Firebird 4.0 Release Notes

Firebird Project: Core Developers
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13 February 2019 - Document v.0400-19 - for Firebird 4.0 Beta 1 Release

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by Firebird Project: Core Developers and Helen Borrie

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Chapter 1

General Notes

Thank you for reviewing this Firebird 4.0 Beta release. We cordially invite you to test it hard against your expectations and engage with us in identifying and fixing any bugs you might encounter.

ODS13 is introduced and it's a major ODS upgrade, so older databases cannot be opened with a Firebird 4 server. At this point in development, nothing more than a backup/restore is needed if you want to upgrade an existing database for your beta testing. The engine library is named `engine13.dll` (Windows) and `engine13.so` (POSIX). The security database is named `security4.fdb`. Binaries layout and configuration are unchanged from Firebird 3.

Known incompatibilities are detailed in Chapter 11, Compatibility Issues.

Bug Reporting

Bugs fixed since Firebird 3 and the Firebird 4 Alpha release are listed and described in the chapter entitled Bugs Fixed.

- If you think you have discovered a new bug in this release, please make a point of reading the instructions for bug reporting in the article How to Report Bugs Effectively, at the Firebird Project website.
- If you think a bug fix has not worked, or has caused a regression, please locate the original bug report in the Tracker, reopen it if necessary, and follow the instructions below.

Follow these guidelines as you attempt to analyse your bug:

1. Write detailed bug reports, supplying the exact build number of your Firebird kit. Also provide details of the OS platform. Include reproducible test data in your report and post it to our Tracker.
2. You are warmly encouraged to make yourself known as a field-tester of this beta by subscribing to the field-testers' list and posting the best possible bug description you can.
3. If you want to start a discussion thread about a bug or an implementation, please do so by subscribing to the firebird-devel list. In that forum you might also see feedback about any tracker ticket you post regarding this Beta.

Documentation

You will find all of the README documents referred to in these notes—as well as many others not referred to —in the doc sub-directory of your Firebird 4.0 installation.

--*The Firebird Project*

Chapter 2

New In Firebird 4.0

Summary of New Features

The following lists summarise the planned features and changes, with links to the topics covering items available to test in this Beta release.

Complete In Beta 1

Support for international time zones
: International time zone support from Firebird 4.0 onward comprises data types, functions and internal algorithms to manage date/time detection, storage and calculations involving international time zones based on UTC (Adriano dos Santos Fernandes).

  For full details, see Support for International Time Zones in the Engine chapter.

  Tracker tickets CORE-694 & CORE-909

Built-in replication
: Built-in logical (row level) replication, both synchronous and asynchronous (Dmitry Yemanov & Roman Simakov)

  For details, see Firebird Replication in the Engine chapter.

  Tracker ticket CORE-2021

New way to capture the database snapshot
: Introducing a new methodology for the Firebird engine to capture the snapshots for retaining the consistency of a transaction's view of database state. The new approach enables read consistency to be maintained for the life of a statement in READ COMMITTED transactions and also allows more optimal garbage collection. The changes are described in more detail in the chapter *Changes in the Firebird Engine* in the topic Commit Order for Capturing the Database Snapshot.

Pooling of external connections
: The external data source (EDS) subsystem has been augmented by a pool of external connections. The pool retains unused external connections for a period to reduce unnecessary overhead from frequent connections and disconnections by clients using the same connection strings (Vlad Khorsun).

  For details, see Pooling of External Connections in the Engine chapter.

  Tracker ticket CORE-5990

Physical standby solution
: Physical standby solution (incremental restore via nbackup).

The changes are described in more detail in the Utilities chapter in the topic *nBackup*: GUID-based Backup and In-Place Merge.

Extended length of metadata identifiers
Metadata names longer than 31 bytes: new maximum length of object names is 63 characters.
The changes are described in more detail in the chapter Data Definition Language, in the topic Extended Length for Object Names.

Configurable time-outs
Timeout periods configurable for statements, transactions and connections.
The changes for statements and connections are described in more detail in the chapter Changes in the Firebird Engine in the topic Timeouts at Two levels (Vlad Khorsun).

Tracker tickets CORE-658 and CORE-985

Extended precision for numerics
Fixed point numerics with precision up to 34 digits are now supported, along with improved intermediate calculations for shorter numerics. For details, see Increased Precision for NUMERIC and DECIMAL Types in the Data Definition Language chapter.

New DECFLOAT data type
The SQL:2016 standard-compliant high-precision numeric type DECFLOAT is introduced, along with related operational functions. It is described in detail in the the topic Data type DECFLOAT in the Data Definition Language chapter.

Enhanced system privileges
Predefined system roles, administrative permissions.
The changes are described in more detail in the Security chapter in the topic Enhanced System Privileges.

See also the Management Statements chapter for some background about what the new system privileges are intended for.

GRANT ROLE TO ROLE
Granting roles to other roles, described in detail in the Security chapter in the topic Granting a Role to Another Role.

User groups
User groups and cumulative permissions are described in detail in the Security chapter in the topic Granting a Role to Another Role.

Batch operations in the API
Batch API operations, bulk load optimizations, support for passing BLOBs in-line.

Tracker ticket CORE-820
For details, see Support for Batch Insert and Update Operations in the API.

Window functions extensions
Extensions to window functions are described in detail in the Data Manipulation Language chapter in the topics Frames for Window Functions, Named Windows and More Window Functions.

