,

NDB$count INT UNSIGNED,



a INT UNSIGNED NOT NULL,

NDB$OP\_TYPE ENUM('WRITE\_ROW','UPDATE\_ROW', 'DELETE\_ROW',

'REFRESH\_ROW', 'READ\_ROW') NOT NULL,

NDB$CFT\_CAUSE ENUM('ROW\_DOES\_NOT\_EXIST', 'ROW\_ALREADY\_EXISTS',

'DATA\_IN\_CONFLICT', 'TRANS\_IN\_CONFLICT') NOT NULL,

NDB$ORIG\_TRANSID BIGINT UNSIGNED NOT NULL,

[*additional\_columns*,]

PRIMARY KEY(NDB$server\_id, NDB$source\_server\_id, NDB$source\_epoch, NDB$count)

) ENGINE=NDB;

**Note**

The NDB$ prefix is required for the four required columns since we included at least one of the columns NDB$OP\_TYPE, NDB$CFT\_CAUSE, or NDB $ORIG\_TRANSID in the table definition.

3. Create the table test.t2 as shown previously.

These steps must be followed for every table for which you wish to perform conflict resolution using NDB$OLD(). For each such table, there must be a corresponding row in mysql.ndb\_replication, and there must be an exceptions table in the same database as the table being replicated.

**Read** **conflict** **detection** **and** **resolution.** NDB Cluster also supports tracking of read operations, which makes it possible in circular replication setups to manage conflicts between reads of a given row in one cluster and updates or deletes of the same row in another. This example uses employee and department tables to model a scenario in which an employee is moved from one department to another on the source cluster (which we refer to hereafter as cluster *A*) while the replica cluster (hereafter *B*) updates the employee count of the employee's former department in an interleaved transaction.

The data tables have been created using the following SQL statements:

# Employee table

CREATE TABLE employee (

id INT PRIMARY KEY,

name VARCHAR(2000),

dept INT NOT NULL

) ENGINE=NDB;

# Department table

CREATE TABLE department (

id INT PRIMARY KEY,

name VARCHAR(2000),

members INT

) ENGINE=NDB;

The contents of the two tables include the rows shown in the (partial) output of the following SELECT statements:

mysql> **SELECT** **id,** **name,** **dept** **FROM** **employee;**

+---------------+------+

| id | name | dept |

+------+--------+------+

...

| 998 | Mike | 3 |

| 999 | Joe | 3 |

| 1000 | Mary | 3 |

...

+------+--------+------+

mysql> **SELECT** **id,** **name,** **members** **FROM** **department;**

+-----+-------------+---------+

| id | name | members |

+-----+-------------+---------+

...

| 3 | Old project | 24 |

...

+-----+-------------+---------+

We assume that we are already using an exceptions table that includes the four required columns (and these are used for this table's primary key), the optional columns for operation type and cause, and the original table's primary key column, created using the SQL statement shown here:

CREATE TABLE employee$EX (

NDB$server\_id INT UNSIGNED,

NDB$source\_server\_id INT UNSIGNED,

NDB$source\_epoch BIGINT UNSIGNED,

NDB$count INT UNSIGNED,

NDB$OP\_TYPE ENUM( 'WRITE\_ROW','UPDATE\_ROW', 'DELETE\_ROW',

'REFRESH\_ROW','READ\_ROW') NOT NULL,

NDB$CFT\_CAUSE ENUM( 'ROW\_DOES\_NOT\_EXIST',

'ROW\_ALREADY\_EXISTS',

'DATA\_IN\_CONFLICT',

'TRANS\_IN\_CONFLICT') NOT NULL,

id INT NOT NULL,

PRIMARY KEY(NDB$server\_id, NDB$source\_server\_id, NDB$source\_epoch, NDB$count)

) ENGINE=NDB;

Suppose there occur the two simultaneous transactions on the two clusters. On cluster *A*, we create a new department, then move employee number 999 into that department, using the following SQL statements:

BEGIN;

INSERT INTO department VALUES (4, "New project", 1);

*UPDATE* *employee* *SET* *dept* *=* *4* *WHERE* *id* *=* *999;*

COMMIT;

At the same time, on cluster *B*, another transaction reads from employee, as shown here:

BEGIN;

*SELECT* *name* *FROM* *employee* *WHERE* *id* *=* *999;*

UPDATE department SET members = members - 1 WHERE id = 3;

commit;

The conflicting transactions are not normally detected by the conflict resolution mechanism, since the conflict is between a read (SELECT) and an update operation. You can circumvent this issue by executing SET ndb\_log\_exclusive\_reads = 1 on the replica cluster. Acquiring exclusive read locks in this way causes any rows read on the source to be flagged as needing conflict resolution on the replica cluster. If we enable exclusive reads in this way prior to the logging of these transactions, the read on cluster *B* is tracked and sent to cluster *A* for resolution; the conflict on the employee row is subsequently detected and the transaction on cluster *B* is aborted.

The conflict is registered in the exceptions table (on cluster *A*) as a READ\_ROW operation (see [Conflict](#_bookmark55) [Resolution Exceptions Table](#_bookmark55), for a description of operation types), as shown here:

mysql> **SELECT** **id,** **NDB$OP\_TYPE,** **NDB$CFT\_CAUSE** **FROM** **employee$EX;**

+-------+-------------+-------------------+

| id | NDB$OP\_TYPE | NDB$CFT\_CAUSE |

+-------+-------------+-------------------+

...

| 999 | READ\_ROW | TRANS\_IN\_CONFLICT |

+-------+-------------+-------------------+

Any existing rows found in the read operation are flagged. This means that multiple rows resulting from the same conflict may be logged in the exception table, as shown by examining the effects a conflict between an update on cluster *A* and a read of multiple rows on cluster *B* from the same table in simultaneous transactions. The transaction executed on cluster *A* is shown here:

BEGIN;

INSERT INTO department VALUES (4, "New project", 0);

*UPDATE* *employee* *SET* *dept* *=* *4* *WHERE* *dept* *=* *3;*

SELECT COUNT(\*) INTO @count FROM employee WHERE dept = 4;

UPDATE department SET members = @count WHERE id = 4;

COMMIT;

Concurrently a transaction containing the statements shown here runs on cluster *B*:

|  |  |
| --- | --- |
| SET ndb\_log\_exclusive\_reads = 1; # Must be set if not already  ...  BEGIN;  *SELECT* *COUNT(\*)* *INTO* *@count* *FROM* *employee* *WHERE* *dept* *=* *3* *FOR*  UPDATE department SET members = @count WHERE id = 3;  COMMIT; | enabled  *UPDATE;* |

In this case, all three rows matching the WHERE condition in the second transaction's SELECT are read, and are thus flagged in the exceptions table, as shown here:

mysql> **SELECT** **id,** **NDB$OP\_TYPE,** **NDB$CFT\_CAUSE** **FROM** **employee$EX;**

+-------+-------------+-------------------+

| id | NDB$OP\_TYPE | NDB$CFT\_CAUSE |

+-------+-------------+-------------------+

...

|

|

|

...

+-------+-------------+-------------------+

TRANS\_IN\_CONFLICT

TRANS\_IN\_CONFLICT

TRANS\_IN\_CONFLICT

READ\_ROW

READ\_ROW

READ\_ROW

| 998

| 999

| 1000

|

|

|

|

|

|

Read tracking is performed on the basis of existing rows only. A read based on a given condition track conflicts only of any rows that are *found* and not of any rows that are inserted in an interleaved transaction. This is similar to how exclusive row locking is performed in a single instance of NDB

Cluster.

**Insert** **conflict** **detection** **and** **resolution** **example** **(NDB** **8.0.30** **and** **later).** The following example illustrates the use of the insert conflict detection functions added in NDB 8.0.30. We assume that we are replicating two tables t1 and t2 in database test, and that we wish to use insert conflict detection with NDB$MAX\_INS() for t1 and NDB$MAX\_DEL\_WIN\_INS() for t2. The two data tables are not created until later in the setup process.

Setting up insert conflict resolution is similar to setting up other conflict detection and resolution algorithms as shown in the previous examples. If the mysql.ndb\_replication table used to configure binary logging and conflict resolution, does not already exist, it is first necessary to create it, as shown here:

CREATE TABLE mysql.ndb\_replication (

db VARBINARY(63),

table\_name VARBINARY(63),

server\_id INT UNSIGNED,

binlog\_type INT UNSIGNED,

conflict\_fn VARBINARY(128),

PRIMARY KEY USING HASH (db, table\_name, server\_id)

) ENGINE=NDB

PARTITION BY KEY(db,table\_name);

The ndb\_replication table acts on a per-table basis; that is, we need to insert a row containing table information, a binlog\_type value, the conflict resolution function to be employed, and the name of the timestamp column (X) for each table to be set up, like this:

INSERT INTO mysql.ndb\_replication VALUES ("test", "t1", 0, 7, "NDB$MAX\_INS(X)");

INSERT INTO mysql.ndb\_replication VALUES ("test", "t2", 0, 7, "NDB$MAX\_DEL\_WIN\_INS(X)");

Here we have set the binlog\_type as NBT\_FULL\_USE\_UPDATE (7) which means that full rows are always logged. See [ndb\_replication Table](#_bookmark41), for other possible values.

You can also create an exceptions table corresponding to each NDB table for which conflict resolution is to be employed. An exceptions table records all rows rejected by the conflict resolution function for

a given table. Exceptions tables for replication conflict detection for tables t1 and t2 can be created using the following two SQL statements:

CREATE TABLE `t1$EX` (

NDB$server\_id INT UNSIGNED,

NDB$master\_server\_id INT UNSIGNED,

NDB$master\_epoch BIGINT UNSIGNED,

NDB$count INT UNSIGNED,

NDB$OP\_TYPE ENUM('WRITE\_ROW', 'UPDATE\_ROW', 'DELETE\_ROW',

'REFRESH\_ROW', 'READ\_ROW') NOT NULL,

NDB$CFT\_CAUSE ENUM('ROW\_DOES\_NOT\_EXIST', 'ROW\_ALREADY\_EXISTS',

'DATA\_IN\_CONFLICT', 'TRANS\_IN\_CONFLICT') NOT NULL,

a INT NOT NULL,

PRIMARY KEY(NDB$server\_id, NDB$master\_server\_id,

NDB$master\_epoch, NDB$count)

) ENGINE=NDB;

CREATE TABLE `t2$EX` (

NDB$server\_id INT UNSIGNED,

NDB$master\_server\_id INT UNSIGNED,

NDB$master\_epoch BIGINT UNSIGNED,

NDB$count INT UNSIGNED,

NDB$OP\_TYPE ENUM('WRITE\_ROW', 'UPDATE\_ROW', 'DELETE\_ROW',

'REFRESH\_ROW', 'READ\_ROW') NOT NULL,

NDB$CFT\_CAUSE ENUM( 'ROW\_DOES\_NOT\_EXIST', 'ROW\_ALREADY\_EXISTS',

'DATA\_IN\_CONFLICT', 'TRANS\_IN\_CONFLICT') NOT NULL,

a INT NOT NULL,

PRIMARY KEY(NDB$server\_id, NDB$master\_server\_id,

NDB$master\_epoch, NDB$count)

) ENGINE=NDB;

Finally, after creating the exception tables just shown, you can create the data tables to be replicated and subject to conflict resolution control, using the following two SQL statements:

CREATE TABLE t1 (

a INT PRIMARY KEY,

b VARCHAR(32),

X INT UNSIGNED

) ENGINE=NDB;

CREATE TABLE t2 (

a INT PRIMARY KEY,

b VARCHAR(32),

X INT UNSIGNED

) ENGINE=NDB;

For each table, the X column is used as the timestamp column.

Once created on the source, t1 and t2 are replicated and can be assumed to exist on both the source and the replica. In the remainder of this example, we use mysqlS> to indicate a mysql client connected to the source, and mysqlR> to indicate a mysql client running on the replica.

First we insert one row each into the tables on the source, like this:

mysqlS> **INSERT** **INTO** **t1** **VALUES** **(1,** **'Initial** **X=1',** **1);**

Query OK, 1 row affected (0.01 sec)

mysqlS> **INSERT** **INTO** **t2** **VALUES** **(1,** **'Initial** **X=1',** **1);**

Query OK, 1 row affected (0.01 sec)

We can be certain that these two rows are replicated without causing any conflicts, since the tables on the replica did not contain any rows prior to issuing the INSERT statements on the source. We can verify this by selecting from the tables on the replica as shown here:

mysqlR> **TABLE** **t1** **ORDER** **BY** **a;**

+---+-------------+------+

| a | b | X |

+---+-------------+------+

| 1 | Initial X=1 | 1 |

+---+-------------+------+

1 row in set (0.00 sec)

mysqlR> **TABLE** **t2** **ORDER** **BY** **a;**

+---+-------------+------+

| a | b | X |

+---+-------------+------+

| 1 | Initial X=1 | 1 |

+---+-------------+------+

1 row in set (0.00 sec)

Next, we insert new rows into the tables on the replica, like this:

mysqlR> **INSERT** **INTO** **t1** **VALUES** **(2,** **'Replica** **X=2',** **2);**

Query OK, 1 row affected (0.01 sec)

mysqlR> **INSERT** **INTO** **t2** **VALUES** **(2,** **'Replica** **X=2',** **2);**

Query OK, 1 row affected (0.01 sec)

Now we insert conflicting rows into the tables on the source having greater timestamp (X) column values, using the statements shown here:

mysqlS> **INSERT** **INTO** **t1** **VALUES** **(2,** **'Source** **X=20',** **20);**

Query OK, 1 row affected (0.01 sec)

mysqlS> **INSERT** **INTO** **t2** **VALUES** **(2,** **'Source** **X=20',** **20);**

Query OK, 1 row affected (0.01 sec)

Now we observe the results by selecting (again) from both tables on the replica, as shown here:

mysqlR> **TABLE** **t1** **ORDER** **BY** **a;**

+---+-------------+-------+

| a | b | X |

+---+-------------+-------+

| 1 | Initial X=1 | 1 |

+---+-------------+-------+

| 2 | Source X=20 | 20 |

+---+-------------+-------+

2 rows in set (0.00 sec)

mysqlR> **TABLE** **t2** **ORDER** **BY** **a;**

+---+-------------+-------+

| a | b | X |

+---+-------------+-------+

| 1 | Initial X=1 | 1 |

+---+-------------+-------+

| 1 | Source X=20 | 20 |

+---+-------------+-------+

2 rows in set (0.00 sec)

The rows inserted on the source, having greater timestamps than those in the conflicting rows on the replica, have replaced those rows. On the replica, we next insert two new rows which do not conflict with any existing rows in t1 or t2, like this:

mysqlR> **INSERT** **INTO** **t1** **VALUES** **(3,** **'Slave** **X=30',** **30);**

Query OK, 1 row affected (0.01 sec)

mysqlR> **INSERT** **INTO** **t2** **VALUES** **(3,** **'Slave** **X=30',** **30);**

Query OK, 1 row affected (0.01 sec)

Inserting more rows on the source with the same primary key value (3) brings about conflicts as before, but this time we use a value for the timestamp column less than that in same column in the conflicting rows on the replica.

mysqlS> **INSERT** **INTO** **t1** **VALUES** **(3,** **'Source** **X=3',** **3);**

Query OK, 1 row affected (0.01 sec)

mysqlS> **INSERT** **INTO** **t2** **VALUES** **(3,** **'Source** **X=3',** **3);**

Query OK, 1 row affected (0.01 sec)

We can see by querying the tables that both inserts from the source were rejected by the replica, and the rows inserted on the replica previously have not been overwritten, as shown here in the mysql client on the replica:

mysqlR> **TABLE** **t1** **ORDER** **BY** **a;**

+---+--------------+-------+

| a | b | X |

+---+--------------+-------+

| 1 | Initial X=1 | 1 |

+---+--------------+-------+

| 2 | Source X=20 | 20 |

+---+--------------+-------+

| 3 | Replica X=30 | 30 |

+---+--------------+-------+

3 rows in set (0.00 sec)

mysqlR> **TABLE** **t2** **ORDER** **BY** **a;**

+---+--------------+-------+

| a | b | X |

+---+--------------+-------+

| 1 | Initial X=1 | 1 |

+---+--------------+-------+

| 2 | Source X=20 | 20 |

+---+--------------+-------+

| 3 | Replica X=30 | 30 |

+---+--------------+-------+

3 rows in set (0.00 sec)

You can see information about the rows that were rejected in the exception tables, as shown here:

mysqlR> **SELECT** **NDB$server\_id,** **NDB$master\_server\_id,** **NDB$count,**

> **NDB$OP\_TYPE,** **NDB$CFT\_CAUSE,** **a**

> **FROM** **t1$EX**

> **ORDER** **BY** **NDB$count\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

NDB$server\_id : 2

NDB$master\_server\_id: 1

NDB$count : 1

NDB$OP\_TYPE : WRITE\_ROW

NDB$CFT\_CAUSE : DATA\_IN\_CONFLICT

a : 3

1 row in set (0.00 sec)

mysqlR> **SELECT** **NDB$server\_id,** **NDB$master\_server\_id,** **NDB$count,**

> **NDB$OP\_TYPE,** **NDB$CFT\_CAUSE,** **a**

> **FROM** **t2$EX**

> **ORDER** **BY** **NDB$count\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

NDB$server\_id : 2

NDB$master\_server\_id: 1

NDB$count : 1

NDB$OP\_TYPE : WRITE\_ROW

NDB$CFT\_CAUSE : DATA\_IN\_CONFLICT

a : 3

1 row in set (0.00 sec)

As we saw earlier, no other rows inserted on the source were rejected by the replica, only those rows having a lesser timestamp value than the rows in conflict on the replica.