FILTER Clause for Aggregate Functions
Tracker ticket CORE-5768

FILTER clause implemented for aggregate functions, see FILTER Clause for Aggregate Functions in the DML chapter.

Enhanced RETURNING clause in DML to enable returning all current field values
Introduces the `RETURNING *` syntax, and variants, to return a complete set of field values after committing a row that has been inserted, updated or deleted (Adriano dos Santos Fernandes). For details, see RETURNING * Now Supported in the DML chapter.

Tracker ticket CORE-3808

Built-in functions FIRST_DAY and LAST_DAY
Tracker ticket CORE-5620

New date/time functions FIRST_DAY and LAST_DAY, see Two New Date/Time Functions in the DML chapter.

Built-in Cryptographic functions
Tracker ticket CORE-5970

New security-related functions, including eight cryptographic ones, see Built-in Cryptographic Functions in the Security chapter.

Monitoring Compression and Encryption Status of Attachments
Compression and encryption status of a connection are now available in the monitoring table MON$ATTACHMENTS:

- MON$WIRE_COMPRESSED (wire compression enabled = 1, disabled = 0)
- MON$WIRE_ENCRYPTED (wire encryption enabled = 1, disabled = 0)

Tracker ticket CORE-5536

Improve performance of gbak restore
The new Batch API was used to improve the performance of *gbak restore*, including parallel operations.

Tracker tickets CORE-2992 and CORE-5952

Backup and Restore with Encryption
Support for backing up and restoring encrypted databases using the crypt and keyholder plug-ins—see Backup and Restore with Encryption in the Utilities chapter.

Also available is compression and decompression of both encrypted and non-encrypted backups.

Compatibility with Older Versions

Notes about compatibility with older Firebird versions are collated in Chapter 12, “Compatibility Issues”.

Chapter 3

Changes in the Firebird Engine

The Firebird engine, V.4, presents no radical changes in architecture or operation. Improvements and enhancements continue, including a doubling of the maximum database page size and the long-awaited ability to impose timeouts on connections and statements that could be troublesome, master-slave replication and international time zone support.

Firebird 4 creates databases with the on-disk structure numbered 13—“ODS 13”. The remote interface protocol number is 16.

Extended Maximum Page Size

Dmitry Yemanov

Tracker ticket CORE-2192

The maximum page size for databases created under ODS 13 has been extended from 16 Kb to 32 Kb.

External Functions (UDFs) Feature Deprecated

The original design of external functions (UDF) support has always been a source of security problems. The most dangerous security holes, that occurred when UDFs and external tables were used simultaneously, were fixed as far back as Firebird 1.5. Nevertheless, UDFs have continued to present vulnerability issues like server crashes and the potential to execute arbitrary code.

The use of UDFs has been aggressively deprecated in Firebird 4:

- The default setting for the configuration parameter `UdfAccess` is `NONE`. In order to run UDFs at all will now require explicit configuration to `Restrict UDF`
- The UDF libraries (ib_udf, fbudf) are no longer distributed in the installation kits
- Most of the functions in the libraries previously distributed in the shared (dynamic) libraries `ib_udf` and `fbudf` had already been replaced with built-in functional analogs. A few remaining UDFs have been replaced with either analog routines in a new library of UDRs named `udf_compat` or converted to stored functions.

  Refer to Deprecation of External Functions (UDFs) in the Compatibility chapter for details and instructions about upgrading to use the safe functions.
- Replacement of UDFs with UDRs or stored functions is strongly recommended

Support for International Time Zones

Adriano dos Santos Fernandes

Tracker tickets CORE-909 and CORE-694

Time zone support from Firebird 4.0 onward consists of

- data types `TIME WITH TIME ZONE` and `TIMESTAMP WITH TIME ZONE`; implicitly also `TIME WITHOUT TIME ZONE` and `TIMESTAMP WITHOUT TIME ZONE`
- expressions and statements to work with time zones
- conversion between data types without/with time zones

> **Important**
>
> The data types `TIME WITHOUT TIME ZONE`, `TIMESTAMP WITHOUT TIME ZONE` and `DATE` are defined to use the *session time zone* when converting from or to a `TIME WITH TIME ZONE` or `TIMESTAMP WITH TIME ZONE`. `TIME` and `TIMESTAMP` are synonymous to their respective `WITHOUT TIME ZONE` data types.

Session Time Zone

As the name implies, the session time zone, can be different for each database attachment. It can be set explicitly in the DPB or SPB with the item `isc_dpb_session_time_zone`; otherwise, by default, it starts defined as the same time zone used by the operating system Firebird process.

Subsequently, the time zone can be changed to a given time zone using a `SET TIME ZONE` statement or reset to its original value with `SET TIME ZONE LOCAL`.

Time Zone Format

A time zone is a string, either a time zone region (for example, 'America/Sao_Paulo') or an hours:minutes displacement from GMT (for example, '-03:00').

A time/timestamp with time zone is considered equal to another time/timestamp with time zone if their conversions to UTC are equivalent. For example, `time '10:00 -02'` and `time '09:00 -03'` are equivalent, since both are the same as `time '12:00 GMT`.

> **Important**
>
> The same equivalence applies in `UNIQUE` constraints and for sorting purposes.

Data Types for Time Zone Support

The syntax for declaring the data types `TIMESTAMP` and `TIME` has been extended to include arguments defining whether the field should be defined with or without time zone adjustments, i.e.,

```
TIME [ { WITHOUT | WITH } TIME ZONE ]

TIMESTAMP [ { WITHOUT | WITH } TIME ZONE ]
```

The default for both `TIME` and `TIMESTAMP` is `WITHOUT TIME ZONE`. For more details, see Data Type Extensions for Time Zone Support in the DDL chapter.

API Support for Time Zones

- Structures (structs)
- Functions

Time Zone Statements and Expressions

Additions and enhancements to syntax in DDL and DML are listed in this section. Follow the links indicated to the details in the DDL and DML chapters.

Statement `SET TIME ZONE`
: Changes the session time zone

Statement `SET TIME ZONE BIND`
: Changes the session time zone bind format for compatibility with old clients

Expression `AT`
: Translates a time/timestamp value to its corresponding value in another time zone

Expression `EXTRACT`
: Two new arguments have been added to the `EXTRACT` expression: `TIMEZONE_HOUR` and `TIMEZONE_MINUTE` to extract the time zone hours displacement and time zone minutes displacement, respectively.

Expression `LOCALTIME`
: Returns the current time as a `TIME WITHOUT TIME ZONE`, i.e., in the session time zone

Expression `LOCALTIMESTAMP`
: Returns the current timestamp as a `TIMESTAMP WITHOUT TIME ZONE`, i.e., in the session time zone

Expressions `CURRENT_TIME` and `CURRENT_TIMESTAMP`
: In version 4.0, `CURRENT_TIME` and `CURRENT_TIMESTAMP` now return `TIME WITH TIME ZONE` and `TIMESTAMP WITH TIME ZONE`, with the time zone set by the session time zone

Virtual table RDB$TIME_ZONES

A virtual table listing time zones supported in the engine. Columns:

RDB$TIME_ZONE_ID type INTEGER

RDB$TIME_ZONE_NAME type CHAR(63)

Package RDB$TIME_ZONE_UTIL

A package of time zone utility functions and procedures:

Function DATABASE_VERSION

`RDB$TIME_ZONE_UTIL.DATABASE_VERSION` returns the version of the time zone database as a `VARCHAR(10) CHARACTER SET ASCII`.

Example

```
select rdb$time_zone_util.database_version() from rdb$database;
```

Returns:

```
  DATABASE_VERSION
  ================
  2017c
```

Procedure TRANSITIONS

`RDB$TIME_ZONE_UTIL.TRANSITIONS` returns the set of rules between the start and end timestamps.

The input parameters are:

`TIME_ZONE_NAME` type `CHAR(63)`
`FROM_TIMESTAMP` type `TIMESTAMP WITH TIME ZONE`
`TO_TIMESTAMP` type `TIMESTAMP WITH TIME ZONE`

Output parameters:

`START_TIMESTAMP`
: type `TIMESTAMP WITH TIME ZONE`—The start timestamp of the transition

`END_TIMESTAMP`
: type `TIMESTAMP WITH TIME ZONE`—The end timestamp of the transition

`ZONE_OFFSET`
: type `SMALLINT`—The zone's offset, in minutes

`DST_OFFSET`
: type `SMALLINT`—The zone's DST offset, in minutes

`EFFECTIVE_OFFSET`
: type `SMALLINT`—Effective offset (`ZONE_OFFSET + DST_OFFSET`)

Example

```
select *
  from rdb$time_zone_util.transitions(
    'America/Sao_Paulo',
    timestamp '2017-01-01',
    timestamp '2019-01-01');
```

Returns:

```
             START_TIMESTAMP                END_TIMESTAMP ZONE_OFFSET DST_OFFSET EFFECTIVE_OFFSE
============================ ============================ =========== ========== ===============
2016-10-16 03:00:00.0000 GMT 2017-02-19 01:59:59.9999 GMT        -180         60             -120
2017-02-19 02:00:00.0000 GMT 2017-10-15 02:59:59.9999 GMT        -180          0             -180
2017-10-15 03:00:00.0000 GMT 2018-02-18 01:59:59.9999 GMT        -180         60             -120
2018-02-18 02:00:00.0000 GMT 2018-10-21 02:59:59.9999 GMT        -180          0             -180
2018-10-21 03:00:00.0000 GMT 2019-02-17 01:59:59.9999 GMT        -180         60             -120
```

Updating the Time Zone Database

Time zones are often changed: of course, when it happens, it is desirable to update the time zone database as soon as possible.

Firebird stores `WITH TIME ZONE` values translated to UTC time. Suppose a value is created with one time zone database and a later update of that database changes the information in the range of our stored value. When that value is read, it will be returned as different to the value that was stored initially.

Firebird uses the IANA time zone database through the ICU library. The ICU library presented in the Firebird kit (Windows), or installed in a POSIX operating system, can sometimes have an outdated time zone database.

An update procedure is described in the online ICU user guide, in the article Updating the Time Zone Data. The simplest way to update is to download the `*.res` files into a directory and set the environment variable `ICU_TIMEZONE_FILES_DIR` to point to it.

Firebird Replication

Dmitry Yemanov
Roman Simakov

Tracker ticket CORE-2021

Firebird 4 introduces built-in support for uni-directional (“master-slave”) logical replication. Logical here means record-level replication, as opposed to physical (page-level) replication. Implementation is primarily directed towards providing for high availability but it can be used for other tasks as well.