**23.8** **NDB** **Cluster** **Release** **Notes**

Changes in NDB Cluster releases are documented separately from this reference manual; you can find release notes for the changes in each NDB Cluster 8.0 release at [NDB 8.0 Release Notes](https://dev.mysql.com/doc/relnotes/mysql-cluster/8.0/en/).

You can obtain release notes for older versions of NDB Cluster from [NDB Cluster Release Notes](https://dev.mysql.com/doc/index-cluster.html#cluster-relnotes).



Chapter 24 Partitioning

**Table** **of** **Contents**

[24.1 Overview Partitioning MySQL](#_bookmark70)ofin [4732](#_bookmark70)

[24.2 Partitioning Types](#_bookmark71) [4735](#_bookmark71)

[24.2.1 RANGE Partitioning](#_bookmark72) [4736](#_bookmark72)

[24.2.2 LIST Partitioning](#_bookmark73) [4740](#_bookmark73)

[24.2.3 COLUMNS Partitioning](#_bookmark74) [4743](#_bookmark74)

[24.2.4 HASH Partitioning](#_bookmark75) [4750](#_bookmark75)

[24.2.5 KEY Partitioning](#_bookmark37) [4753](#_bookmark37)

[24.2.6 Subpartitioning](#_bookmark76) [4754](#_bookmark76)

[24.2.7 How MySQL Partitioning Handles NULL](#_bookmark77) [4756](#_bookmark77)

[24.3 Partition Management](#_bookmark78) [4760](#_bookmark78)

[24.3.1 Management RANGE LIST Partitions](#_bookmark79)ofand [4761](#_bookmark79)

[24.3.2 Management HASH KEY Partitions](#_bookmark80)ofand [4767](#_bookmark80)

[24.3.3 Exchanging Partitions Subpartitions Tables](#_bookmark81)andwith [4768](#_bookmark81)

24.3.4 Maintenance of Partitions 4775

24.3.5 Obtaining Information About Partitions 4776

24.4 Partition Pruning 4778

24.5 Partition Selection 4781

24.6 Restrictions and Limitations on Partitioning 4787

24.6.1 Partitioning Keys, Primary Keys, and Unique Keys 4793

24.6.2 Partitioning Limitations Relating to Storage Engines 4796

24.6.3 Partitioning Limitations Relating to Functions 4797

This chapter discusses *user-defined* *partitioning*.

**Note**

Table partitioning differs from partitioning as used by window functions. For information about window functions, see Section 12.21, “Window Functions” .

In MySQL 8.0, partitioning support is provided by the InnoDB and NDB storage engines.

MySQL 8.0 does not currently support partitioning of tables using any storage engine other than InnoDB or NDB, such as MyISAM. An attempt to create a partitioned tables using a storage engine that does not supply native partitioning support fails with [ER\_CHECK\_NOT\_IMPLEMENTED](https://dev.mysql.com/doc/mysql-errors/8.0/en/server-error-reference.html#error_er_check_not_implemented).

MySQL 8.0 Community binaries provided by Oracle include partitioning support provided by the InnoDB and NDB storage engines. For information about partitioning support offered in MySQL Enterprise Edition binaries, see Chapter 30, *MySQL* *Enterprise* *Edition*.

If you are compiling MySQL 8.0 from source, configuring the build with InnoDB support is sufficient to produce binaries with partition support for InnoDB tables. For more information, see Section 2.8, “Installing MySQL from Source” .

Nothing further needs to be done to enable partitioning support by InnoDB (for example, no special entries are required in the my.cnf file).

It is not possible to disable partitioning support by the InnoDB storage engine.

See [Section 24.1, “Overview of Partitioning in MySQL”](#_bookmark70) , for an introduction to partitioning and partitioning concepts.

Several types of partitioning are supported, as well as subpartitioning; see [Section 24.2, “Partitioning](#_bookmark71) [Types”](#_bookmark71) , and [Section 24.2.6, “Subpartitioning”](#_bookmark76) .

[Section 24.3, “Partition Management”](#_bookmark78) , covers methods of adding, removing, and altering partitions in existing partitioned tables.

Section 24.3.4, “Maintenance of Partitions” , discusses table maintenance commands for use with partitioned tables.

The PARTITIONS table in the INFORMATION\_SCHEMA database provides information about partitions and partitioned tables. See Section 26.3.21, “The INFORMATION\_SCHEMA PARTITIONS Table” , for more information; for some examples of queries against this table, see [Section 24.2.7, “How MySQL](#_bookmark77) [Partitioning Handles NULL”](#_bookmark77) .

For known issues with partitioning in MySQL 8.0, see Section 24.6, “Restrictions and Limitations on Partitioning” .

You may also find the following resources to be useful when working with partitioned tables.

**Additional** **Resources.** Other sources of information about user-defined partitioning in MySQL

include the following:

• [MySQL Partitioning Forum](https://forums.mysql.com/list.php?106)

This is the official discussion forum for those interested in or experimenting with MySQL Partitioning technology. It features announcements and updates from MySQL developers and others. It is monitored by members of the Partitioning Development and Documentation Teams.

• [Mikael Ronström's Blog](http://mikaelronstrom.blogspot.com/)

MySQL Partitioning Architect and Lead Developer Mikael Ronström frequently posts articles here concerning his work with MySQL Partitioning and NDB Cluster.

• [PlanetMySQL](http://www.planetmysql.org/)

A MySQL news site featuring MySQL-related blogs, which should be of interest to anyone using my MySQL. We encourage you to check here for links to blogs kept by those working with MySQL Partitioning, or to have your own blog added to those covered.

**24.1** **Overview** **of** **Partitioning** **in** **MySQL**

This section provides a conceptual overview of partitioning in MySQL 8.0.

For information on partitioning restrictions and feature limitations, see Section 24.6, “Restrictions and Limitations on Partitioning” .

The SQL standard does not provide much in the way of guidance regarding the physical aspects of data storage. The SQL language itself is intended to work independently of any data structures or media underlying the schemas, tables, rows, or columns with which it works. Nonetheless, most advanced database management systems have evolved some means of determining the physical location to be used for storing specific pieces of data in terms of the file system, hardware or even both. In MySQL, the InnoDB storage engine has long supported the notion of a tablespace (see Section 15.6.3, “Tablespaces”), and the MySQL Server, even prior to the introduction of partitioning, could be configured to employ different physical directories for storing different databases (see Section 8.12.2, “Using Symbolic Links” , for an explanation of how this is done).

*Partitioning* takes this notion a step further, by enabling you to distribute portions of individual tables across a file system according to rules which you can set largely as needed. In effect, different portions of a table are stored as separate tables in different locations. The user-selected rule by which the division of data is accomplished is known as a *partitioning* *function*, which in MySQL can be the modulus, simple matching against a set of ranges or value lists, an internal hashing function, or a linear hashing function. The function is selected according to the partitioning type specified by the user, and takes as its parameter the value of a user-supplied expression. This expression can be a column value,

a function acting on one or more column values, or a set of one or more column values, depending on the type of partitioning that is used.

In the case of RANGE, LIST, and [LINEAR] HASH partitioning, the value of the partitioning column is passed to the partitioning function, which returns an integer value representing the number of the partition in which that particular record should be stored. This function must be nonconstant and nonrandom. It may not contain any queries, but may use an SQL expression that is valid in MySQL, as long as that expression returns either NULL or an integer *intval* such that

-MAXVALUE <= *intval* <= MAXVALUE

(MAXVALUE is used to represent the least upper bound for the type of integer in question. -MAXVALUE represents the greatest lower bound.)

For [LINEAR] KEY, RANGE COLUMNS, and LIST COLUMNS partitioning, the partitioning expression consists of a list of one or more columns.

For [LINEAR] KEY partitioning, the partitioning function is supplied by MySQL.

For more information about permitted partitioning column types and partitioning functions, see [Section 24.2, “Partitioning Types”](#_bookmark71) , as well as Section 13.1.20, “CREATE TABLE Statement” , which provides partitioning syntax descriptions and additional examples. For information about restrictions on partitioning functions, see Section 24.6.3, “Partitioning Limitations Relating to Functions” .

This is known as *horizontal* *partitioning*—that is, different rows of a table may be assigned to different physical partitions. MySQL 8.0 does not support *vertical* *partitioning*, in which different columns of a table are assigned to different physical partitions. There are no plans at this time to introduce vertical partitioning into MySQL.

For creating partitioned tables, you must use a storage engine that supports them. In MySQL 8.0, all partitions of the same partitioned table must use the same storage engine. However, there is nothing preventing you from using different storage engines for different partitioned tables on the same MySQL server or even in the same database.

In MySQL 8.0, the only storage engines that support partitioning are InnoDB and NDB. Partitioning cannot be used with storage engines that do not support it; these include the MyISAM, MERGE, CSV, and FEDERATED storage engines.

Partitioning by KEY or LINEAR KEY is possible with NDB, but other types of user-defined partitioning are not supported for tables using this storage engine. In addition, an NDB table that employs user- defined partitioning must have an explicit primary key, and any columns referenced in the table's partitioning expression must be part of the primary key. However, if no columns are listed in the PARTITION BY KEY or PARTITION BY LINEAR KEY clause of the CREATE TABLE or ALTER TABLE statement used to create or modify a user-partitioned NDB table, then the table is not required to have an explicit primary key. For more information, see Section 23.2.7.1, “Noncompliance with SQL Syntax in NDB Cluster” .

When creating a partitioned table, the default storage engine is used just as when creating any other table; to override this behavior, it is necessary only to use the [STORAGE] ENGINE option just as you would for a table that is not partitioned. The target storage engine must provide native partitioning support, or the statement fails. You should keep in mind that [STORAGE] ENGINE (and other table options) need to be listed *before* any partitioning options are used in a CREATE TABLE statement. This example shows how to create a table that is partitioned by hash into 6 partitions and which uses the InnoDB storage engine (regardless of the value of default\_storage\_engine):

CREATE TABLE ti (id INT, amount DECIMAL(7,2), tr\_date DATE)

ENGINE=INNODB

PARTITION BY HASH( MONTH(tr\_date) )

PARTITIONS 6;

Each PARTITION clause can include a [STORAGE] ENGINE option, but in MySQL 8.0 this has no effect.



Unless otherwise specified, the remaining examples in this discussion assume that default\_storage\_engine is InnoDB.

**Important**

Partitioning applies to all data and indexes of a table; you cannot partition only the data and not the indexes, or vice versa, nor can you partition only a portion of the table.

Data and indexes for each partition can be assigned to a specific directory using the DATA DIRECTORY and INDEX DIRECTORY options for the PARTITION clause of the CREATE TABLE statement used to create the partitioned table.

Only the DATA DIRECTORY option is supported for individual partitions and subpartitions of InnoDB tables. As of MySQL 8.0.21, the directory specified in a DATA DIRECTORY clause must be known to InnoDB. For more information, see Using the DATA DIRECTORY Clause.

All columns used in the table's partitioning expression must be part of every unique key that the table may have, including any primary key. This means that a table such as this one, created by the following SQL statement, cannot be partitioned:

CREATE TABLE tnp (

id INT NOT NULL AUTO\_INCREMENT,

ref BIGINT NOT NULL,

name VARCHAR(255),

PRIMARY KEY pk (id),

UNIQUE KEY uk (name)

);

Because the keys pk and uk have no columns in common, there are no columns available for use in a partitioning expression. Possible workarounds in this situation include adding the name column to the table's primary key, adding the id column to uk, or simply removing the unique key altogether. See Section 24.6.1, “Partitioning Keys, Primary Keys, and Unique Keys” , for more information.

In addition, MAX\_ROWS and MIN\_ROWS can be used to determine the maximum and minimum numbers of rows, respectively, that can be stored in each partition. See [Section 24.3, “Partition Management”](#_bookmark78) , for more information on these options.

The MAX\_ROWS option can also be useful for creating NDB Cluster tables with extra partitions, thus allowing for greater storage of hash indexes. See the documentation for the DataMemory data node configuration parameter, as well as Section 23.2.2, “NDB Cluster Nodes, Node Groups, Fragment Replicas, and Partitions” , for more information.

Some advantages of partitioning are listed here:

• Partitioning makes it possible to store more data in one table than can be held on a single disk or file system partition.

• Data that loses its usefulness can often be easily removed from a partitioned table by dropping the partition (or partitions) containing only that data. Conversely, the process of adding new data can in some cases be greatly facilitated by adding one or more new partitions for storing specifically that data.

• Some queries can be greatly optimized in virtue of the fact that data satisfying a given WHERE clause can be stored only on one or more partitions, which automatically excludes any remaining partitions from the search. Because partitions can be altered after a partitioned table has been created, you can reorganize your data to enhance frequent queries that may not have been often used when the partitioning scheme was first set up. This ability to exclude non-matching partitions (and thus any rows they contain) is often referred to as *partition* *pruning*. For more information, see Section 24.4, “Partition Pruning” .

In addition, MySQL supports explicit partition selection for queries. For example, SELECT \* FROM t PARTITION (p0,p1) WHERE c < 5 selects only those rows in partitions p0 and p1 that

match the WHERE condition. In this case, MySQL does not check any other partitions of table t; this can greatly speed up queries when you already know which partition or partitions you wish to examine. Partition selection is also supported for the data modification statements DELETE, INSERT, REPLACE, UPDATE, and LOAD DATA, LOAD XML. See the descriptions of these statements for more information and examples.

**24.2** **Partitioning** **Types**

This section discusses the types of partitioning which are available in MySQL 8.0. These include the types listed here:

• **RANGE** **partitioning.** This type of partitioning assigns rows to partitions based on column values falling within a given range. See [Section 24.2.1, “RANGE Partitioning”](#_bookmark72) . For information about an extension to this type, RANGE COLUMNS, see [Section 24.2.3.1, “RANGE COLUMNS partitioning”](#_bookmark82) .

• **LIST** **partitioning.** Similar to partitioning by RANGE, except that the partition is selected based on columns matching one of a set of discrete values. See [Section 24.2.2, “LIST Partitioning”](#_bookmark73) . For information about an extension to this type, LIST COLUMNS, see [Section 24.2.3.2, “LIST COLUMNS](#_bookmark83) [partitioning”](#_bookmark83) .

• **HASH** **partitioning.** With this type of partitioning, a partition is selected based on the value returned by a user-defined expression that operates on column values in rows to be inserted into the table. The function may consist of any expression valid in MySQL that yields an integer value. See [Section 24.2.4, “HASH Partitioning”](#_bookmark75) .

An extension to this type, LINEAR HASH, is also available, see [Section 24.2.4.1, “LINEAR HASH](#_bookmark84) [Partitioning”](#_bookmark84) .

• **KEY** **partitioning.** This type of partitioning is similar to partitioning by HASH, except that only one or more columns to be evaluated are supplied, and the MySQL server provides its own hashing function. These columns can contain other than integer values, since the hashing function supplied by MySQL guarantees an integer result regardless of the column data type. An extension to this type, LINEAR KEY, is also available. See [Section 24.2.5, “KEY Partitioning”](#_bookmark37) .

A very common use of database partitioning is to segregate data by date. Some database systems support explicit date partitioning, which MySQL does not implement in 8.0. However, it is not difficult in MySQL to create partitioning schemes based on DATE, TIME, or DATETIME columns, or based on expressions making use of such columns.

When partitioning by KEY or LINEAR KEY, you can use a DATE, TIME, or DATETIME column as the partitioning column without performing any modification of the column value. For example, this table creation statement is perfectly valid in MySQL:

CREATE TABLE members (

firstname VARCHAR(25) NOT NULL,

lastname VARCHAR(25) NOT NULL,

username VARCHAR(16) NOT NULL,

email VARCHAR(35),

joined DATE NOT NULL

)

PARTITION BY KEY(joined)

PARTITIONS 6;

In MySQL 8.0, it is also possible to use a DATE or DATETIME column as the partitioning column using RANGE COLUMNS and LIST COLUMNS partitioning.

Other partitioning types require a partitioning expression that yields an integer value or NULL. If you wish to use date-based partitioning by RANGE, LIST, HASH, or LINEAR HASH, you can simply employ a function that operates on a DATE, TIME, or DATETIME column and returns such a value, as shown here:

CREATE TABLE members (

firstname VARCHAR(25) NOT NULL,

lastname VARCHAR(25) NOT NULL,

username VARCHAR(16) NOT NULL,

email VARCHAR(35),

joined DATE NOT NULL

)

PARTITION BY RANGE( YEAR(joined) ) (

PARTITION p0 VALUES LESS THAN (1960),

PARTITION p1 VALUES LESS THAN (1970),

PARTITION p2 VALUES LESS THAN (1980),

PARTITION p3 VALUES LESS THAN (1990),

PARTITION p4 VALUES LESS THAN MAXVALUE

);

Additional examples of partitioning using dates may be found in the following sections of this chapter:

• [Section 24.2.1, “RANGE Partitioning”](#_bookmark72)

• [Section 24.2.4, “HASH Partitioning”](#_bookmark75)

• [Section 24.2.4.1, “LINEAR HASH Partitioning”](#_bookmark84)

For more complex examples of date-based partitioning, see the following sections:

• Section 24.4, “Partition Pruning”

• [Section 24.2.6, “Subpartitioning”](#_bookmark76)

MySQL partitioning is optimized for use with the TO\_DAYS(), YEAR(), and TO\_SECONDS() functions. However, you can use other date and time functions that return an integer or NULL, such as WEEKDAY(), DAYOFYEAR(), or MONTH(). See Section 12.7, “Date and Time Functions” , for more information about such functions.

It is important to remember—regardless of the type of partitioning that you use—that partitions are always numbered automatically and in sequence when created, starting with 0. When a new row is inserted into a partitioned table, it is these partition numbers that are used in identifying the correct partition. For example, if your table uses 4 partitions, these partitions are numbered 0, 1, 2, and 3. For the RANGE and LIST partitioning types, it is necessary to ensure that there is a partition defined for each partition number. For HASH partitioning, the user-supplied expression must evaluate to an integer value. For KEY partitioning, this issue is taken care of automatically by the hashing function which the MySQL server employs internally.

Names of partitions generally follow the rules governing other MySQL identifiers, such as those for tables and databases. However, you should note that partition names are not case-sensitive. For example, the following CREATE TABLE statement fails as shown:

mysql> **CREATE** **TABLE** **t2** **(val** **INT)**

-> **PARTITION** **BY** **LIST(val)(**

|  |  |
| --- | --- |
| -> -> -> **);**  ERROR 1488 | **PARTITION** **mypart** **VALUES** **IN** **(1,3,5),**  **PARTITION** **MyPart** **VALUES** **IN** **(2,4,6)**  (HY000): Duplicate partition name mypart |

Failure occurs because MySQL sees no difference between the partition names mypart and MyPart.

When you specify the number of partitions for the table, this must be expressed as a positive, nonzero integer literal with no leading zeros, and may not be an expression such as 0.8E+01 or 6-2, even if it evaluates to an integer value. Decimal fractions are not permitted.

In the sections that follow, we do not necessarily provide all possible forms for the syntax that can be used for creating each partition type; for this information, see Section 13.1.20, “CREATE TABLE

Statement” .

**24.2.1** **RANGE** **Partitioning**



A table that is partitioned by range is partitioned in such a way that each partition contains rows for which the partitioning expression value lies within a given range. Ranges should be contiguous but not overlapping, and are defined using the VALUES LESS THAN operator. For the next few examples, suppose that you are creating a table such as the following to hold personnel records for a chain of 20 video stores, numbered 1 through 20:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT NOT NULL,

store\_id INT NOT NULL

);

**Note**

The employees table used here has no primary or unique keys. While the examples work as shown for purposes of the present discussion, you should keep in mind that tables are extremely likely in practice to have primary keys, unique keys, or both, and that allowable choices for partitioning columns depend on the columns used for these keys, if any are present. For a discussion of these issues, see Section 24.6.1, “Partitioning Keys, Primary Keys, and Unique Keys” .

This table can be partitioned by range in a number of ways, depending on your needs. One way would be to use the store\_id column. For instance, you might decide to partition the table 4 ways by adding a PARTITION BY RANGE clause as shown here:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT NOT NULL,

store\_id INT NOT NULL

)

PARTITION BY RANGE (store\_id) (

PARTITION p0 VALUES LESS THAN (6),

PARTITION p1 VALUES LESS THAN (11),

PARTITION p2 VALUES LESS THAN (16),

PARTITION p3 VALUES LESS THAN (21)

);

In this partitioning scheme, all rows corresponding to employees working at stores 1 through 5 are stored in partition p0, to those employed at stores 6 through 10 are stored in partition p1, and so on. Each partition is defined in order, from lowest to highest. This is a requirement of the PARTITION BY RANGE syntax; you can think of it as being analogous to a series of if ... elseif ... statements in C or Java in this regard.

It is easy to determine that a new row containing the data (72, 'Mitchell', 'Wilson',

'1998-06-25', DEFAULT, 7, 13) is inserted into partition p2, but what happens when your chain

adds a 21st store? Under this scheme, there is no rule that covers a row whose store\_id is greater

than 20, so an error results because the server does not know where to place it. You can keep this

from occurring by using a “catchall” VALUES LESS THAN clause in the CREATE TABLE statement that

provides for all values greater than the highest value explicitly named:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT NOT NULL,

store\_id INT NOT NULL

)

PARTITION BY RANGE (store\_id) (

PARTITION p0 VALUES LESS THAN (6),

PARTITION p1 VALUES LESS THAN (11),

PARTITION p2 VALUES LESS THAN (16),

*PARTITION* *p3* *VALUES* *LESS* *THAN* *MAXVALUE*

);

(As with the other examples in this chapter, we assume that the default storage engine is InnoDB.)

Another way to avoid an error when no matching value is found is to use the IGNORE keyword as part of the INSERT statement. For an example, see [Section 24.2.2, “LIST Partitioning”](#_bookmark73) .

MAXVALUE represents an integer value that is always greater than the largest possible integer value (in mathematical language, it serves as a *least* *upper* *bound*). Now, any rows whose store\_id column value is greater than or equal to 16 (the highest value defined) are stored in partition p3. At some point in the future—when the number of stores has increased to 25, 30, or more—you can use an ALTER TABLE statement to add new partitions for stores 21-25, 26-30, and so on (see [Section 24.3, “Partition](#_bookmark78) [Management”](#_bookmark78) , for details of how to do this).

In much the same fashion, you could partition the table based on employee job codes—that is, based on ranges of job\_code column values. For example—assuming that two-digit job codes are used for regular (in-store) workers, three-digit codes are used for office and support personnel, and four-digit codes are used for management positions—you could create the partitioned table using the following statement:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT NOT NULL,

store\_id INT NOT NULL

)

PARTITION BY RANGE (job\_code) (

PARTITION p0 VALUES LESS THAN (100),

PARTITION p1 VALUES LESS THAN (1000),

PARTITION p2 VALUES LESS THAN (10000)

);

In this instance, all rows relating to in-store workers would be stored in partition p0, those relating to office and support staff in p1, and those relating to managers in partition p2.

It is also possible to use an expression in VALUES LESS THAN clauses. However, MySQL must be able to evaluate the expression's return value as part of a LESS THAN (<) comparison.

Rather than splitting up the table data according to store number, you can use an expression based on one of the two DATE columns instead. For example, let us suppose that you wish to partition based on the year that each employee left the company; that is, the value of YEAR(separated). An example of a CREATE TABLE statement that implements such a partitioning scheme is shown here:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT,

store\_id INT

)

PARTITION BY RANGE ( YEAR(separated) ) (

PARTITION p0 VALUES LESS THAN (1991),

PARTITION p1 VALUES LESS THAN (1996),

PARTITION p2 VALUES LESS THAN (2001),

PARTITION p3 VALUES LESS THAN MAXVALUE

);

In this scheme, for all employees who left before 1991, the rows are stored in partition p0; for those who left in the years 1991 through 1995, in p1; for those who left in the years 1996 through 2000, in p2; and for any workers who left after the year 2000, in p3.

It is also possible to partition a table by RANGE, based on the value of a TIMESTAMP column, using the UNIX\_TIMESTAMP() function, as shown in this example:

CREATE TABLE quarterly\_report\_status (

report\_id INT NOT NULL,

report\_status VARCHAR(20) NOT NULL,

report\_updated TIMESTAMP NOT NULL DEFAULT CURRENT\_TIMESTAMP ON UPDATE CURRENT\_TIMESTAMP

)

PARTITION BY RANGE ( UNIX\_TIMESTAMP(report\_updated) ) (

PARTITION p0 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-01-01 00:00:00') ),

PARTITION p1 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-04-01 00:00:00') ),

PARTITION p2 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-07-01 00:00:00') ),

PARTITION p3 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-10-01 00:00:00') ),

PARTITION p4 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-01-01 00:00:00') ),

PARTITION p5 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-04-01 00:00:00') ),

PARTITION p6 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-07-01 00:00:00') ),

PARTITION p7 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-10-01 00:00:00') ),

PARTITION p8 VALUES LESS THAN ( UNIX\_TIMESTAMP('2010-01-01 00:00:00') ),

PARTITION p9 VALUES LESS THAN (MAXVALUE)

);

Any other expressions involving TIMESTAMP values are not permitted. (See Bug #42849.) Range partitioning is particularly useful when one or more of the following conditions is true:

• You want or need to delete “old” data. If you are using the partitioning scheme shown previously for the employees table, you can simply use ALTER TABLE employees DROP PARTITION p0; to delete all rows relating to employees who stopped working for the firm prior to 1991. (See Section 13.1.9, “ALTER TABLE Statement” , and [Section 24.3, “Partition Management”](#_bookmark78) , for more information.) For a table with a great many rows, this can be much more efficient than running a DELETE query such as DELETE FROM employees WHERE YEAR(separated) <= 1990;.

• You want to use a column containing date or time values, or containing values arising from some other series.

• You frequently run queries that depend directly on the column used for partitioning the table. For example, when executing a query such as EXPLAIN SELECT COUNT(\*) FROM employees WHERE separated BETWEEN '2000-01-01' AND '2000-12-31' GROUP BY store\_id;, MySQL can quickly determine that only partition p2 needs to be scanned because the remaining partitions cannot contain any records satisfying the WHERE clause. See Section 24.4, “Partition

Pruning” , for more information about how this is accomplished.

A variant on this type of partitioning is RANGE COLUMNS partitioning. Partitioning by RANGE COLUMNS makes it possible to employ multiple columns for defining partitioning ranges that apply both to placement of rows in partitions and for determining the inclusion or exclusion of specific partitions when performing partition pruning. See [Section 24.2.3.1, “RANGE COLUMNS partitioning”](#_bookmark82) , for more information.

**Partitioning** **schemes** **based** **on** **time** **intervals.** If you wish to implement a partitioning scheme based on ranges or intervals of time in MySQL 8.0, you have two options:

1. Partition the table by RANGE, and for the partitioning expression, employ a function operating on a DATE, TIME, or DATETIME column and returning an integer value, as shown here:

CREATE TABLE members (

firstname VARCHAR(25) NOT NULL,

lastname VARCHAR(25) NOT NULL,

username VARCHAR(16) NOT NULL,

email VARCHAR(35),

joined DATE NOT NULL

)

PARTITION BY RANGE( YEAR(joined) ) (



PARTITION p0 VALUES LESS THAN (1960),

PARTITION p1 VALUES LESS THAN (1970),

PARTITION p2 VALUES LESS THAN (1980),

PARTITION p3 VALUES LESS THAN (1990),

PARTITION p4 VALUES LESS THAN MAXVALUE

);

In MySQL 8.0, it is also possible to partition a table by RANGE based on the value of a TIMESTAMP column, using the UNIX\_TIMESTAMP() function, as shown in this example:

CREATE TABLE quarterly\_report\_status (

report\_id INT NOT NULL,

report\_status VARCHAR(20) NOT NULL,

report\_updated TIMESTAMP NOT NULL DEFAULT CURRENT\_TIMESTAMP ON UPDATE CURRENT\_TIMESTAMP

)

PARTITION BY RANGE ( UNIX\_TIMESTAMP(report\_updated) ) (

PARTITION p0 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-01-01 00:00:00') ),

PARTITION p1 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-04-01 00:00:00') ),

PARTITION p2 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-07-01 00:00:00') ),

PARTITION p3 VALUES LESS THAN ( UNIX\_TIMESTAMP('2008-10-01 00:00:00') ),

PARTITION p4 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-01-01 00:00:00') ),

PARTITION p5 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-04-01 00:00:00') ),

PARTITION p6 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-07-01 00:00:00') ),

PARTITION p7 VALUES LESS THAN ( UNIX\_TIMESTAMP('2009-10-01 00:00:00') ),

PARTITION p8 VALUES LESS THAN ( UNIX\_TIMESTAMP('2010-01-01 00:00:00') ),

PARTITION p9 VALUES LESS THAN (MAXVALUE)

);

In MySQL 8.0, any other expressions involving TIMESTAMP values are not permitted. (See Bug #42849.)

**Note**

It is also possible in MySQL 8.0 to use UNIX\_TIMESTAMP(timestamp\_column) as a partitioning expression for tables that are partitioned by LIST. However, it is usually not practical to do so.

2. Partition the table by RANGE COLUMNS, using a DATE or DATETIME column as the partitioning column. For example, the members table could be defined using the joined column directly, as shown here:

CREATE TABLE members (

firstname VARCHAR(25) NOT NULL,

lastname VARCHAR(25) NOT NULL,

username VARCHAR(16) NOT NULL,

email VARCHAR(35),

joined DATE NOT NULL

)

PARTITION BY RANGE COLUMNS(joined) (

PARTITION p0 VALUES LESS THAN ('1960-01-01'),

PARTITION p1 VALUES LESS THAN ('1970-01-01'),

PARTITION p2 VALUES LESS THAN ('1980-01-01'),

PARTITION p3 VALUES LESS THAN ('1990-01-01'),

PARTITION p4 VALUES LESS THAN MAXVALUE

);

**Note**

The use of partitioning columns employing date or time types other than DATE or DATETIME is not supported with RANGE COLUMNS.

**24.2.2** **LIST** **Partitioning**

List partitioning in MySQL is similar to range partitioning in many ways. As in partitioning by RANGE, each partition must be explicitly defined. The chief difference between the two types of partitioning is that, in list partitioning, each partition is defined and selected based on the membership of a column



value in one of a set of value lists, rather than in one of a set of contiguous ranges of values. This is done by using PARTITION BY LIST(*expr*) where *expr* is a column value or an expression based on a column value and returning an integer value, and then defining each partition by means of a VALUES IN (*value\_list*), where *value\_list* is a comma-separated list of integers.

**Note**

In MySQL 8.0, it is possible to match against only a list of integers (and possibly NULL—see [Section 24.2.7, “How MySQL Partitioning Handles NULL”](#_bookmark77)) when partitioning by LIST.

However, other column types may be used in value lists when employing LIST COLUMN partitioning, which is described later in this section.

Unlike the case with partitions defined by range, list partitions do not need to be declared in any particular order. For more detailed syntactical information, see Section 13.1.20, “CREATE TABLE

Statement” .

For the examples that follow, we assume that the basic definition of the table to be partitioned is provided by the CREATE TABLE statement shown here:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT,

store\_id INT

);

(This is the same table used as a basis for the examples in [Section 24.2.1, “RANGE Partitioning”](#_bookmark72) . As with the other partitioning examples, we assume that the default\_storage\_engine is InnoDB.)

Suppose that there are 20 video stores distributed among 4 franchises as shown in the following table.

|  |  |
| --- | --- |
| **Region** | **Store** **ID** **Numbers** |
| North | 3, 5, 6, 9, 17 |
| East | 1, 2, 10, 11, 19, 20 |
| West | 4, 12, 13, 14, 18 |
| Central | 7, 8, 15, 16 |

To partition this table in such a way that rows for stores belonging to the same region are stored in the same partition, you could use the CREATE TABLE statement shown here:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT,

store\_id INT

)

PARTITION BY LIST(store\_id) (

PARTITION pNorth VALUES IN (3,5,6,9,17),

PARTITION pEast VALUES IN (1,2,10,11,19,20),

PARTITION pWest VALUES IN (4,12,13,14,18),

PARTITION pCentral VALUES IN (7,8,15,16)

);

This makes it easy to add or drop employee records relating to specific regions to or from the table. For instance, suppose that all stores in the West region are sold to another company. In MySQL 8.0, all rows relating to employees working at stores in that region can be deleted with the query

ALTER TABLE employees TRUNCATE PARTITION pWest, which can be executed much more efficiently than the equivalent DELETE statement DELETE FROM employees WHERE store\_id IN

(4,12,13,14,18);. (Using ALTER TABLE employees DROP PARTITION pWest would also delete all of these rows, but would also remove the partition pWest from the definition of the table; you would need to use an ALTER TABLE ... ADD PARTITION statement to restore the table's original partitioning scheme.)

As with RANGE partitioning, it is possible to combine LIST partitioning with partitioning by hash or key to produce a composite partitioning (subpartitioning). See [Section 24.2.6, “Subpartitioning”](#_bookmark76) .

Unlike the case with RANGE partitioning, there is no “catch-all” such as MAXVALUE; all expected values for the partitioning expression should be covered in PARTITION ... VALUES IN (...) clauses. An INSERT statement containing an unmatched partitioning column value fails with an error, as shown in this example:

mysql> **CREATE** **TABLE** **h2** **(**

-> **c1** **INT,**

-> **c2** **INT**

-> **)**

-> **PARTITION** **BY** **LIST(c1)** **(**

-> **PARTITION** **p0** **VALUES** **IN** **(1,** **4,** **7),**

-> **PARTITION** **p1** **VALUES** **IN** **(2,** **5,** **8)**

-> **);**

Query OK, 0 rows affected (0.11 sec)

mysql> **INSERT** **INTO** **h2** **VALUES** **(3,** **5);**

ERROR 1525 (HY000): Table has no partition for value 3

When inserting multiple rows using a single INSERT statement into a single InnoDB table, InnoDB considers the statement a single transaction, so that the presence of any unmatched values causes the statement to fail completely, and so no rows are inserted.

You can cause this type of error to be ignored by using the IGNORE keyword, although a warning is issued for each row containing unmatched partitioning column values, as shown here.

mysql> **TRUNCATE** **h2;**

Query OK, 1 row affected (0.00 sec)

mysql> **TABLE** **h2;**

Empty set (0.00 sec)

mysql> **INSERT** **IGNORE** **INTO** **h2** **VALUES** **(2,** **5),** **(6,** **10),** **(7,** **5),** **(3,** **1),** **(1,** **9);**

Query OK, 3 rows affected, 2 warnings (0.01 sec)

Records: 5 Duplicates: 2 Warnings: [2](#_bookmark85)

mysql> **SHOW** **WARNINGS;**

+ +------+------------------------------------+

| Level | Code | Message |

+---------+------+------------------------------------+

| Warning | 1526 | Table has no partition for value 6 |

| Warning | 1526 | Table has no partition for value 3 |

+---------+------+------------------------------------+

2 rows in set (0.00 sec)

You can see in the output of the following TABLE statement that rows containing unmatched partitioning column values were silently rejected, while rows containing no unmatched values were inserted into the table:

mysql> **TABLE** **h2;**

+------+------+

| c1 | c2 |

+------+------+

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| |  |  | | 7  1  2 | |  |  | | 5  9  5 | |  |  | |

+------+------+

3 rows in set (0.00 sec)

MySQL also provides support for LIST COLUMNS partitioning, a variant of LIST partitioning

that enables you to use columns of types other than integer for partitioning columns, and to use multiple columns as partitioning keys. For more information, see [Section 24.2.3.2, “LIST COLUMNS](#_bookmark83) [partitioning”](#_bookmark83) .