Events that are tracked for replication include

- inserted/updated/deleted records
- sequence changes
- DDL statements

Replication is transactional and commit order is preserved. Replication can track changes either in all tables, or in a customized subset of tables. Any table that is to be replicated must have a primary key or, at least, a unique key.

Replication Modes

Both *synchronous* and *asynchronous* modes are available.

Synchronous Mode

In synchronous replication, the primary (master) database is permanently connected to the replica (slave) database(s) and changes are replicated immediately. Effectively the databases are in sync after every commit, which could have an impact on performance due to additional network traffic and round-trips.

> **Note**
>
> Although some recent uncommitted changes may be buffered, they are not transmitted until committed.

More than one synchronous replication can be configured, if necessary.

Asynchronous Mode

In asynchronous replication, changes are written into local journal files that are transferred over the wire and applied to the replica database. The impact on performance is much lower, but imposes a delay—*replication lag*— while changes wait to be applied to the replica database; i.e. the replica database is always “catching up” to the master database.

Access Modes

There are two access modes for replica databases: *read-only* and *read-write*.

- With a read-only replica, only queries that do not modify data are allowed. Modifications are limited to the replication process only.

  > **Note**
  >
  > Global temporary tables can be modified, as they are not replicated.

- A read-write replica allows execution of any query. In this access mode, potential conflicts must be resolved by users.

Journalling

Asynchronous replication is implemented with journalling. Replicated changes are written into the journal which consists of multiple files, known as *replication segments*. The Firebird server writes segments continuously, one after another. Every segment has a unique number which is generated sequentially. This number, known as a *segment sequence*, is combined with the database UUID to provide globally unique identification of journal segments. The global sequence counter is stored inside the replicated database and is reset only when the database is restored from backup.

Segments are rotated regularly, a process that is controlled by either *maximum segment size* or *timeout*. Both thresholds are configurable. Once the active segment reaches the threshold, it is marked as “full” and writing switches to the next available segment.

Full segments are archived and then reused for subsequent writes. Archiving consists of copying the segment in preparation for transferring it to the replica host and applying it there. Copying can be done by the Firebird server itself or, alternatively, by a user-specified custom command.

On the replica side, journal segments are applied in the replication sequence order. The Firebird server periodically scans for new segments appearing in the configured directory. Once the next segment is found, it gets replicated. For each replication source, the replication state is stored in a local file named for the UUID and the replication source. It contains markers for

- latest segment sequence (LSS)
- oldest segment sequence (OSS)
- a list of active transactions started between the OSS and the LSS

About the LSS and OSS

LSS refers to the last replicated segment. OSS refers to the segment that started the earliest transaction that was incomplete at the time LSS was processed.

These markers control two things:

1. what segment must be replicated next and

2. when segment files can be safely deleted

Segments with numbers between the OSS and the LSS are preserved in case the journal needs replaying after the replicator disconnects from the replica database; for example, due to a replication error or an idle timeout.

If there are no active transactions pending and the LSS was processed without errors, all segments up to and including the LSS are deleted.

If a critical error occurs, replication is temporarily suspended and will be retried after the timeout.

Error Reporting

All replication errors and warnings (such as detected conflicts) are written into the `replication.log` file. It may also include detailed descriptions of the operations performed by the replicator.

> **Log file location**
>
> The `replication.log` file is stored in the *Firebird log directory*. By default, the Firebird log directory is the root directory of the Firebird installation.

Setting Up Replication

Setup involves tasks on both the master and replica sides.

Setting Up the Master Side

Replication is configured using a single configuration file, `replication.conf`, on the host serving the master database. Both global and per-database settings are possible within the same file. The available options are listed inside `replication.conf`, along with commented descriptions of each.

> **Per-database configurations**
>
> When configuring options at per-database level, the full database path must be specified within the the {database} section. Aliases and wildcards are not accepted.

Defining a Custom Replication Set

The tables to be replicated can be customized using two settings: `include_filter` and `exclude_filter`. They are regular expressions that are applied to table names, defining the rules for including or excluding them from the replication set.

Synchronous/Asynchronous Modes

Synchronous Mode
: Synchronous replication can be turned on by setting the `sync_replica` specifying a connection string to the replica database, prefixed with username and password. Multiple entries are allowed.

  In the SuperServer and SuperClassic architectures, the replica database is attached internally when the first user gets connected to the master database and is detached when the last user disconnects from the master database.

  In the Classic Server architecture, each server process keeps its own active connection to the replica database.

Asynchronous Mode
: For asynchronous replication the journalling mechanism must be set up. The primary parameter is `log_directory` which defines location of the replication journal. Specifying this location turns on asynchronous replication and tells the Firebird server to start producing the journal segments.

A Minimal Configuration

A minimal master-side configuration would look like this:

```
database = /data/mydb.fdb
{
    log_directory = /dblogs/mydb/
    log_archive_directory = /shiplogs/mydb/
}
```

Archiving is performed by the Firebird server copying the segments from `/dblogs/mydb/` to `/shiplogs/mydb/`.

The same setup, but with user-defined archiving:

```
database = /data/mydb.fdb
{
    log_directory = /dblogs/mydb/
    log_archive_directory = /shiplogs/mydb/
    log_archive_command = "test ! -f $\(archpathname\) && cp $(logpathname) $(archpathname)"
}
```

—where `$(logpathname)` and `$(archpathname)` are built-in macros that provide the custom shell command with real file names.