**24.2.3** **COLUMNS** **Partitioning**

The next two sections discuss *COLUMNS* *deJ}!}!on!n6*, which are variants on RANGE and LIST partitioning. COLUMNS partitioning enables the use of multiple columns in partitioning keys. All of these columns are taken into account both for the purpose of placing rows in partitions and for the determination of which partitions are to be checked for matching rows in partition pruning.

In addition, both RANGE COLUMNS partitioning and LIST COLUMNS partitioning support the use of non- integer columns for defining value ranges or list members. The permitted data types are shown in the following list:

• All integer types: TINYINT, SMALLINT, MEDIUMINT, INT ( INTEGER), and BIGINT. (This is the same as with partitioning by RANGE and LIST.)

Other numeric data types (such as DECIMAL or FLOAT) are not supported as partitioning columns.

• DATE and DATETIME.

Columns using other data types relating to dates or times are not supported as partitioning columns. • The following string types: CHAR, VARCHAR, BINARY, and VARBINARY.

TEXT and BLOB columns are not supported as partitioning columns.

The discussions of RANGE COLUMNS and LIST COLUMNS partitioning in the next two sections assume that you are already familiar with partitioning based on ranges and lists as supported in MySQL 5.1 and later; for more information about these, see [Section 24.2.1, “RANGE Partitioning”](#_bookmark72) , and [Section 24.2.2,](#_bookmark73) [“LIST Partitioning”](#_bookmark73) , respectively.

**24.2.3.1** **RANGE** **COLUMNS** **partitioning**

Range columns partitioning is similar to range partitioning, but enables you to define partitions using ranges based on multiple column values. In addition, you can define the ranges using columns of types other than integer types.

RANGE COLUMNS partitioning differs significantly from RANGE partitioning in the following ways:

• RANGE COLUMNS does not accept expressions, only names of columns.

• RANGE COLUMNS accepts a list of one or more columns.

RANGE COLUMNS partitions are based on comparisons between *}nd/?s* (lists of column values) rather than comparisons between scalar values. Placement of rows in RANGE COLUMNS partitions is also based on comparisons between tuples; this is discussed further later in this section.

• RANGE COLUMNS partitioning columns are not restricted to integer columns; string, DATE and DATETIME columns can also be used as partitioning columns. (See [Section 24.2.3, “COLUMNS](#_bookmark74) [Partitioning”](#_bookmark74) , for details.)

The basic syntax for creating a table partitioned by RANGE COLUMNS is shown here:

CREATE TABLE *table\_name*

PARTITION BY RANGE COLUMNS(*column\_list*) (

PARTITION

PARTITION

...]

)

*column\_list*:

*partition\_name* VALUES LESS THAN (*value\_list*)[,

*partition\_name* VALUES LESS THAN (*value\_list*)][,



*column\_name* [, *column\_name*][, . . .]

*value\_list*:

*value* [, *value*][, ...]

**Note**

Not all CREATE TABLE options that can be used when creating partitioned tables are shown here. For complete information, see Section 13.1.20,

“CREATE TABLE Statement” .

In the syntax just shown, *column\_list* is a list of one or more columns (sometimes called a *partitioning* *column* *list*), and *value\_list* is a list of values (that is, it is a *partition* *definition* *value* *list*). A *value\_list* must be supplied for each partition definition, and each *value\_list* must have the same number of values as the *column\_list* has columns. Generally speaking, if you use *N*columns in the COLUMNS clause, then each VALUES LESS THAN clause must also be supplied with a list of *N* values.

The elements in the partitioning column list and in the value list defining each partition must occur in the same order. In addition, each element in the value list must be of the same data type as the corresponding element in the column list. However, the order of the column names in the partitioning column list and the value lists does not have to be the same as the order of the table column definitions in the main part of the CREATE TABLE statement. As with table partitioned by RANGE, you can use MAXVALUE to represent a value such that any legal value inserted into a given column is always less than this value. Here is an example of a CREATE TABLE statement that helps to illustrate all of these points:

mysql> **CREATE** **TABLE** **rcx** **(**

-> **a** **INT,**

-> **b** **INT,**

-> **c** **CHAR(3),**

-> **d** **INT**

-> **)**

-> **PARTITION** **BY** **RANGE** **COLUMNS(a,d,c)** **(**

-> **PARTITION** **p0** **VALUES** **LESS** **THAN** **(5,10,'ggg'),**

-> **PARTITION** **p1** **VALUES** **LESS** **THAN** **(10,20,'mmm'),**

-> **PARTITION** **p2** **VALUES** **LESS** **THAN** **(15,30,'sss'),**

-> **PARTITION** **p3** **VALUES** **LESS** **THAN** **(MAXVALUE,MAXVALUE,MAXVALUE)**

-> **);**

Query OK, 0 rows affected (0.15 sec)

Table rcx contains the columns a, b, c, d. The partitioning column list supplied to the COLUMNS clause uses 3 of these columns, in the order a, d, c. Each value list used to define a partition contains 3 values in the same order; that is, each value list tuple has the form ( INT, INT, CHAR(3)), which corresponds to the data types used by columns a, d, and c (in that order).

Placement of rows into partitions is determined by comparing the tuple from a row to be inserted that matches the column list in the COLUMNS clause with the tuples used in the VALUES LESS THAN clauses to define partitions of the table. Because we are comparing tuples (that is, lists or sets of values) rather than scalar values, the semantics of VALUES LESS THAN as used with RANGE COLUMNS partitions differs somewhat from the case with simple RANGE partitions. In RANGE partitioning, a row generating an expression value that is equal to a limiting value in a VALUES LESS THAN is never placed in the corresponding partition; however, when using RANGE COLUMNS partitioning, it is sometimes possible for a row whose partitioning column list's first element is equal in value to the that

of the first element in a VALUES LESS THAN value list to be placed in the corresponding partition. Consider the RANGE partitioned table created by this statement:

|  |  |
| --- | --- |
| CREATE TABLE r1 (  a INT,  b INT  )  PARTITION BY RANGE (a) (  PARTITION p0 VALUES LESS  PARTITION p1 VALUES LESS | THAN (5),  THAN (MAXVALUE) |

);

If we insert 3 rows into this table such that the column value for a is 5 for each row, all 3 rows are stored in partition p1 because the a column value is in each case not less than 5, as we can see by executing the proper query against the Information Schema PARTITIONS table:

mysql> **INSERT** **INTO** **r1** **VALUES** **(5,10),** **(5,11),** **(5,12);**

Query OK, 3 rows affected (0.00 sec)

Records: 3 Duplicates: 0 Warnings: [0](#_bookmark86)

mysql> **SELECT** **PARTITION\_NAME,** **TABLE\_ROWS**

|  |  |
| --- | --- |
| ->  -> | **FROM** **INFORMATION\_SCHEMA.PARTITIONS**  **WHERE** **TABLE\_NAME** **=** **'r1';** |

+----------------+------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | p0  | p1 | |  | | 0  3 | |  | |

+----------------+------------+

2 rows in set (0.00 sec)

Now consider a similar table rc1 that uses RANGE COLUMNS partitioning with both columns a and b referenced in the COLUMNS clause, created as shown here:

CREATE TABLE rc1 (

a INT,

b INT

)

PARTITION BY RANGE COLUMNS(a, b) (

PARTITION p0 VALUES LESS THAN (5, 12),

PARTITION p3 VALUES LESS THAN (MAXVALUE, MAXVALUE)

);

If we insert exactly the same rows into rc1 as we just inserted into r1, the distribution of the rows is quite different:

mysql> **INSERT** **INTO** **rc1** **VALUES** **(5,10),** **(5,11),** **(5,12);**

Query OK, 3 rows affected (0.00 sec)

Records: 3 Duplicates: 0 Warnings: [0](#_bookmark86)

mysql> **SELECT** **PARTITION\_NAME,** **TABLE\_ROWS**

|  |  |
| --- | --- |
| ->  -> | **FROM** **INFORMATION\_SCHEMA.PARTITIONS**  **WHERE** **TABLE\_NAME** **=** **'rc1';** |

+----------------+------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | p0  | p3 | |  | | 2  1 | |  | |

+----------------+------------+

2 rows in set (0.00 sec)

This is because we are comparing rows rather than scalar values. We can compare the row values inserted with the limiting row value from the VALUES THAN LESS THAN clause used to define partition p0 in table rc1, like this:

mysql> **SELECT** **(5,10)** **<** **(5,12),** **(5,11)** **<** **(5,12),** **(5,12)** **<** **(5,12);**

+-----------------+-----------------+-----------------+

| (5,10) < (5,12) | (5,11) < (5,12) | (5,12) < (5,12) |

+-----------------+-----------------+-----------------+

| 1 | 1 | 0 |

+-----------------+-----------------+-----------------+

1 row in set (0.00 sec)

The 2 tuples (5,10) and (5,11) evaluate as less than (5,12), so they are stored in partition p0. Since 5 is not less than 5 and 12 is not less than 12, (5,12) is considered not less than (5,12), and is stored in partition p1.

The SELECT statement in the preceding example could also have been written using explicit row constructors, like this:

SELECT ROW(5,10) < ROW(5,12), ROW(5,11) < ROW(5,12), ROW(5,12) < ROW(5,12);

For more information about the use of row constructors in MySQL, see Section 13.2.15.5, “Row Subqueries” .

For a table partitioned by RANGE COLUMNS using only a single partitioning column, the storing of rows in partitions is the same as that of an equivalent table that is partitioned by RANGE. The following CREATE TABLE statement creates a table partitioned by RANGE COLUMNS using 1 partitioning column:

CREATE TABLE rx (

a INT,

b INT

)

PARTITION BY RANGE COLUMNS (a) (

PARTITION p0 VALUES LESS THAN (5),

PARTITION p1 VALUES LESS THAN (MAXVALUE)

);

If we insert the rows (5,10), (5,11), and (5,12) into this table, we can see that their placement is the same as it is for the table r we created and populated earlier:

mysql> **INSERT** **INTO** **rx** **VALUES** **(5,10),** **(5,11),** **(5,12);**

Query OK, 3 rows affected (0.00 sec)

Records: 3 Duplicates: 0 Warnings: [0](#_bookmark86)

mysql> **SELECT** **PARTITION\_NAME,TABLE\_ROWS**

|  |  |
| --- | --- |
| ->  -> | **FROM** **INFORMATION\_SCHEMA.PARTITIONS**  **WHERE** **TABLE\_NAME** **=** **'rx';** |

+----------------+------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | p0  | p1 | |  | | 0  3 | |  | |

+----------------+------------+

2 rows in set (0.00 sec)

It is also possible to create tables partitioned by RANGE COLUMNS where limiting values for one or more columns are repeated in successive partition definitions. You can do this as long as the tuples of column values used to define the partitions are strictly increasing. For example, each of the following CREATE TABLE statements is valid:

CREATE TABLE rc2 (

a INT,

b INT

)

PARTITION BY RANGE COLUMNS(a,b) (

PARTITION p0 VALUES LESS THAN (0,10),

PARTITION p1 VALUES LESS THAN (10,20),

PARTITION p2 VALUES LESS THAN (10,30),

PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE)

);

CREATE TABLE rc3 (

a INT,

b INT

)

PARTITION BY RANGE COLUMNS(a,b) (

PARTITION p0 VALUES LESS THAN (0,10),

PARTITION p1 VALUES LESS THAN (10,20),

PARTITION p2 VALUES LESS THAN (10,30),

PARTITION p3 VALUES LESS THAN (10,35),

PARTITION p4 VALUES LESS THAN (20,40),

PARTITION p5 VALUES LESS THAN (MAXVALUE,MAXVALUE)

);

The following statement also succeeds, even though it might appear at first glance that it would not, since the limiting value of column b is 25 for partition p0 and 20 for partition p1, and the limiting value of column c is 100 for partition p1 and 50 for partition p2:

CREATE TABLE rc4 (

a INT,

b INT,

c INT

)

PARTITION BY RANGE COLUMNS(a,b,c) (

PARTITION p0 VALUES LESS THAN (0,25,50),

PARTITION p1 VALUES LESS THAN (10,20,100),

PARTITION p2 VALUES LESS THAN (10,30,50),

PARTITION p3 VALUES LESS THAN (MAXVALUE,MAXVALUE,MAXVALUE)

);

When designing tables partitioned by RANGE COLUMNS, you can always test successive partition definitions by comparing the desired tuples using the mysql client, like this:

mysql> **SELECT** **(0,25,50)** **<** **(10,20,100),** **(10,20,100)** **<** **(10,30,50);**

+-------------------------+--------------------------+

| (0,25,50) < (10,20,100) | (10,20,100) < (10,30,50) |

+-------------------------+--------------------------+

| 1 | 1 |

+-------------------------+--------------------------+

1 row in set (0.00 sec)

If a CREATE TABLE statement contains partition definitions that are not in strictly increasing order, it fails with an error, as shown in this example:

|  |  |  |
| --- | --- | --- |
| mysql>  ->  ->  ->  ->  ->  ->  ->  ->  ->  ->  ERROR | **CREATE** **TABLE** **rcf** **(**  **a** **INT,**  **b** **INT,**  **c** **INT**  **)**  **PARTITION** **BY** **RANGE** **COLUMNS(a,b,c)** **(**  **PARTITION** **p0** **VALUES** **LESS** **THAN** **(0,25,50),**  **PARTITION** **p1** **VALUES** **LESS** **THAN** **(20,20,100),**  **PARTITION** **p2** **VALUES** **LESS** **THAN** **(10,30,50),**  **PARTITION** **p3** **VALUES** **LESS** **THAN** **(MAXVALUE,MAXVALUE,MAXVALUE)**  **);**  1493 (HY000): VALUES LESS THAN value must be strictly increasing for each | partition |

When you get such an error, you can deduce which partition definitions are invalid by making “less than” comparisons between their column lists. In this case, the problem is with the definition of partition p2 because the tuple used to define it is not less than the tuple used to define partition p3, as shown here:

mysql> **SELECT** **(0,25,50)** **<** **(20,20,100),** **(20,20,100)** **<** **(10,30,50);**

+-------------------------+--------------------------+

| (0,25,50) < (20,20,100) | (20,20,100) < (10,30,50) |

+-------------------------+--------------------------+

| 1 | 0 |

+-------------------------+--------------------------+

1 row in set (0.00 sec)

It is also possible for MAXVALUE to appear for the same column in more than one VALUES LESS THAN clause when using RANGE COLUMNS. However, the limiting values for individual columns in successive partition definitions should otherwise be increasing, there should be no more than one partition defined where MAXVALUE is used as the upper limit for all column values, and this partition definition should appear last in the list of PARTITION ... VALUES LESS THAN clauses. In addition, you cannot use MAXVALUE as the limiting value for the first column in more than one partition definition.

As stated previously, it is also possible with RANGE COLUMNS partitioning to use non-integer columns as partitioning columns. (See [Section 24.2.3, “COLUMNS Partitioning”](#_bookmark74) , for a complete listing of these.) Consider a table named employees (which is not partitioned), created using the following statement:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',



job\_code INT NOT NULL,

store\_id INT NOT NULL

);

Using RANGE COLUMNS partitioning, you can create a version of this table that stores each row in one of four partitions based on the employee's last name, like this:

CREATE TABLE employees\_by\_lname (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT NOT NULL,

store\_id INT NOT NULL

)

PARTITION BY RANGE COLUMNS (lname) (

PARTITION p0 VALUES LESS THAN ('g'),

PARTITION p1 VALUES LESS THAN ('m'),

PARTITION p2 VALUES LESS THAN ('t'),

PARTITION p3 VALUES LESS THAN (MAXVALUE)

);

Alternatively, you could cause the employees table as created previously to be partitioned using this scheme by executing the following ALTER TABLE statement:

ALTER TABLE employees PARTITION BY RANGE COLUMNS (lname) (

PARTITION p0 VALUES LESS THAN ('g'),

PARTITION p1 VALUES LESS THAN ('m'),

PARTITION p2 VALUES LESS THAN ('t'),

PARTITION p3 VALUES LESS THAN (MAXVALUE)

);

**Note**

Because different character sets and collations have different sort orders, the character sets and collations in use may effect which partition of a table partitioned by RANGE COLUMNS a given row is stored in when using string columns as partitioning columns. In addition, changing the character set or collation for a given database, table, or column after such a table is created may cause changes in how rows are distributed. For example, when using a case- sensitive collation, 'and' sorts before 'Andersen', but when using a collation that is case-insensitive, the reverse is true.

For information about how MySQL handles character sets and collations, see Chapter 10, *Character* *Sets,* *Collations,* *Unicode*.

Similarly, you can cause the employees table to be partitioned in such a way that each row is stored in one of several partitions based on the decade in which the corresponding employee was hired using the ALTER TABLE statement shown here:

ALTER TABLE employees PARTITION BY RANGE COLUMNS (hired) (

PARTITION p0 VALUES LESS THAN ('1970-01-01'),

PARTITION p1 VALUES LESS THAN ('1980-01-01'),

PARTITION p2 VALUES LESS THAN ('1990-01-01'),

PARTITION p3 VALUES LESS THAN ('2000-01-01'),

PARTITION p4 VALUES LESS THAN ('2010-01-01'),

PARTITION p5 VALUES LESS THAN (MAXVALUE)

);

See Section 13.1.20, “CREATE TABLE Statement” , for additional information about PARTITION BY RANGE COLUMNS syntax.