> **About custom archiving**
>
> Custom archiving, through use of the setting `log_archive_command` allows use of any system shell command, including scripts or batch files, to deliver segments to the replica side. It could use compression, FTP, or whatever else is available on the server.
>
> The actual transport implementation is up to the DBA: Firebird just produces segments on the master side and expects them to appear at the replica side. If the replica storage can be remotely attached to the master host, it becomes just a matter of copying the segment files. In other cases, some transport solution is required.

The same setup, with archiving performed every 10 seconds:

```
database = /data/mydb.fdb
{
    log_directory = /dblogs/mydb/
    log_archive_directory = /shiplogs/mydb/
    log_archive_command = "test ! -f $(archpathname) && cp $(logpathname) $(archpathname)"
    log_archive_timeout = 10
}
```

Read `replication.conf` for other possible settings.

Applying the Master Side Settings

To apply any changes to the master-side settings, all users must be reconnected.

Setting Up the Replica Side

The same `replication.conf` file is used for setting up the replica side. Setting the parameter `log_source_directory` specifies the location that the Firebird server scans for the transmitted segments. In addition, the DBA may specify explicitly which source database is accepted for replication, by setting the parameter `source_guid`.

A Sample Replica Setup

A configuration for a replica could looks like this:

```
database = /data/mydb.fdb
{
    log_source_directory = /incominglogs/
    source_guid = {6F9619FF-8B86-D011-B42D-00CF4FC964FF}
}
```

Read `replication.conf` for other possible settings.

Applying the Replica Side Settings

To apply changes to any replica-side settings, the Firebird server must be restarted.

Creating a Replica Database

Task 1—Make the initial replica

In the Beta 1 release, any physical copying method can be used to create an initial replica of the source database:

- File-level copy while the Firebird server is shut down
- `ALTER DATABASE BEGIN BACKUP` + file-level copy + `ALTER DATABASE END BACKUP`
- `nbackup -l` + file-level copy + `nbackup -n`
- `nbackup -b 0`

Task 2—Activate the replica access mode

Activating the access mode— for the copied database involves the command-line utility *gfix* with the new `-replica` switch and either `read-only` or `read-write` as the argument:

- To set the database copy as a read-only replica

  ```
  gfix -replica read-only <database>
  ```

  If the replica is read-only then only the replicator connection can modify the database. This is mostly intended for high-availability solutions, as the replica database is guaranteed to match the master one and can be used for fast recovery. Regular user connections may perform any operations allowed for read-only transactions: select from tables, execute read-only procedures, write into global temporary tables, etc. Database maintenance such as sweeping, shutdown, monitoring is also allowed.

  A read-only replica can be useful for distributing read-only load, for example, analytics, away from the master database.

  > **Warning**
  >
  > Read-only connections have the potential to conflict with replication if DDL statements that are performed on the master database are of the kind that requires an exclusive lock on metadata.

- To set the database copy as a read-write replica

  ```
  gfix -replica read-write <database>
  ```

  Read-write replicas allow both the replicator connection and regular user connections to modify the database concurrently. With this mode, there is no guarantee that the replica database will be in sync with the master one. Therefore, use of a read-write replica for high availability conditions is not recommended unless user connections on the replica side are limited to modifying only tables that are excluded from replication.

Task 3—Converting the replica to a regular database

A third `gfix -replica` argument is available for "switching off" replication to a read-write replica when conditions call for replication flow to be discontinued for some reason. Typically, it would be used to promote the replica to become the master database after a failure; or to make physical backup copies from the replica.

```
gfix -replica none <database>
```

Pooling of External Connections

Vlad Khorsun

Tracker ticket CORE-5990

To avoid delays when external connections are being established frequently, the external data source (EDS) subsystem has been augmented by a pool of external connections. The pool retains unused external connections for a period to reduce unnecessary overhead from frequent connections and disconnections by clients using the same connection strings.

Key Characteristics of Connection Pooling

The implementation of connection pooling in Firebird 4 eliminates the problem of interminable external connections by controlling and limiting the number of idle connections. The same pool is used for all external connections to all databases and all local connections handled by a given Firebird process. It supports a quick search of all pooled connections using four parameters, described below in New Connections.

Terminology: Two terms recur in the management of the connection pool, in configuration, by DDL `ALTER` statements during run-time and in new context variables in the `SYSTEM` namespace:

Connection life time
: The time interval allowed from the moment of the last usage of a connection to the moment after which it will be forcibly closed. SQL parameter `LIFETIME`, configuration parameter `ExtConnPoolLifeTime`, context variable `EXT_CONN_POOL_LIFETIME`.

Pool size
: The maximum allowed number of idle connections in the pool. SQL parameter `SIZE`, configuration parameter `ExtConnPoolSize`, context variable `EXT_CONN_POOL_SIZE`.

How the Connection Pool Works

Every successful connection is associated with a pool, which maintains two lists—one for idle connections and one for active connections. When a connection in the "active" list has no active requests and no active transactions, it is assumed to be "unused". A reset of the unused connection is attempted using an `ALTER SESSION RESET` statement and,

- if the reset succeeds (no errors occur) the connection is moved into the "idle" list;
- if the reset fails, the connection is closed;

- if the pool has reached its maximum size, the oldest idle connection is closed.
- When the *lifetime* of an idle connection expires, it is deleted from the pool and closed.