**24.2.3.2** **LIST** **COLUMNS** **partitioning**

MySQL 8.0 provides support for LIST COLUMNS partitioning. This is a variant of LIST partitioning that enables the use of multiple columns as partition keys, and for columns of data types other than

integer types to be used as partitioning columns; you can use string types, DATE, and DATETIME columns. (For more information about permitted data types for COLUMNS partitioning columns, see [Section 24.2.3, “COLUMNS Partitioning”](#_bookmark74) .)

Suppose that you have a business that has customers in 12 cities which, for sales and marketing purposes, you organize into 4 regions of 3 cities each as shown in the following table:

|  |  |
| --- | --- |
| **Region** | **Cities** |
| 1 | Oskarshamn, Högsby, Mönsterås |
| 2 | Vimmerby, Hultsfred, Västervik |
| 3 | Nässjö, Eksjö, Vetlanda |
| 4 | Uppvidinge, Alvesta, Växjo |

With LIST COLUMNS partitioning, you can create a table for customer data that assigns a row to any of 4 partitions corresponding to these regions based on the name of the city where a customer resides, as shown here:

CREATE TABLE customers\_1 (

first\_name VARCHAR(25),

last\_name VARCHAR(25),

street\_1 VARCHAR(30),

street\_2 VARCHAR(30),

city VARCHAR(15),

renewal DATE

)

PARTITION BY LIST COLUMNS(city) (

PARTITION pRegion\_1 VALUES IN('Oskarshamn', 'Högsby', 'Mönsterås'),

PARTITION pRegion\_2 VALUES IN('Vimmerby', 'Hultsfred', 'Västervik'),

PARTITION pRegion\_3 VALUES IN('Nässjö', 'Eksjö', 'Vetlanda'),

PARTITION pRegion\_4 VALUES IN('Uppvidinge', 'Alvesta', 'Växjo')

);

As with partitioning by RANGE COLUMNS, you do not need to use expressions in the COLUMNS() clause to convert column values into integers. (In fact, the use of expressions other than column names is not permitted with COLUMNS().)

It is also possible to use DATE and DATETIME columns, as shown in the following example that uses the same name and columns as the customers\_1 table shown previously, but employs LIST COLUMNS partitioning based on the renewal column to store rows in one of 4 partitions depending on the week in February 2010 the customer's account is scheduled to renew:

CREATE TABLE customers\_2 (

first\_name VARCHAR(25),

last\_name VARCHAR(25),

street\_1 VARCHAR(30),

street\_2 VARCHAR(30),

city VARCHAR(15),

renewal DATE

)

PARTITION BY LIST COLUMNS(renewal) (

PARTITION pWeek\_1

'2010-02-04',

PARTITION pWeek\_2

'2010-02-11',

PARTITION pWeek\_3

'2010-02-18',

PARTITION pWeek\_4

'2010-02-25',

);

VALUES IN('2010-02-01', '2010-02-02', '2010-02-03',

'2010-02-05', '2010-02-06', '2010-02-07'),

VALUES IN('2010-02-08', '2010-02-09', '2010-02-10',

'2010-02-12', '2010-02-13', '2010-02-14'),

VALUES IN('2010-02-15', '2010-02-16', '2010-02-17',

'2010-02-19', '2010-02-20', '2010-02-21'),

VALUES IN('2010-02-22', '2010-02-23', '2010-02-24',

'2010-02-26', '2010-02-27', '2010-02-28')

This works, but becomes cumbersome to define and maintain if the number of dates involved grows very large; in such cases, it is usually more practical to employ RANGE or RANGE COLUMNS partitioning instead. In this case, since the column we wish to use as the partitioning key is a DATE column, we use RANGE COLUMNS partitioning, as shown here:



CREATE TABLE customers\_3 (

first\_name VARCHAR(25),

last\_name VARCHAR(25),

street\_1 VARCHAR(30),

street\_2 VARCHAR(30),

city VARCHAR(15),

renewal DATE

)

PARTITION BY RANGE COLUMNS(renewal) (

PARTITION pWeek\_1 VALUES LESS THAN('2010-02-09'),

PARTITION pWeek\_2 VALUES LESS THAN('2010-02-15'),

PARTITION pWeek\_3 VALUES LESS THAN('2010-02-22'),

PARTITION pWeek\_4 VALUES LESS THAN('2010-03-01')

);

See [Section 24.2.3.1, “RANGE COLUMNS partitioning”](#_bookmark82) , for more information.

In addition (as with RANGE COLUMNS partitioning), you can use multiple columns in the COLUMNS() clause.

See Section 13.1.20, “CREATE TABLE Statement” , for additional information about PARTITION BY LIST COLUMNS() syntax.

**24.2.4** **HASH** **Partitioning**

Partitioning by HASH is used primarily to ensure an even distribution of data among a predetermined number of partitions. With range or list partitioning, you must specify explicitly which partition a given column value or set of column values should be stored in; with hash partitioning, this decision is taken care of for you, and you need only specify a column value or expression based on a column value to be hashed and the number of partitions into which the partitioned table is to be divided.

To partition a table using HASH partitioning, it is necessary to append to the CREATE TABLE statement a PARTITION BY HASH (*expr*) clause, where *expr* is an expression that returns an integer. This can simply be the name of a column whose type is one of MySQL's integer types. In addition, you most likely want to follow this with PARTITIONS *num*, where *num* is a positive integer representing the number of partitions into which the table is to be divided.

**Note**

For simplicity, the tables in the examples that follow do not use any keys. You should be aware that, if a table has any unique keys, every column used in the partitioning expression for this table must be part of every unique key, including the primary key. See Section 24.6.1, “Partitioning Keys, Primary Keys, and Unique Keys” , for more information.

The following statement creates a table that uses hashing on the store\_id column and is divided into 4 partitions:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT,

store\_id INT

)

PARTITION BY HASH(store\_id)

PARTITIONS 4;

If you do not include a PARTITIONS clause, the number of partitions defaults to 1; using the PARTITIONS keyword without a number following it results in a syntax error.

You can also use an SQL expression that returns an integer for *expr*. For instance, you might want to partition based on the year in which an employee was hired. This can be done as shown here:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT,

store\_id INT

)

PARTITION BY HASH( YEAR(hired) )

PARTITIONS 4;

*expr* must return a nonconstant, nonrandom integer value (in other words, it should be varying but deterministic), and must not contain any prohibited constructs as described in Section 24.6, “Restrictions and Limitations on Partitioning” . You should also keep in mind that this expression is evaluated each time a row is inserted or updated (or possibly deleted); this means that very complex expressions may give rise to performance issues, particularly when performing operations (such as batch inserts) that affect a great many rows at one time.

The most efficient hashing function is one which operates upon a single table column and whose value increases or decreases consistently with the column value, as this allows for “pruning” on ranges of partitions. That is, the more closely that the expression varies with the value of the column on which it is based, the more efficiently MySQL can use the expression for hash partitioning.

For example, where date\_col is a column of type DATE, then the expression TO\_DAYS(date\_col) is said to vary directly with the value of date\_col, because for every change in the value of date\_col, the value of the expression changes in a consistent manner. The variance of the expression YEAR(date\_col) with respect to date\_col is not quite as direct as that of TO\_DAYS(date\_col), because not every possible change in date\_col produces an equivalent change in YEAR(date\_col). Even so, YEAR(date\_col) is a good candidate for a hashing function, because it varies directly with a portion of date\_col and there is no possible change in date\_col that produces a disproportionate change in YEAR(date\_col).

By way of contrast, suppose that you have a column named int\_col whose type is INT. Now consider the expression POW(5-int\_col,3) + 6. This would be a poor choice for a hashing function because a change in the value of int\_col is not guaranteed to produce a proportional change in the value of the expression. Changing the value of int\_col by a given amount can produce widely differing changes in the value of the expression. For example, changing int\_col from 5 to 6 produces a change of -1 in the value of the expression, but changing the value of int\_col from 6 to 7 produces a change of -7 in the expression value.

In other words, the more closely the graph of the column value versus the value of the expression follows a straight line as traced by the equation y=*c*x where *c* is some nonzero constant, the better the expression is suited to hashing. This has to do with the fact that the more nonlinear an expression is, the more uneven the distribution of data among the partitions it tends to produce.

In theory, pruning is also possible for expressions involving more than one column value, but determining which of such expressions are suitable can be quite difficult and time-consuming. For this reason, the use of hashing expressions involving multiple columns is not particularly recommended.

When PARTITION BY HASH is used, the storage engine determines which partition of *num* partitions to use based on the modulus of the result of the expression. In other words, for a given expression *expr*, the partition in which the record is stored is partition number *N*, where *N* = MOD(*expr*, *num*). Suppose that table t1 is defined as follows, so that it has 4 partitions:

|  |  |  |
| --- | --- | --- |
| CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)  PARTITION BY HASH( YEAR(col3) )  PARTITIONS 4; |  |  |
| If you insert a record into t1 whose col3 value is '2005- stored is determined as follows: | 09 | -15', then the partition in which it is |
| MOD(YEAR('2005-09-01'),4)  = MOD(2005,4) |  |  |

= 1

MySQL 8.0 also supports a variant of HASH partitioning known as *linear* *hashing* which employs a more complex algorithm for determining the placement of new rows inserted into the partitioned table. See [Section 24.2.4.1, “LINEAR HASH Partitioning”](#_bookmark84) , for a description of this algorithm.

The user-supplied expression is evaluated each time a record is inserted or updated. It may also— depending on the circumstances—be evaluated when records are deleted.

**24.2.4.1** **LINEAR** **HASH** **Partitioning**

MySQL also supports linear hashing, which differs from regular hashing in that linear hashing utilizes a linear powers-of-two algorithm whereas regular hashing employs the modulus of the hashing function's value.

Syntactically, the only difference between linear-hash partitioning and regular hashing is the addition of the LINEAR keyword in the PARTITION BY clause, as shown here:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30),

hired DATE NOT NULL DEFAULT '1970-01-01',

separated DATE NOT NULL DEFAULT '9999-12-31',

job\_code INT,

store\_id INT

)

PARTITION BY LINEAR HASH( YEAR(hired) )

PARTITIONS 4;

Given an expression *expr*, the partition in which the record is stored when linear hashing is used is partition number *N*from among *num* partitions, where *N* is derived according to the following algorithm:

1. Find the next power of 2 greater than *num*. We call this value *V*; it can be calculated as:

*V* = POWER(2, CEILING(LOG(2, *num*)))

(Suppose that *num* is 13. Then LOG(2,13) is 3.7004397181411. CEILING(3.7004397181411) is 4, and *V*= POWER(2,4), which is 16.)

2. Set *N* = *F*(*column\_list*) & (*V*- 1).

3. While *N* >= *num*:

• Set *V*= *V*/ 2

• Set *N* = *N*& ( *V*- 1)

Suppose that the table t1, using linear hash partitioning and having 6 partitions, is created using this statement:

CREATE TABLE t1 (col1 INT, col2 CHAR(5), col3 DATE)

PARTITION BY LINEAR HASH( YEAR(col3) )

PARTITIONS 6;

Now assume that you want to insert two records into t1 having the col3 column values '2003-04-14' and '1998-10-19'. The partition number for the first of these is determined as follows:

*V* = POWER(2, CEILING( LOG(2,6) )) = 8

*N* = YEAR('2003-04-14') & (8 - 1)

= 2003 & 7

= 3

(*3* *>=* *6* *is* *FALSE:* *record* *stored* *in* *partition* *#3*)

The number of the partition where the second record is stored is calculated as shown here:

*V* = 8

*N* = YEAR('1998-10-19') & (8 - 1)

= 1998 & 7

= 6

(*6* *>=* *6* *is* *TRUE:* *additional* *step* *required*)

*N* = 6 & ((8 / 2) - 1)

= 6 & 3

= 2

(*2* *>=* *6* *is* *FALSE:* *record* *stored* *in* *partition* *#2*)

The advantage in partitioning by linear hash is that the adding, dropping, merging, and splitting of partitions is made much faster, which can be beneficial when dealing with tables containing extremely large amounts (terabytes) of data. The disadvantage is that data is less likely to be evenly distributed between partitions as compared with the distribution obtained using regular hash partitioning.

**24.2.5** **KEY** **Partitioning**

Partitioning by key is similar to partitioning by hash, except that where hash partitioning employs a user-defined expression, the hashing function for key partitioning is supplied by the MySQL server. NDB Cluster uses MD5() for this purpose; for tables using other storage engines, the server employs its own internal hashing function.

The syntax rules for CREATE TABLE ... PARTITION BY KEY are similar to those for creating a table that is partitioned by hash. The major differences are listed here:

• KEY is used rather than HASH.

• KEY takes only a list of zero or more column names. Any columns used as the partitioning key must comprise part or all of the table's primary key, if the table has one. Where no column name is specified as the partitioning key, the table's primary key is used, if there is one. For example, the following CREATE TABLE statement is valid in MySQL 8.0:

CREATE TABLE k1 (

id INT NOT NULL PRIMARY KEY,

name VARCHAR(20)

)

PARTITION BY KEY()

PARTITIONS 2;

If there is no primary key but there is a unique key, then the unique key is used for the partitioning key:

CREATE TABLE k1 (

id INT NOT NULL,

name VARCHAR(20),

UNIQUE KEY (id)

)

PARTITION BY KEY()

PARTITIONS 2;

However, if the unique key column were not defined as NOT NULL, then the previous statement would fail.

In both of these cases, the partitioning key is the id column, even though it is not shown in the output of SHOW CREATE TABLE or in the PARTITION\_EXPRESSION column of the Information Schema PARTITIONS table.

Unlike the case with other partitioning types, columns used for partitioning by KEY are not restricted to integer or NULL values. For example, the following CREATE TABLE statement is valid:

CREATE TABLE tm1 (

s1 CHAR(32) PRIMARY KEY

)



PARTITION BY KEY(s1)

PARTITIONS 10;

The preceding statement would *not* be valid, were a different partitioning type to be specified. (In this case, simply using PARTITION BY KEY() would also be valid and have the same effect as PARTITION BY KEY(s1), since s1 is the table's primary key.)

For additional information about this issue, see Section 24.6, “Restrictions and Limitations on Partitioning” .

Columns with index prefixes are not supported in partitioning keys. This means that CHAR, VARCHAR, BINARY, and VARBINARY columns can be used in a partitioning key, as long as they do not employ prefixes; because a prefix must be specified for BLOB and TEXT columns in index definitions, it is not possible to use columns of these two types in partitioning keys. Prior to MySQL 8.0.21, columns using prefixes were permitted when creating, altering, or upgrading a partitioned table, even though they were not included in the table's partitioning key; in MySQL 8.0.21 and later, this permissive behavior is deprecated, and the server displays appropriate warnings or errors when one or more such columns are used. See Column index prefixes not supported for key partitioning, for more information and examples.

**Note**

Tables using the NDB storage engine are implicitly partitioned by KEY, using the table's primary key as the partitioning key (as with other MySQL storage engines). In the event that the NDB Cluster table has no explicit primary key, the “hidden” primary key generated by the NDB storage engine for each NDB Cluster table is used as the partitioning key.

If you define an explicit partitioning scheme for an NDB table, the table must have an explicit primary key, and any columns used in the partitioning expression must be part of this key. However, if the table uses an “empty” partitioning expression—that is, PARTITION BY KEY() with no column references—then no explicit primary key is required.

You can observe this partitioning using the ndb\_desc utility (with the -p option).

**Important**

For a key-partitioned table, you cannot execute an ALTER TABLE DROP PRIMARY KEY, as doing so generates the error ERROR 1466 (HY000): Field in list of fields for partition function not found in table. This is not an issue for NDB Cluster tables which are partitioned by KEY; in such cases, the table is reorganized using the “hidden” primary key as the table's new partitioning key. See Chapter 23, *MySQL* *NDB* *Cluster* *8.0*.

It is also possible to partition a table by linear key. Here is a simple example:

CREATE TABLE tk (

col1 INT NOT NULL,

col2 CHAR(5),

col3 DATE

)

PARTITION BY LINEAR KEY (col1)

PARTITIONS 3;

The LINEAR keyword has the same effect on KEY partitioning as it does on HASH partitioning, with the partition number being derived using a powers-of-two algorithm rather than modulo arithmetic. See [Section 24.2.4.1, “LINEAR HASH Partitioning”](#_bookmark84) , for a description of this algorithm and its implications.

**24.2.6** **Subpartitioning**



Subpartitioning—also known as *composite* *partitioning*— is the further division of each partition in a partitioned table. Consider the following CREATE TABLE statement:

CREATE TABLE ts (id INT, purchased DATE)

PARTITION BY RANGE( YEAR(purchased) )

SUBPARTITION BY HASH( TO\_DAYS(purchased) )

SUBPARTITIONS 2 (

PARTITION p0 VALUES LESS THAN (1990),

PARTITION p1 VALUES LESS THAN (2000),

PARTITION p2 VALUES LESS THAN MAXVALUE

);

Table ts has 3 RANGE partitions. Each of these partitions—p0, p1, and p2— is further divided into 2 subpartitions. In effect, the entire table is divided into 3 \* 2 = 6 partitions. However, due to the action of the PARTITION BY RANGE clause, the first 2 of these store only those records with a value less than 1990 in the purchased column.

It is possible to subpartition tables that are partitioned by RANGE or LIST. Subpartitions may use either HASH or KEY partitioning. This is also known as *composite* *partitioning*.

**Note**

SUBPARTITION BY HASH and SUBPARTITION BY KEY generally follow the same syntax rules as PARTITION BY HASH and PARTITION BY KEY, respectively. An exception to this is that SUBPARTITION BY KEY (unlike PARTITION BY KEY) does not currently support a default column, so the column used for this purpose must be specified, even if the table has an explicit primary key. This is a known issue which we are working to address; see Issues with subpartitions, for more information and an example.

It is also possible to define subpartitions explicitly using SUBPARTITION clauses to specify options for individual subpartitions. For example, a more verbose fashion of creating the same table ts as shown in the previous example would be:

CREATE TABLE ts (id INT, purchased DATE)

PARTITION BY RANGE( YEAR(purchased) )

SUBPARTITION BY HASH( TO\_DAYS(purchased) ) (

PARTITION p0 VALUES LESS THAN (1990) (

SUBPARTITION s0,

SUBPARTITION s1

),

PARTITION p1 VALUES LESS THAN (2000) (

SUBPARTITION s2,

SUBPARTITION s3

),

PARTITION p2 VALUES LESS THAN MAXVALUE (

SUBPARTITION s4,

SUBPARTITION s5

)

);

Some syntactical items of note are listed here:

• Each partition must have the same number of subpartitions.

• If you explicitly define any subpartitions using SUBPARTITION on any partition of a partitioned table, you must define them all. In other words, the following statement fails:

CREATE TABLE ts (id INT, purchased DATE)

PARTITION BY RANGE( YEAR(purchased) )

SUBPARTITION BY HASH( TO\_DAYS(purchased) ) (

PARTITION p0 VALUES LESS THAN (1990) (

SUBPARTITION s0,

SUBPARTITION s1

),

PARTITION p1 VALUES LESS THAN (2000),

PARTITION p2 VALUES LESS THAN MAXVALUE (

SUBPARTITION s2,

SUBPARTITION s3

)

);

This statement would still fail even if it used SUBPARTITIONS 2.

• Each SUBPARTITION clause must include (at a minimum) a name for the subpartition. Otherwise, you may set any desired option for the subpartition or allow it to assume its default setting for that option.

• Subpartition names must be unique across the entire table. For example, the following CREATE TABLE statement is valid:

CREATE TABLE ts (id INT, purchased DATE)

PARTITION BY RANGE( YEAR(purchased) )

SUBPARTITION BY HASH( TO\_DAYS(purchased) ) (

PARTITION p0 VALUES LESS THAN (1990) (

SUBPARTITION s0,

SUBPARTITION s1

),

PARTITION p1 VALUES LESS THAN (2000) (

SUBPARTITION s2,

SUBPARTITION s3

),

PARTITION p2 VALUES LESS THAN MAXVALUE (

SUBPARTITION s4,

SUBPARTITION s5

)

);

**24.2.7** **How** **MySQL** **Partitioning** **Handles** **NULL**

Partitioning in MySQL does nothing to disallow NULL as the value of a partitioning expression, whether it is a column value or the value of a user-supplied expression. Even though it is permitted to use NULL as the value of an expression that must otherwise yield an integer, it is important to keep in mind that NULL is not a number. MySQL's partitioning implementation treats NULL as being less than any non-NULL value, just as ORDER BY does.

This means that treatment of NULL varies between partitioning of different types, and may produce behavior which you do not expect if you are not prepared for it. This being the case, we discuss in this section how each MySQL partitioning type handles NULL values when determining the partition in which a row should be stored, and provide examples for each.

**Handling** **of** **NULL** **with** **RANGE** **partitioning.** If you insert a row into a table partitioned by RANGE such that the column value used to determine the partition is NULL, the row is inserted into the lowest partition. Consider these two tables in a database named p, created as follows:

mysql> **CREATE** **TABLE** **t1** **(**

-> **c1** **INT,**

-> **c2** **VARCHAR(20)**

-> **)**

-> **PARTITION** **BY** **RANGE(c1)** **(**

-> **PARTITION** **p0** **VALUES** **LESS** **THAN** **(0),**

-> **PARTITION** **p1** **VALUES** **LESS** **THAN** **(10),**

-> **PARTITION** **p2** **VALUES** **LESS** **THAN** **MAXVALUE**

-> **);**

Query OK, 0 rows affected (0.09 sec)

mysql> **CREATE** **TABLE** **t2** **(**

-> **c1** **INT,**

-> **c2** **VARCHAR(20)**

-> **)**

-> **PARTITION** **BY** **RANGE(c1)** **(**

->

->

->

->

**PARTITION** **p0** **VALUES** **LESS** **THAN** **(-5),**

**PARTITION** **p1** **VALUES** **LESS** **THAN** **(0),**

**PARTITION** **p2** **VALUES** **LESS** **THAN** **(10),**

**PARTITION** **p3** **VALUES** **LESS** **THAN** **MAXVALUE**

-> **);**

Query OK, 0 rows affected (0.09 sec)

You can see the partitions created by these two CREATE TABLE statements using the following query against the PARTITIONS table in the INFORMATION\_SCHEMA database:

mysql> **SELECT** **TABLE\_NAME,** **PARTITION\_NAME,** **TABLE\_ROWS,** **AVG\_ROW\_LENGTH,** **DATA\_LENGTH**

> **FROM** **INFORMATION\_SCHEMA.PARTITIONS**

> **WHERE** **TABLE\_SCHEMA** **=** **'p'** **AND** **TABLE\_NAME** **LIKE** **'t\_';**

+------------+----------------+------------+----------------+-------------+

| TABLE\_NAME | PARTITION\_NAME | TABLE\_ROWS | AVG\_ROW\_LENGTH | DATA\_LENGTH |

+------------+----------------+------------+----------------+-------------+

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  | | t1  t1  t1  t2  t2  t2  t2 | |  |  |  |  |  |  | | p0  p1  p2  p0  p1  p2  p3 | |  |  |  |  |  |  | | 0  0  0  0  0  0  0 | |  |  |  |  |  |  | | 0  0  0  0  0  0  0 | |  |  |  |  |  |  | | 0  0  0  0  0  0  0 | |  |  |  |  |  |  | |

+------------+----------------+------------+----------------+-------------+

7 rows in set (0.00 sec)

(For more information about this table, see Section 26.3.21, “The INFORMATION\_SCHEMA PARTITIONS Table” .) Now let us populate each of these tables with a single row containing a NULL in the column used as the partitioning key, and verify that the rows were inserted using a pair of SELECT statements:

mysql> **INSERT** **INTO** **t1** **VALUES** **(NULL,** **'mothra');**

Query OK, 1 row affected (0.00 sec)

mysql> **INSERT** **INTO** **t2** **VALUES** **(NULL,** **'mothra');**

Query OK, 1 row affected (0.00 sec)

mysql> **SELECT** **\*** **FROM** **t1;**

+------+--------+

| id | name |

+------+--------+

| NULL | mothra |

+------+--------+

1 row in set (0.00 sec)

mysql> **SELECT** **\*** **FROM** **t2;**

+------+--------+

| id | name |

+------+--------+

| NULL | mothra |

+------+--------+

1 row in set (0.00 sec)

You can see which partitions are used to store the inserted rows by rerunning the previous query against INFORMATION\_SCHEMA.PARTITIONS and inspecting the output:

mysql> **SELECT** **TABLE\_NAME,** **PARTITION\_NAME,** **TABLE\_ROWS,** **AVG\_ROW\_LENGTH,** **DATA\_LENGTH**

> **FROM** **INFORMATION\_SCHEMA.PARTITIONS**

> **WHERE** **TABLE\_SCHEMA** **=** **'p'** **AND** **TABLE\_NAME** **LIKE** **'t\_';**

+------------+----------------+------------+----------------+-------------+

| TABLE\_NAME | PARTITION\_NAME | TABLE\_ROWS | AVG\_ROW\_LENGTH | DATA\_LENGTH |

+------------+----------------+------------+----------------+-------------+

*|*

|

|

*|*

|

|

|

+------------+----------------+------------+----------------+-------------+

7 rows in set (0.01 sec)

*p0*

p1

p2

*p0*

p1

p2

p3

*t1*

t1

t1

*t2*

t2

t2

t2

*20*

0

0

*20*

0

0

0

*20*

0

0

*20*

0

0

0

*1*

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*1*

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*|*

You can also demonstrate that these rows were stored in the lowest-numbered partition of each table by dropping these partitions, and then re-running the SELECT statements:

|  |  |
| --- | --- |
| mysql> **ALTER** **TABLE** **t1** **DROP** **PARTITION**  Query OK, 0 rows affected (0.16 sec)  mysql> **ALTER** **TABLE** **t2** **DROP** **PARTITION**  Query OK, 0 rows affected (0.16 sec)  mysql> **SELECT** **\*** **FROM** **t1;**  Empty set (0.00 sec)  mysql> **SELECT** **\*** **FROM** **t2;**  Empty set (0.00 sec) | **p0;**  **p0;** |

(For more information on ALTER TABLE ... DROP PARTITION, see Section 13.1.9, “ALTER TABLE Statement” .)

NULL is also treated in this way for partitioning expressions that use SQL functions. Suppose that we define a table using a CREATE TABLE statement such as this one:

CREATE TABLE tndate (

id INT,

dt DATE

)

PARTITION BY RANGE( YEAR(dt)

PARTITION p0 VALUES LESS

PARTITION p1 VALUES LESS

PARTITION p2 VALUES LESS

);

As with other MySQL functions, YEAR(NULL) returns NULL. A row with a dt column value of NULL is treated as though the partitioning expression evaluated to a value less than any other value, and so is inserted into partition p0.

) (

THAN (1990),

THAN (2000),

THAN MAXVALUE

**Handling** **of** **NULL** **with** **LIST** **partitioning.** A table that is partitioned by LIST admits NULL values if and only if one of its partitions is defined using that value-list that contains NULL. The converse of this is that a table partitioned by LIST which does not explicitly use NULL in a value list rejects rows resulting in a NULL value for the partitioning expression, as shown in this example:

mysql> **CREATE** **TABLE** **ts1** **(**

-> **c1** **INT,**

-> **c2** **VARCHAR(20)**

-> **)**

-> **PARTITION** **BY** **LIST(c1)** **(**

-> **PARTITION** **p0** **VALUES** **IN** **(0,** **3,** **6),**

-> **PARTITION** **p1** **VALUES** **IN** **(1,** **4,** **7),**

-> **PARTITION** **p2** **VALUES** **IN** **(2,** **5,** **8)**

-> **);**

Query OK, 0 rows affected (0.01 sec)

mysql> **INSERT** **INTO** **ts1** **VALUES** **(9,** **'mothra');**

ERROR 1504 (HY000): Table has no partition for value 9

mysql> **INSERT** **INTO** **ts1** **VALUES** **(NULL,** **'mothra');**

ERROR 1504 (HY000): Table has no partition for value NULL

Only rows having a c1 value between 0 and 8 inclusive can be inserted into ts1. NULL falls outside this range, just like the number 9. We can create tables ts2 and ts3 having value lists containing NULL, as shown here:

mysql> **CREATE** **TABLE** **ts2** **(**

-> **c1** **INT,**

-> **c2** **VARCHAR(20)**

-> **)**

-> **PARTITION** **BY** **LIST(c1)** **(**

-> **PARTITION** **p0** **VALUES** **IN** **(0,** **3,** **6),**

-> **PARTITION** **p1** **VALUES** **IN** **(1,** **4,** **7),**

-> **PARTITION** **p2** **VALUES** **IN** **(2,** **5,** **8),**

-> **PARTITION** **p3** **VALUES** **IN** **(NULL)**

-> **);**

Query OK, 0 rows affected (0.01 sec)

mysql> **CREATE** **TABLE** **ts3** **(**

-> **c1** **INT,**

-> **c2** **VARCHAR(20)**

-> **)**

-> **PARTITION** **BY** **LIST(c1)** **(**

-> **PARTITION** **p0** **VALUES** **IN** **(0,** **3,** **6),**

-> **PARTITION** **p1** **VALUES** **IN** **(1,** **4,** **7,** **NULL),**

-> **PARTITION** **p2** **VALUES** **IN** **(2,** **5,** **8)**

-> **);**

Query OK, 0 rows affected (0.01 sec)

When defining value lists for partitioning, you can (and should) treat NULLjust as you would any other value. For example, both VALUES IN (NULL) and VALUES IN (1, 4, 7, NULL) are valid, as are VALUES IN (1, NULL, 4, 7), VALUES IN (NULL, 1, 4, 7), and so on. You can insert a row having NULL for column c1 into each of the tables ts2 and ts3:

mysql> **INSERT** **INTO** **ts2** **VALUES** **(NULL,** **'mothra');**

Query OK, 1 row affected (0.00 sec)

mysql> **INSERT** **INTO** **ts3** **VALUES** **(NULL,** **'mothra');**

Query OK, 1 row affected (0.00 sec)

By issuing the appropriate query against INFORMATION\_SCHEMA.PARTITIONS, you can determine which partitions were used to store the rows just inserted (we assume, as in the previous examples, that the partitioned tables were created in the p database):

mysql> **SELECT** **TABLE\_NAME,** **PARTITION\_NAME,** **TABLE\_ROWS,** **AVG\_ROW\_LENGTH,** **DATA\_LENGTH**

> **FROM** **INFORMATION\_SCHEMA.PARTITIONS**

> **WHERE** **TABLE\_SCHEMA** **=** **'p'** **AND** **TABLE\_NAME** **LIKE** **'ts\_';**

+------------+----------------+------------+----------------+-------------+

| TABLE\_NAME | PARTITION\_NAME | TABLE\_ROWS | AVG\_ROW\_LENGTH | DATA\_LENGTH |

+------------+----------------+------------+----------------+-------------+

|

|

|

*|*

|

*|*

|

+------------+----------------+------------+----------------+-------------+

7 rows in set (0.01 sec)

ts2

ts2

ts2

*ts2*

ts3

*ts3*

ts3

p0

p1

p2

*p3*

p0

*p1*

p2

0

0

0

*20*

0

*20*

0

0

0

0

*20*

0

*20*

0

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As shown earlier in this section, you can also verify which partitions were used for storing the rows by deleting these partitions and then performing a SELECT.

**Handling** **of** **NULL** **with** **HASH** **and** **KEY** **partitioning.** NULL is handled somewhat differently for tables partitioned by HASH or KEY. In these cases, any partition expression that yields a NULL value is treated as though its return value were zero. We can verify this behavior by examining the effects on the file system of creating a table partitioned by HASH and populating it with a record containing appropriate values. Suppose that you have a table th (also in the p database) created using the following statement:

mysql> **CREATE** **TABLE** **th** **(**

-> **c1** **INT,**

-> **c2** **VARCHAR(20)**

-> **)**

-> **PARTITION** **BY** **HASH(c1)**

-> **PARTITIONS** **2;**

Query OK, 0 rows affected (0.00 sec)

The partitions belonging to this table can be viewed using the query shown here:

mysql> SELECT TABLE\_NAME,PARTITION\_NAME,TABLE\_ROWS,AVG\_ROW\_LENGTH,DATA\_LENGTH

> FROM INFORMATION\_SCHEMA .PARTITIONS

> WHERE TABLE\_SCHEMA = 'p' AND TABLE\_NAME ='th';

+------------+----------------+------------+----------------+-------------+

| TABLE\_NAME | PARTITION\_NAME | TABLE\_ROWS | AVG\_ROW\_LENGTH | DATA\_LENGTH |

+------------+----------------+------------+----------------+-------------+



|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  | | th  th | | p0  | p1 | |  | | 0  0 | |  | | 0  0 | |  | | 0  0 | |  | |

+------------+----------------+------------+----------------+-------------+

2 rows in set (0.00 sec)

TABLE\_ROWS for each partition is 0. Now insert two rows into th whose c1 column values are NULL and 0, and verify that these rows were inserted, as shown here:

mysql> **INSERT** **INTO** **th** **VALUES** **(NULL,** **'mothra'),** **(0,** **'gigan');**

Query OK, 1 row affected (0.00 sec)

mysql> **SELECT** **\*** **FROM** **th;**

+------+---------+

| c1 | c2 |

+------+---------+

| NULL | mothra |

+------+---------+

| 0 | gigan |

+------+---------+

2 rows in set (0.01 sec)

Recall that for any integer *N*, the value of NULL MOD *N* is always NULL. For tables that are partitioned by HASH or KEY, this result is treated for determining the correct partition as 0. Checking the Information Schema PARTITIONS table once again, we can see that both rows were inserted into partition p0:

mysql> **SELECT** **TABLE\_NAME,** **PARTITION\_NAME,** **TABLE\_ROWS,** **AVG\_ROW\_LENGTH,** **DATA\_LENGTH**

> **FROM** **INFORMATION\_SCHEMA.PARTITIONS**

> **WHERE** **TABLE\_SCHEMA** **=** **'p'** **AND** **TABLE\_NAME** **='th';**

+------------+----------------+------------+----------------+-------------+

| TABLE\_NAME | PARTITION\_NAME | TABLE\_ROWS | AVG\_ROW\_LENGTH | DATA\_LENGTH |

+------------+----------------+------------+----------------+-------------+

*|*

|

+------------+----------------+------------+----------------+-------------+

2 rows in set (0.00 sec)

*|* *p0*

| p1

*th*

th

*20*

0

*20*

0

*2*

0

*|*

|

*|*

|

*|*

|

*|*

|

By repeating the last example using PARTITION BY KEY in place of PARTITION BY HASH in the definition of the table, you can verify that NULL is also treated like 0 for this type of partitioning.

**24.3** **Partition** **Management**

There are a number of ways using SQL statements to modify partitioned tables; it is possible to add, drop, redefine, merge, or split existing partitions using the partitioning extensions to the ALTER TABLE statement. There are also ways to obtain information about partitioned tables and partitions. We discuss these topics in the sections that follow.