New Connections

When the engine is asked to create a new external connection, the pool first looks for a candidate in the “idle” list. The search, which is case-sensitive, involves four parameters:

1. connection string
2. username
3. password
4. role

If suitable connection is found, it is tested to check that it is still alive.

- If it fails the check, it is deleted and the search is repeated, without reporting any error to the client
- Otherwise, the live connection is moved from the “idle” list to the “active” list and returned to the caller
- If there are multiple suitable connections, the most recently used one is chosen
- If there is no suitable connection, a new one is created and added to the “active” list.

Managing the Connection Pool

A new SQL statement has been introduced to manage the pool during run-time from any connection, between Firebird restarts, i.e., changes made with `ALTER EXTERNAL CONNECTIONS POOL` are not persistent.

This is the syntax pattern:

```
ALTER EXTERNAL CONNECTIONS POOL { <parameter variants> }
```

Syntax Variants Available

ALTER EXTERNAL CONNECTIONS POOL SET SIZE <int>
: Sets the maximum number of idle connections

ALTER EXTERNAL CONNECTIONS POOL SET LIFETIME <int> <time_part>
: Sets the lifetime of an idle connection, from 1 second to 24 hours. The `<time_part>` can be `SECOND | MINUTE | HOUR`.

ALTER EXTERNAL CONNECTIONS POOL CLEAR ALL
: Closes all idle connections and instigates dissociation of all active connections immediately they become unused

ALTER EXTERNAL CONNECTIONS POOL CLEAR OLDEST
: Closea expired idle connections

For full descriptions and examples of the variants, see ALTER EXTERNAL CONNECTIONS POOL Statement in the chapter *Management Statements*.

Querying the Connection Pool

The state of the external connections pool can be queried using a set of new context variables in the 'SYSTEM' namespace:

```
EXT_CONN_POOL_SIZE          Pool size
EXT_CONN_POOL_LIFETIME      Idle connection lifetime, in seconds
EXT_CONN_POOL_IDLE_COUNT    Count of currently inactive connections
EXT_CONN_POOL_ACTIVE_COUNT  Count of active connections
                            associated with the pool
```

Parameters for Configuring the Connection Pool

Two new parameters, for `firebird.conf` only, are for configuring the connection pool at process start. Follow the links for details.

ExtConnPoolSize
: Configures the maximum number of idle connections allowed in the pool

ExtConnPoolLifetime
: Configures the number of seconds a connection should stay available after it has gone idle

Timeouts at Two levels

Vladyslav Khorsun

Tracker ticket CORE-5488

Firebird 4 introduces configurable timeouts for running SQL statements and for idle connections (sessions).

Idle Session Timeouts

An idle session timeout allows a user connection to close automatically after a specified period of inactivity. The database admin could use it to enforce closure of old connections that have become inactive, to reduce unnecessary consumption of resources. It could also be used by application and tools developers as an alternative to writing their own modules for controlling connection lifetime.

By default, the idle timeout is not enabled. No minimum or maximum limit is imposed but a reasonably large period, such as a few hours, is recommended.

How the Idle Session Timeout Works

•

When the user API call leaves the engine (returns to the calling connection) a special idle timer associated with the current connection is started

- When another user API call from that connection enters the engine, the idle timer is stopped
- If the idle time is attained, the engine immediately closes the connection in the same way as with asynchronous connection cancellation:
  - all active statements and cursors are closed
  - all active transactions are rolled back
  - The network connection remains open at this point, allowing the client application to get the exact error code on the next API call. The network connection will be closed on the server side, after an error is reported or in due course as a result of a network timeout from a client-side disconnection.

> **Note**
> Whenever a connection is cancelled, the next user API call returns the error **isc_att_shutdown** with a secondary error specifying the exact reason. Now, we have
>
> | | |
> |---|---|
> | isc_att_shut_idle: | Idle timeout expired |
> | in addition to | |
> | isc_att_shut_killed: | Killed by database administrator |
> | isc_att_shut_db_down: | Database is shut down |
> | isc_att_shut_engine: | Engine is shut down |

Setting the Idle Session Timeout

> **Note**
> The idle timer will not start if the timeout period is set to zero.

An idle session timeout can be set:

- At database level the database administrator can set the configuration parameter **ConnectionIdleTimeout**, an integer value **in minutes**. The default value of zero means no timeout is set. It is configurable per-database, so it may be set globally in `firebird.conf` and overridden for individual databases in `databases.conf` as required.

  The scope of this method is all user connections, except system connections (garbage collector, cache writer, etc.).

- at connection level, the idle session timeout is supported by both the API and a new SQL statement syntax. The scope of this method is specific to the supplied connection (attachment). Its value in the API is **in seconds**. In the SQL syntax it can be hours, minutes or seconds. Scope for this method is the connection to which it is applied.

Determining the Timeout that is In Effect

The effective idle timeout value is determined whenever a user API call leaves the engine, checking first at connection level and then at database level. A connection-level timeout can override the value of a database-level setting, as long as the period of time for the connection-level setting is no longer than any non-zero timeout that is applicable at database level.

Important

Take note of the difference between the time units at each level. At database level, in the `conf` file, the default unit for SessionTimeout is in seconds but can be configured in hours or minutes. In SQL, the default unit is seconds but can be expressed in hours or minutes explicitly.

At the API level, the unit is milliseconds.

Absolute precision is not guaranteed in any case, especially when the system load is high, but timeouts are guaranteed not to expire earlier than the moment specified.

SQL Syntax for Setting an Idle Session Timeout

The statement for setting an idle timeout at connection level can run outside transaction control and takes effect immediately. The syntax pattern is as follows:

```
SET SESSION IDLE TIMEOUT <value> [HOUR | MINUTE | SECOND]
```

If the time unit is not set, it defaults to MINUTE.

Support at API Level

Get/set idle connection timeout, seconds

```
interface Attachment
 uint getIdleTimeout(Status status);
 void setIdleTimeout(Status status, uint timeOut);
```

The values of the idle connection timeout at both configuration and connection levels, along with the current actual timeout, can be obtained using the **isc_database_info()** API with some new info tags:

fb_info_ses_idle_timeout_db	Value set at config level
fb_info_ses_idle_timeout_att	Value set at given connection level
fb_info_ses_idle_timeout_run	Actual timeout value for the given connection, evaluated considering the values set at config and connection levels, see Determining the Timeout that is In Effect above.

Notes regarding remote client implementation

1. Attachment::setIdleTimeout() issues a “SET SESSION IDLE TIMEOUT” SQL statement
2. Attachment::getIdleTimeout() calls isc_database_info() with the fb_info_ses_idle_timeout_att tag
3. If the protocol of the remote Firebird server is less than 16, it does not support idle connection timeouts. If that is the case,
   - Attachment::setIdleTimeout() will return the error isc_wish_list
   - Attachment::getIdleTimeout() will return zero and set the isc_wish_list error
   - isc_database_info() will return the usual isc_info_error tag in the info buffer

Context Variable Relating to Idle Session Timeouts

The 'SYSTEM' context has a new variable: `SESSION_IDLE_TIMEOUT`. It contains the current value of idle connection timeout that was set at connection level, or zero, if no timeout was set.

Idle Session Timeouts in the Monitoring Tables

In MON$ATTACHMENTS:

MON$IDLE_TIMEOUT	Connection level idle timeout
MON$IDLE_TIMER	Idle timer expiration time

MON$IDLE_TIMEOUT contains timeout value set at connection level, in seconds. Zero, if timeout is not set.

MON$IDLE_TIMER contains NULL if an idle timeout was not set or if a timer is not running.

Statement Timeouts

The statement timeout feature enables the ability to set a timeout for an SQL statement, allowing execution of a statement to be stopped automatically when it has been running longer than the given timeout period. It gives the database administrator an instrument for limiting excessive resource consumption from heavy queries.

Statement timeouts could be useful to application developers when creating and debugging complex queries without advance knowledge of execution time. Testers and others could find them handy for detecting long running queries and establishing finite run times for test suites.

How the Statement Timeout Works

When the statement starts execution or a cursor is opened, the engine starts a special timer. It is stopped when the statement completes execution or the last record has been fetched by the cursor.

> **Note**
> FETCH does not reset this timer.

When the timeout point is reached:

- if statement execution is active, it stops at closest possible moment
- if statement is not active currently (between fetches, for example), it is marked as cancelled and the next fetch will actually break execution and return an error

> **Statement types excluded from timeouts**
>
> Statement timeouts are not applicable to some types of statement and will simply be ignored:
>
> - All DDL statements
> - All internal queries issued by the engine itself

Setting a Statement Timeout

> **Note**
> The timer will not start if the timeout period is set to zero.

A statement timeout can be set:

- at database level, by the database administrator, by setting the configuration parameter **StatementTimeout** in firebird.conf or databases.conf, an integer representing the number of seconds after which statement execution will be cancelled automatically by the engine. Zero means no timeout is set. A non-zero setting will affect all statements in all connections.
- at connection level, using the API and/or the new SQL statement syntax for setting a statement timeout. A connection-level setting (via SQL or the API) affects all statements for the given connection; Units for the timeout period at this level can be specified to any granularity from hours to milliseconds.
- at statement level, using the API, in milliseconds

Determining the Statement Timeout that is In Effect

The statement timeout value that is in effect is determined whenever a statement starts executing or a cursor is opened. In searching out the timeout in effect, the engine goes up through the levels, from statement through to database and/or global levels until it finds a non-zero value. If the value in effect turns out to be zero then no statement timer is running and no timeout applies.

A statement-level or connection-level timeout can override the value of a database-level setting, as long as the period of time for the lower-level setting is no longer than any non-zero timeout that is applicable at database level.

> **Important**
>
> Take note of the difference between the time units at each level. At database level, in the conf file, the default unit for StatementTimeout is in seconds but can be configured in hours or minutes. In SQL, the default unit is seconds but can be expressed in hours, minutes or milliseconds explicitly. At the API level, the unit is milliseconds.
>
> Absolute precision is not guaranteed in any case, especially when the system load is high, but timeouts are guaranteed not to expire earlier than the moment specified.