• For information about partition management in tables partitioned by RANGE or LIST, see [Section 24.3.1, “Management of RANGE and LIST Partitions”](#_bookmark79) .

• For a discussion of managing HASH and KEY partitions, see [Section 24.3.2, “Management of HASH](#_bookmark80) [and KEY Partitions”](#_bookmark80) .

• See Section 24.3.5, “Obtaining Information About Partitions” , for a discussion of mechanisms provided in MySQL 8.0 for obtaining information about partitioned tables and partitions.

• For a discussion of performing maintenance operations on partitions, see Section 24.3.4, “Maintenance of Partitions” .

**Note**

All partitions of a partitioned table must have the same number of subpartitions; it is not possible to change the subpartitioning once the table has been created.

To change a table's partitioning scheme, it is necessary only to use the ALTER TABLE statement with a *partition\_options* option, which has the same syntax as that as used with CREATE TABLE



for creating a partitioned table; this option (also) always begins with the keywords PARTITION BY. Suppose that the following CREATE TABLE statement was used to create a table that is partitioned by range:

CREATE TABLE trb3 (id INT, name VARCHAR(50), purchased DATE)

PARTITION BY RANGE( YEAR(purchased) ) (

PARTITION p0 VALUES LESS THAN (1990),

PARTITION p1 VALUES LESS THAN (1995),

PARTITION p2 VALUES LESS THAN (2000),

PARTITION p3 VALUES LESS THAN (2005)

);

To repartition this table so that it is partitioned by key into two partitions using the id column value as the basis for the key, you can use this statement:

ALTER TABLE trb3 PARTITION BY KEY(id) PARTITIONS 2;

This has the same effect on the structure of the table as dropping the table and re-creating it using

CREATE TABLE trb3 PARTITION BY KEY(id) PARTITIONS 2;.

ALTER TABLE ... ENGINE = ... changes only the storage engine used by the table, and leaves the table's partitioning scheme intact. The statement succeeds only if the target storage engine provides partitioning support. You can use ALTER TABLE ... REMOVE PARTITIONING to remove a table's partitioning; see Section 13.1.9, “ALTER TABLE Statement” .

**Important**

Only a single PARTITION BY, ADD PARTITION, DROP PARTITION, REORGANIZE PARTITION, or COALESCE PARTITION clause can be used in a given ALTER TABLE statement. If you (for example) wish to drop a partition and reorganize a table's remaining partitions, you must do so in two separate ALTER TABLE statements (one using DROP PARTITION and then a second one using REORGANIZE PARTITION).

You can delete all rows from one or more selected partitions using ALTER TABLE ... TRUNCATE

PARTITION.

**24.3.1** **Management** **of** **RANGE** **and** **LIST** **Partitions**

Adding and dropping of range and list partitions are handled in a similar fashion, so we discuss the management of both sorts of partitioning in this section. For information about working with tables that are partitioned by hash or key, see [Section 24.3.2, “Management of HASH and KEY Partitions”](#_bookmark80) .

Dropping a partition from a table that is partitioned by either RANGE or by LIST can be accomplished using the ALTER TABLE statement with the DROP PARTITION option. Suppose that you have created a table that is partitioned by range and then populated with 10 records using the following CREATE TABLE and INSERT statements:

mysql> **CREATE** **TABLE** **tr** **(id** **INT,** **name** **VARCHAR(50),** **purchased** **DATE)**

-> **PARTITION** **BY** **RANGE(** **YEAR(purchased)** **)** **(**

->

->

->

->

->

->

->

Query OK, 0 rows affected (0.28 sec)

mysql> **INSERT** **INTO** **tr** **VALUES**

|  |  |
| --- | --- |
| ->  ->  ->  ->  ->  -> | **(1,** **'desk** **organiser',** **'2003-10-15'),**  **(2,** **'alarm** **clock',** **'1997-11-05'),**  **(3,** **'chair',** **'2009-03-10'),**  **(4,** **'bookcase',** **'1989-01-10'),**  **(5,** **'exercise** **bike',** **'2014-05-09'),**  **(6,** **'sofa',** **'1987-06-05'),** |

**p0** **VALUES** **LESS** **THAN** **(1990),**

**p1** **VALUES** **LESS** **THAN** **(1995),**

**p2** **VALUES** **LESS** **THAN** **(2000),**

**p3** **VALUES** **LESS** **THAN** **(2005),**

**p4** **VALUES** **LESS** **THAN** **(2010),**

**p5** **VALUES** **LESS** **THAN** **(2015)**

**PARTITION**

**PARTITION**

**PARTITION**

**PARTITION**

**PARTITION**

**PARTITION**

**);**



-> **(7,** **'espresso** **maker',** **'2011-11-22'),**

-> **(8,** **'aquarium',** **'1992-08-04'),**

-> **(9,** **'study** **desk',** **'2006-09-16'),**

-> **(10,** **'lava** **lamp',** **'1998-12-25');**

Query OK, 10 rows affected (0.05 sec)

Records: 10 Duplicates: 0 Warnings: [0](#_bookmark87)

You can see which items should have been inserted into partition p2 as shown here:

mysql> **SELECT** **\*** **FROM** **tr**

-> **WHERE** **purchased** **BETWEEN** **'1995-01-01'** **AND** **'1999-12-31';**

+------+-------------+------------+

| id | name | purchased |

+------+-------------+------------+

| 2 | alarm clock | 1997-11-05 |

| 10 | lava lamp | 1998-12-25 |

+------+-------------+------------+

2 rows in set (0.00 sec)

You can also get this information using partition selection, as shown here:

mysql> **SELECT** **\*** **FROM** **tr** **PARTITION** **(p2);**

+------+-------------+------------+

| id | name | purchased |

+------+-------------+------------+

| 2 | alarm clock | 1997-11-05 |

| 10 | lava lamp | 1998-12-25 |

+------+-------------+------------+

2 rows in set (0.00 sec)

See Section 24.5, “Partition Selection” , for more information.

To drop the partition named p2, execute the following command:

mysql> **ALTER** **TABLE** **tr** **DROP** **PARTITION** **p2;**

Query OK, 0 rows affected (0.03 sec)

**Note**

The NDBCLUSTER storage engine does not support ALTER TABLE ... DROP PARTITION. It does, however, support the other partitioning-related extensions to ALTER TABLE that are described in this chapter.

It is very important to remember that, *when* *you* *drop* *a* *partition,* *you* *also* *delete* *all* *the* *data* *that* *was* *stored* *in* *that* *partition*. You can see that this is the case by re-running the previous SELECT query:

mysql> **SELECT** **\*** **FROM** **tr** **WHERE** **purchased**

-> **BETWEEN** **'1995-01-01'** **AND** **'1999-12-31';**

Empty set (0.00 sec)

**Note**

DROP PARTITION is supported by native partitioning in-place APIs and may be used with ALGORITHM={COPY |INPLACE}. DROP PARTITION with ALGORITHM=INPLACE deletes data stored in the partition and drops the partition. However, DROP PARTITION with ALGORITHM=COPY or old\_alter\_table=ON rebuilds the partitioned table and attempts to move data from the dropped partition to another partition with a compatible PARTITION ... VALUES definition. Data that cannot be moved to another partition is deleted.

Because of this, you must have the DROP privilege for a table before you can execute ALTER TABLE ... DROP PARTITION on that table.

If you wish to drop all data from all partitions while preserving the table definition and its partitioning scheme, use the TRUNCATE TABLE statement. (See Section 13.1.37, “TRUNCATE TABLE Statement” .)

If you intend to change the partitioning of a table *without* losing data, use ALTER TABLE ... REORGANIZE PARTITION instead. See below or in Section 13.1.9, “ALTER TABLE Statement” , for information about REORGANIZE PARTITION.

If you now execute a SHOW CREATE TABLE statement, you can see how the partitioning makeup of the table has been changed:

mysql> **SHOW** **CREATE** **TABLE** **tr\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Table: tr

Create Table: CREATE TABLE `tr` (

`id` int(11) DEFAULT NULL,

`name` varchar(50) DEFAULT NULL,

`purchased` date DEFAULT NULL

) ENGINE=InnoDB DEFAULT CHARSET=latin1

/\*!50100 PARTITION BY RANGE ( YEAR(purchased))

(PARTITION p0 VALUES LESS THAN (1990) ENGINE = InnoDB,

PARTITION p1 VALUES LESS THAN (1995) ENGINE = InnoDB,

PARTITION p3 VALUES LESS THAN (2005) ENGINE = InnoDB,

PARTITION p4 VALUES LESS THAN (2010) ENGINE = InnoDB,

PARTITION p5 VALUES LESS THAN (2015) ENGINE = InnoDB) \*/

1 row in set (0.00 sec)

When you insert new rows into the changed table with purchased column values between '1995-01-01' and '2004-12-31' inclusive, those rows are stored in partition p3. You can verify this as follows:

mysql> **INSERT** **INTO** **tr** **VALUES** **(11,** **'pencil** **holder',** **'1995-07-12');**

Query OK, 1 row affected (0.00 sec)

mysql> **SELECT** **\*** **FROM** **tr** **WHERE** **purchased**

-> **BETWEEN** **'1995-01-01'** **AND** **'2004-12-31';**

+------+----------------+------------+

| id | name | purchased |

+------+----------------+------------+

| 1 | desk organiser | 2003-10-15 |

| 11 | pencil holder | 1995-07-12 |

+------+----------------+------------+

2 rows in set (0.00 sec)

mysql> **ALTER** **TABLE** **tr** **DROP** **PARTITION** **p3;**

Query OK, 0 rows affected (0.03 sec)

mysql> **SELECT** **\*** **FROM** **tr** **WHERE** **purchased**

-> **BETWEEN** **'1995-01-01'** **AND** **'2004-12-31';**

Empty set (0.00 sec)

The number of rows dropped from the table as a result of ALTER TABLE ... DROP PARTITION is

not reported by the server as it would be by the equivalent DELETE query.

Dropping LIST partitions uses exactly the same ALTER TABLE ... DROP PARTITION syntax as used for dropping RANGE partitions. However, there is one important difference in the effect this has on your use of the table afterward: You can no longer insert into the table any rows having any of the values that were included in the value list defining the deleted partition. (See [Section 24.2.2, “LIST](#_bookmark73) [Partitioning”](#_bookmark73) , for an example.)

To add a new range or list partition to a previously partitioned table, use the ALTER TABLE ... ADD PARTITION statement. For tables which are partitioned by RANGE, this can be used to add a new range to the end of the list of existing partitions. Suppose that you have a partitioned table containing membership data for your organization, which is defined as follows:

CREATE TABLE members (

id INT,

fname VARCHAR(25),

lname VARCHAR(25),

dob DATE

)

PARTITION BY RANGE( YEAR(dob) ) (

PARTITION p0 VALUES LESS THAN (1980),

PARTITION p1 VALUES LESS THAN (1990),

PARTITION p2 VALUES LESS THAN (2000)

);

Suppose further that the minimum age for members is 16. As the calendar approaches the end of 2015, you realize that you must soon be prepared to admit members who were born in 2000 (and later). You can modify the members table to accommodate new members born in the years 2000 to 2010 as shown here:

ALTER TABLE members ADD PARTITION (PARTITION p3 VALUES LESS THAN (2010));

With tables that are partitioned by range, you can use ADD PARTITION to add new partitions to the high end of the partitions list only. Trying to add a new partition in this manner between or before existing partitions results in an error as shown here:

mysql> **ALTER** **TABLE** **members**

> **ADD** **PARTITION** **(**

> **PARTITION** **n** **VALUES** **LESS** **THAN** **(1970));**

ERROR 1463 (HY000): VALUES LESS THAN value must be strictly »

increasing for each partition

You can work around this problem by reorganizing the first partition into two new ones that split the range between them, like this:

ALTER TABLE members

REORGANIZE PARTITION p0 INTO (

PARTITION n0 VALUES LESS THAN (1970),

PARTITION n1 VALUES LESS THAN (1980)

);

Using SHOW CREATE TABLE you can see that the ALTER TABLE statement has had the desired effect:

mysql> **SHOW** **CREATE** **TABLE** **members\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Table: members

Create Table: CREATE TABLE `members` (

`id` int(11) DEFAULT NULL,

`fname` varchar(25) DEFAULT NULL,

`lname` varchar(25) DEFAULT NULL,

`dob` date DEFAULT NULL

) ENGINE=InnoDB DEFAULT CHARSET=latin1

/\*!50100 PARTITION BY RANGE ( YEAR(dob))

(PARTITION n0 VALUES LESS THAN (1970) ENGINE = InnoDB,

PARTITION n1 VALUES LESS THAN (1980) ENGINE = InnoDB,

PARTITION p1 VALUES LESS THAN (1990) ENGINE = InnoDB,

PARTITION p2 VALUES LESS THAN (2000) ENGINE = InnoDB,

PARTITION p3 VALUES LESS THAN (2010) ENGINE = InnoDB) \*/

1 row in set (0.00 sec)

See also Section 13.1.9.1, “ALTER TABLE Partition Operations” .

You can also use ALTER TABLE ... ADD PARTITION to add new partitions to a table that is partitioned by LIST. Suppose a table tt is defined using the following CREATE TABLE statement:

|  |  |
| --- | --- |
| CREATE TABLE tt (  id INT,  data INT  )  PARTITION BY LIST(data)  PARTITION p0 VALUES  PARTITION p1 VALUES  ); | (  IN (5, 10, 15),  IN (6, 12, 18) |

You can add a new partition in which to store rows having the data column values 7, 14, and 21 as shown:

ALTER TABLE tt ADD PARTITION (PARTITION p2 VALUES IN (7, 14, 21));

Keep in mind that you *cannot* add a new LIST partition encompassing any values that are already included in the value list of an existing partition. If you attempt to do so, an error results:

mysql> **ALTER** **TABLE** **tt** **ADD** **PARTITION**

> **(PARTITION** **np** **VALUES** **IN** **(4,** **8,** **12));**

ERROR 1465 (HY000): Multiple definition of same constant »

in list partitioning

Because any rows with the data column value 12 have already been assigned to partition p1, you cannot create a new partition on table tt that includes 12 in its value list. To accomplish this, you could drop p1, and add np and then a new p1 with a modified definition. However, as discussed earlier, this would result in the loss of all data stored in p1—and it is often the case that this is not what you really want to do. Another solution might appear to be to make a copy of the table with the new partitioning and to copy the data into it using CREATE TABLE ... SELECT ..., then drop the old table and rename the new one, but this could be very time-consuming when dealing with a large amounts of data. This also might not be feasible in situations where high availability is a requirement.

You can add multiple partitions in a single ALTER TABLE ... ADD PARTITION statement as shown here:

CREATE TABLE employees (

id INT NOT NULL,

fname VARCHAR(50) NOT NULL,

lname VARCHAR(50) NOT NULL,

hired DATE NOT NULL

)

PARTITION BY RANGE( YEAR(hired) ) (

PARTITION p1 VALUES LESS THAN (1991),

PARTITION p2 VALUES LESS THAN (1996),

PARTITION p3 VALUES LESS THAN (2001),

PARTITION p4 VALUES LESS THAN (2005)

);

ALTER TABLE employees ADD PARTITION (

PARTITION p5 VALUES LESS THAN (2010),

PARTITION p6 VALUES LESS THAN MAXVALUE

);

Fortunately, MySQL's partitioning implementation provides ways to redefine partitions without losing data. Let us look first at a couple of simple examples involving RANGE partitioning. Recall the members table which is now defined as shown here:

mysql> **SHOW** **CREATE** **TABLE** **members\G**

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* 1. row \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Table: members

Create Table: CREATE TABLE `members` (

`id` int(11) DEFAULT NULL,

`fname` varchar(25) DEFAULT NULL,

`lname` varchar(25) DEFAULT NULL,

`dob` date DEFAULT NULL

) ENGINE=InnoDB DEFAULT CHARSET=latin1

/\*!50100 PARTITION BY RANGE ( YEAR(dob))

(PARTITION n0 VALUES LESS THAN (1970) ENGINE = InnoDB,

PARTITION n1 VALUES LESS THAN (1980) ENGINE = InnoDB,

PARTITION p1 VALUES LESS THAN (1990) ENGINE = InnoDB,

PARTITION p2 VALUES LESS THAN (2000) ENGINE = InnoDB,

PARTITION p3 VALUES LESS THAN (2010) ENGINE = InnoDB) \*/

1 row in set (0.00 sec)

Suppose that you would like to move all rows representing members born before 1960 into a separate partition. As we have already seen, this cannot be done using ALTER TABLE ... ADD PARTITION. However, you can use another partition-related extension to ALTER TABLE to accomplish this:

ALTER TABLE members REORGANIZE PARTITION n0 INTO (

PARTITION s0 VALUES LESS THAN (1960),

PARTITION s1 VALUES LESS THAN (1970)

);

In effect, this command splits partition p0 into two new partitions s0 and s1. It also moves the data that was stored in p0 into the new partitions according to the rules embodied in the two PARTITION ... VALUES ... clauses, so that s0 contains only those records for which YEAR(dob) is less than 1960 and s1 contains those rows in which YEAR(dob) is greater than or equal to 1960 but less than 1970.

A REORGANIZE PARTITION clause may also be used for merging adjacent partitions. You can reverse the effect of the previous statement on the members table as shown here:

ALTER TABLE members REORGANIZE PARTITION s0,s1 INTO (

PARTITION p0 VALUES LESS THAN (1970)

);

No data is lost in splitting or merging partitions using REORGANIZE PARTITION. In executing the above statement, MySQL moves all of the records that were stored in partitions s0 and s1 into partition

p0.

The general syntax for REORGANIZE PARTITION is shown here:

ALTER TABLE *tbl\_name*

REORGANIZE PARTITION *partition\_list*

INTO (*partition\_definitions*);

Here, *tbl\_name* is the name of the partitioned table, and *partition\_list* is a comma-separated list of names of one or more existing partitions to be changed. *partition\_definitions*

is a comma-separated list of new partition definitions, which follow the same rules as for the *partition\_definitions* list used in CREATE TABLE. You are not limited to merging several partitions into one, or to splitting one partition into many, when using REORGANIZE PARTITION. For example, you can reorganize all four partitions of the members table into two, like this:

ALTER TABLE members REORGANIZE PARTITION p0,p1,p2,p3 INTO (

PARTITION m0 VALUES LESS THAN (1980),

PARTITION m1 VALUES LESS THAN (2000)

);

You can also use REORGANIZE PARTITION with tables that are partitioned by LIST. Let us return to the problem of adding a new partition to the list-partitioned tt table and failing because the new partition had a value that was already present in the value-list of one of the existing partitions. We can handle this by adding a partition that contains only nonconflicting values, and then reorganizing the new partition and the existing one so that the value which was stored in the existing one is now moved to the new one:

ALTER TABLE tt ADD PARTITION (PARTITION np VALUES IN (4, 8));

ALTER TABLE tt REORGANIZE PARTITION p1,np INTO (

PARTITION p1 VALUES IN (6, 18),

PARTITION np VALUES in (4, 8, [12)](#_bookmark88)

);

Here are some key points to keep in mind when using ALTER TABLE ... REORGANIZE PARTITION to repartition tables that are partitioned by RANGE or LIST:

• The PARTITION options used to determine the new partitioning scheme are subject to the same rules as those used with a CREATE TABLE statement.

A new RANGE partitioning scheme cannot have any overlapping ranges; a new LIST partitioning scheme cannot have any overlapping sets of values.

• The combination of partitions in the *partition\_definitions* list should account for the same range or set of values overall as the combined partitions named in the *partition\_list*.

For example, partitions p1 and p2 together cover the years 1980 through 1999 in the members table used as an example in this section. Any reorganization of these two partitions should cover the same range of years overall.

• For tables partitioned by RANGE, you can reorganize only adjacent partitions; you cannot skip range partitions.

For instance, you could not reorganize the example members table using a statement beginning with ALTER TABLE members REORGANIZE PARTITION p0,p2 INTO ... because p0 covers the years prior to 1970 and p2 the years from 1990 through 1999 inclusive, so these are not adjacent partitions. (You cannot skip partition p1 in this case.)

• You cannot use REORGANIZE PARTITION to change the type of partitioning used by the table (for example, you cannot change RANGE partitions to HASH partitions or the reverse). You also cannot use this statement to change the partitioning expression or column. To accomplish either of these tasks without dropping and re-creating the table, you can use ALTER TABLE ... PARTITION BY ..., as shown here:

ALTER TABLE members

PARTITION BY HASH( YEAR(dob) )

PARTITIONS 8;

**24.3.2** **Management** **of** **HASH** **and** **KEY** **Partitions**

Tables which are partitioned by hash or by key are very similar to one another with regard to making changes in a partitioning setup, and both differ in a number of ways from tables which have been partitioned by range or list. For that reason, this section addresses the modification of tables partitioned by hash or by key only. For a discussion of adding and dropping of partitions of tables that are partitioned by range or list, see [Section 24.3.1, “Management of RANGE and LIST Partitions”](#_bookmark79) .

You cannot drop partitions from tables that are partitioned by HASH or KEY in the same way that you can from tables that are partitioned by RANGE or LIST. However, you can merge HASH or KEY partitions using ALTER TABLE ... COALESCE PARTITION. Suppose that a clients table containing data about clients is divided into 12 partitions, created as shown here:

CREATE TABLE clients (

id INT,

fname VARCHAR(30),

lname VARCHAR(30),

signed DATE

)

PARTITION BY HASH( MONTH(signed) )

PARTITIONS 12;

To reduce the number of partitions from 12 to 8, execute the following ALTER TABLE statement:

mysql> **ALTER** **TABLE** **clients** **COALESCE** **PARTITION** **4;**

Query OK, 0 rows affected (0.02 sec)

COALESCE works equally well with tables that are partitioned by HASH, KEY, LINEAR HASH, or LINEAR KEY. Here is an example similar to the previous one, differing only in that the table is partitioned by LINEAR KEY:

mysql> **CREATE** **TABLE** **clients\_lk** **(**

-> **id** **INT,**

-> **fname** **VARCHAR(30),**

-> **lname** **VARCHAR(30),**

-> **signed** **DATE**

-> **)**

-> **PARTITION** **BY** **LINEAR** **KEY(signed)**

-> **PARTITIONS** **12;**

Query OK, 0 rows affected (0.03 sec)

mysql> **ALTER** **TABLE** **clients\_lk** **COALESCE** **PARTITION** **4;**

Query OK, 0 rows affected (0.06 sec)

Records: 0 Duplicates: 0 Warnings: [0](#_bookmark89)

The number following COALESCE PARTITION is the number of partitions to merge into the remainder — in other words, it is the number of partitions to remove from the table.

Attempting to remove more partitions than are in the table results in an error like this one:

mysql> **ALTER** **TABLE** **clients** **COALESCE** **PARTITION** **18;**

ERROR 1478 (HY000): Cannot remove all partitions, use DROP TABLE instead

To increase the number of partitions for the clients table from 12 to 18, use ALTER TABLE ... ADD PARTITION as shown here:

ALTER TABLE clients ADD PARTITION PARTITIONS 6;

**24.3.3** **Exchanging** **Partitions** **and** **Subpartitions** **with** **Tables**

In MySQL 8.0, it is possible to exchange a table partition or subpartition with a table using ALTER TABLE *pt* EXCHANGE PARTITION *p* WITH TABLE *nt*, where *pt* is the partitioned table and *p* is the partition or subpartition of *pt* to be exchanged with unpartitioned table *nt*, provided that the following statements are true:

1. Table *nt* is not itself partitioned.

2. Table *nt* is not a temporary table.

3. The structures of tables *pt* and *nt* are otherwise identical.

4. Table nt contains no foreign key references, and no other table has any foreign keys that refer to nt.

5. There are no rows in *nt* that lie outside the boundaries of the partition definition for *p*. This condition does not apply if WITHOUT VALIDATION is used.

6. Both tables must use the same character set and collation.

7. For InnoDB tables, both tables must use the same row format. To determine the row format of an InnoDB table, query INFORMATION\_SCHEMA.INNODB\_TABLES.

8. Any partition-level MAX\_ROWS setting for p must be the same as the table-level MAX\_ROWS value set for nt. The setting for any partition-level MIN\_ROWS setting for p must also be the same any table- level MIN\_ROWS value set for nt.

This is true in either case whether not pt has an explicit table-level MAX\_ROWS or MIN\_ROWS option in effect.

9. The AVG\_ROW\_LENGTH cannot differ between the two tables pt and nt.

10. pt does not have any partitions that use the DATA DIRECTORY option. This restriction is lifted for InnoDB tables in MySQL 8.0.14 and later.

11. INDEX DIRECTORY cannot differ between the table and the partition to be exchanged with it.

12. No table or partition TABLESPACE options can be used in either of the tables.

In addition to the ALTER, INSERT, and CREATE privileges usually required for ALTER TABLE statements, you must have the DROP privilege to perform ALTER TABLE ... EXCHANGE

PARTITION.

You should also be aware of the following effects of ALTER TABLE ... EXCHANGE PARTITION:

• Executing ALTER TABLE ... EXCHANGE PARTITION does not invoke any triggers on either the partitioned table or the table to be exchanged.

• Any AUTO\_INCREMENT columns in the exchanged table are reset.

• The IGNORE keyword has no effect when used with ALTER TABLE ... EXCHANGE PARTITION.

The syntax for ALTER TABLE ... EXCHANGE PARTITION is shown here, where *pt* is the partitioned table, *p* is the partition (or subpartition) to be exchanged, and *nt* is the nonpartitioned table to be exchanged with *p*:

ALTER TABLE *pt*

EXCHANGE PARTITION *p*

WITH TABLE *nt*;

Optionally, you can append WITH VALIDATION or WITHOUT VALIDATION. When WITHOUT VALIDATION is specified, the ALTER TABLE ... EXCHANGE PARTITION operation does not perform any row-by-row validation when exchanging a partition a nonpartitioned table, allowing database administrators to assume responsibility for ensuring that rows are within the boundaries of the partition definition. WITH VALIDATION is the default.

One and only one partition or subpartition may be exchanged with one and only one nonpartitioned table in a single ALTER TABLE EXCHANGE PARTITION statement. To exchange multiple partitions or subpartitions, use multiple ALTER TABLE EXCHANGE PARTITION statements. EXCHANGE PARTITION may not be combined with other ALTER TABLE options. The partitioning and (if applicable) subpartitioning used by the partitioned table may be of any type or types supported in MySQL 8.0.

**Exchanging** **a** **Partition** **with** **a** **Nonpartitioned** **Table**

Suppose that a partitioned table e has been created and populated using the following SQL statements:

CREATE TABLE e (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30)

)

PARTITION BY RANGE (id) (

PARTITION p0 VALUES LESS THAN (50),

PARTITION p1 VALUES LESS THAN (100),

PARTITION p2 VALUES LESS THAN (150),

PARTITION p3 VALUES LESS THAN (MAXVALUE)

);

INSERT INTO e VALUES

(1669, "Jim", "Smith"),

(337, "Mary", "Jones"),

(16, "Frank", "White"),

(2005, "Linda", "Black");

Now we create a nonpartitioned copy of e named e2. This can be done using the mysql client as shown here:

mysql> **CREATE** **TABLE** **e2** **LIKE** **e;**

Query OK, 0 rows affected (0.04 sec)

mysql> **ALTER** **TABLE** **e2** **REMOVE** **PARTITIONING;**

Query OK, 0 rows affected (0.07 sec)

Records: 0 Duplicates: 0 Warnings: [0](#_bookmark90)

You can see which partitions in table e contain rows by querying the Information Schema PARTITIONS table, like this:

mysql> **SELECT** **PARTITION\_NAME,** **TABLE\_ROWS**

**FROM** **INFORMATION\_SCHEMA.PARTITIONS**

**WHERE** **TABLE\_NAME** **=** **'e';**

+----------------+------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | p0  | p1  | p2  | p3 | |  |  |  | | 1  0  0  3 | |  |  |  | |



+----------------+------------+

2 rows in set (0.00 sec)

**Note**

For partitioned InnoDB tables, the row count given in the TABLE\_ROWS column of the Information Schema PARTITIONS table is only an estimated value used in SQL optimization, and is not always exact.

To exchange partition p0 in table e with table e2, you can use ALTER TABLE, as shown here:

mysql> **ALTER** **TABLE** **e** **EXCHANGE** **PARTITION** **p0** **WITH** **TABLE** **e2;**

Query OK, 0 rows affected (0.04 sec)

More precisely, the statement just issued causes any rows found in the partition to be swapped with those found in the table. You can observe how this has happened by querying the Information Schema PARTITIONS table, as before. The table row that was previously found in partition p0 is no longer present:

mysql> **SELECT** **PARTITION\_NAME,** **TABLE\_ROWS**

**FROM** **INFORMATION\_SCHEMA.PARTITIONS**

**WHERE** **TABLE\_NAME** **=** **'e';**

+----------------+------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | p0  | p1  | p2  | p3 | |  |  |  | | 0  0  0  3 | |  |  |  | |

+----------------+------------+

4 rows in set (0.00 sec)

If you query table e2, you can see that the “missing” row can now be found there:

mysql> **SELECT** **\*** **FROM** **e2;**

+----+-------+-------+

| id | fname | lname |

+----+-------+-------+

| 16 | Frank | White |

+----+-------+-------+

1 row in set (0.00 sec)

The table to be exchanged with the partition does not necessarily have to be empty. To demonstrate this, we first insert a new row into table e, making sure that this row is stored in partition p0 by choosing an id column value that is less than 50, and verifying this afterward by querying the PARTITIONS table:

mysql> **INSERT** **INTO** **e** **VALUES** **(41,** **"Michael",** **"Green");**

Query OK, 1 row affected (0.05 sec)

mysql> **SELECT** **PARTITION\_NAME,** **TABLE\_ROWS**

**FROM** **INFORMATION\_SCHEMA.PARTITIONS**

**WHERE** **TABLE\_NAME** **=** **'e';**

+----------------+------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+------------+

|  |  |  |  |
| --- | --- | --- | --- |
| | p0  | p1  | p2  | p3 | |  |  |  | | 1  0  0  3 | |  |  |  | |

+----------------+------------+

4 rows in set (0.00 sec)

Now we once again exchange partition p0 with table e2 using the same ALTER TABLE statement as previously:

mysql> **ALTER** **TABLE** **e** **EXCHANGE** **PARTITION** **p0** **WITH** **TABLE** **e2;**

Query OK, 0 rows affected (0.28 sec)

**WHERE** **TABLE\_NAME** **=** **'e';**

+----------------+------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+------------+

| p0

| p1

| p2

| p3

|

|

|

|

|

|

|

|

1

0

0

3

+----------------+------------+

4 rows in set (0.00 sec)

mysql> **SELECT** **\*** **FROM** **e2;**

+----+---------+-------+

| id | fname | lname |

+----+---------+-------+

| 41 | Michael | Green |

+----+---------+-------+

1 row in set (0.00 sec)

The output of the following queries shows that the table row that was stored in partition p0 and the table row that was stored in table e2, prior to issuing the ALTER TABLE statement, have now switched places:

mysql> **SELECT** **\*** **FROM** **e;**

+------+-------+-------+

| id | fname | lname |

+------+-------+-------+

|

|

|

|

+------+-------+-------+

4 rows in set (0.00 sec)

mysql> **SELECT** **PARTITION\_NAME,** **TABLE\_ROWS**

**FROM** **INFORMATION\_SCHEMA.PARTITIONS**

White

Smith

Jones

Black

Frank

Jim

Mary

Linda

16

1669

337

2005

|

|

|

|

|

|

|

|

|

|

|

|

**Nonmatching** **Rows**

You should keep in mind that any rows found in the nonpartitioned table prior to issuing the ALTER TABLE ... EXCHANGE PARTITION statement must meet the conditions required for them to be stored in the target partition; otherwise, the statement fails. To see how this occurs, first insert a row into e2 that is outside the boundaries of the partition definition for partition p0 of table e. For example, insert a row with an id column value that is too large; then, try to exchange the table with the partition again:

mysql> **INSERT** **INTO** **e2** **VALUES** **(51,** **"Ellen",** **"McDonald");**

Query OK, 1 row affected (0.08 sec)

mysql> **ALTER** **TABLE** **e** **EXCHANGE** **PARTITION** **p0** **WITH** **TABLE** **e2;**

ERROR 1707 (HY000): Found row that does not match the partition

Only the WITHOUT VALIDATION option would permit this operation to succeed:

mysql> **ALTER** **TABLE** **e** **EXCHANGE** **PARTITION** **p0** **WITH** **TABLE** **e2** **WITHOUT** **VALIDATION;**

Query OK, 0 rows affected (0.02 sec)

When a partition is exchanged with a table that contains rows that do not match the partition definition, it is the responsibility of the database administrator to fix the non-matching rows, which can be performed using REPAIR TABLE or ALTER TABLE ... REPAIR PARTITION.

**Exchanging** **Partitions** **Without** **Row-By-Row** **Validation**

To avoid time consuming validation when exchanging a partition with a table that has many rows, it is possible to skip the row-by-row validation step by appending WITHOUT VALIDATION to the ALTER TABLE ... EXCHANGE PARTITION statement.

The following example compares the difference between execution times when exchanging a partition with a nonpartitioned table, with and without validation. The partitioned table (table e) contains two

partitions of 1 million rows each. The rows in p0 of table e are removed and p0 is exchanged with a nonpartitioned table of 1 million rows. The WITH VALIDATION operation takes 0.74 seconds. By comparison, the WITHOUT VALIDATION operation takes 0.01 seconds.

# Create a partitioned table with 1 million rows in each partition

CREATE TABLE e (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30)

)

PARTITION BY RANGE (id) (

PARTITION p0 VALUES LESS THAN (1000001),

PARTITION p1 VALUES LESS THAN (2000001),

);

mysql> SELECT COUNT(\*) FROM e;

| COUNT(\*) |

+----------+

| 2000000 |

+----------+

1 row in set (0.27 sec)

# View the rows in each partition

SELECT PARTITION\_NAME, TABLE\_ROWS FROM INFORMATION\_SCHEMA.PARTITIONS WHERE TABLE\_NAME = 'e';

+----------------+-------------+

| PARTITION\_NAME | TABLE\_ROWS |

+----------------+-------------+

| p0 | 1000000 |

| p1 | 1000000 |

+----------------+-------------+

2 rows in set (0.00 sec)

# Create a nonpartitioned table of the same structure and populate it with 1 million rows

CREATE TABLE e2 (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30)

);

mysql> SELECT COUNT(\*) FROM e2;

+ +

| COUNT(\*) |

+----------+

| 1000000 |

+----------+

1 row in set (0.24 sec)

# Create another nonpartitioned table of the same structure and populate it with 1 million rows

CREATE TABLE e3 (

id INT NOT NULL,

fname VARCHAR(30),

lname VARCHAR(30)

);

mysql> SELECT COUNT(\*) FROM e3;

+ +

| COUNT(\*) |

+----------+

| 1000000 |

+----------+

1 row in set (0.25 sec)

# Drop the rows from p0 of table e

mysql> DELETE FROM e WHERE id < 1000001;

Query OK, 1000000 rows affected (5.55 sec)

# Confirm that there are no rows in partition p0