Whenever a statement times out and is cancelled, the next user API call returns the error **isc_cancelled** with a secondary error specifying the exact reason, viz.,

isc_cfg_stmt_timeout:	Config level timeout expired
isc_att_stmt_timeout:	Attachment level timeout expired
isc_req_stmt_timeout:	Statement level timeout expired

Notes about Statement Timeouts

1. A client application could wait longer than the time than set by the timeout value if the engine needs to undo a large number of actions as a result of the statement cancellation

2. When the engine runs an EXECUTE STATEMENT statement, it passes the remainder of the currently active timeout to the new statement. If the external (remote) engine does not support statement timeouts, the local engine silently ignores any corresponding error.

3. When engine acquires some lock from the lock manager, it tries to lower the value of the lock timeout using the remainder of the currently active statement timeout, if possible. Due to lock manager internals, any statement timeout remainder will be rounded up to whole seconds.

SQL Syntax for Setting a Statement Timeout

The statement for setting a statement execution timeout at connection level can run outside transaction control and takes effect immediately. The statement syntax pattern is:

```
SET STATEMENT TIMEOUT <value> [HOUR | MINUTE | SECOND | MILLISECOND]
```

If the time part unit is not set, it defaults to SECOND.

Support for Statement Timeouts at API Level

statement execution timeout at connection level, milliseconds:

```
interface Attachment
 uint getStatementTimeout(Status status);
 void setStatementTimeout(Status status, uint timeOut);
```

Get\set statement execution timeout at statement level, milliseconds:

```
interface Statement
 uint getTimeout(Status status);
 void setTimeout(Status status, uint timeOut);
```

Set statement execution timeout at statement level using ISC API, milliseconds:

```
ISC_STATUS ISC_EXPORT fb_dsql_set_timeout(ISC_STATUS*, isc_stmt_handle*, ISC_ULONG);
```

Getting the statement execution timeout at config and\or connection levels can be done using the `isc_database_info()` API function with some new info tags:

fb_info_statement_timeout_db
fb_info_statement_timeout_att

Getting the statement execution timeout at statement level can be done using the `isc_dsql_info()` API function with some new info tags:

isc_info_sql_stmt_timeout_user	Timeout value of given statement
isc_info_sql_stmt_timeout_run	Actual timeout value of given statement. Valid only for statements currently executing, i.e., when a time-out timer is actually running. Evaluated considering the

values set at config, connection and statement levels, see Determining the Statement Timeout that is In Effect above.

Notes regarding remote client implementation

1. Attachment::setStatementTimeout() issues a “SET STATEMENT TIMEOUT” SQL statement
2. Attachment::getStatementTimeout() calls isc_database_info() with the fb_info_statement_timeout_att tag
3. Statement::setTimeout() saves the given timeout value and passes it with op_execute and op_execute2 packets
4. Statement::getTimeout() returns the saved timeout value
5. fb_dsql_set_timeout() is a wrapper over Statement::setTimeout()
6. If the protocol of the remote Firebird server is less than 16, it does not support statement timeouts. If that is the case,
   - “set” and “get” functions will return an isc_wish_list error
   - “info” will return the usual isc_info_error tag in the info buffer

Context Variable relating to Statement Timeouts

The 'SYSTEM' context has a new variable: `STATEMENT_TIMEOUT`. It contains the current value of the statement execution timeout that was set at connection level, or zero, if no timeout was set.

Statement Timeouts in the Monitoring Tables

In MON$ATTACHMENTS:

MON$STATEMENT_TIMEOUT	Connection level statement timeout

In MON$STATEMENTS:

MON$STATEMENT_TIMEOUT	Statement level statement timeout
MON$STATEMENT_TIMER	Timeout timer expiration time

MON$STATEMENT_TIMEOUT contains timeout value set at connection or statement level, in milliseconds. Zero, if timeout is not set.

MON$STATEMENT_TIMER contains NULL if no timeout was set or if a timer is not running.

Support for Statement Timeouts in isql

A new command has been introduced in *isql* to enable an execution timeout in milliseconds to be set for the next statement. The syntax is:

```
SET LOCAL_TIMEOUT <int>
```

After statement execution, the timer is automatically reset to zero.

Commit Order for Capturing the Database Snapshot

Nickolay Samofatov
Roman Simakov
Vladyslav Khorsun

Tracker ticket CORE-5953

Traditionally, a SNAPSHOT (“concurrency”) transaction takes a private copy of the transaction inventory page (TIP) at its start and uses it to refer to the state of the latest committed versions of all records in the database, right up until it commits or rolls back its own changes. Thus, by definition, a SNAPSHOT transaction sees the database state only as it was at the moment it started.

In the traditional model, a READ COMMITTED transaction does not use a stable snapshot view of database state and does not keep a private copy of the TIP. Instead, it asks the TIP for the most recent state of a record committed by another transaction. In Super (“SuperServer”) mode, the TIP cache is shared to provide optimal access to it by READ COMMITTED transactions.

The 'Commit Order' Approach

Firebird 4 takes a new approach to establishing how a transaction captures the state of the most recent write committed for the record version that the current transaction wants to read, change or delete. This new approach uses the concept of *commit order*.

It is sufficient to know the *order of commits* in order to capture the state of any transaction at the moment when a snapshot is created.

Commit Order for Transactions

The elements for establishing and utilising commit order are:

- Initialize a *Commit Number (CN)* for each database when the database is first opened
- Each time a transaction is committed, the Commit Number for that database is incremented and the new CN is associated with the specific transaction
- This specific transaction and commit number combination—“transaction CN” are stored in memory and can be queried subsequently while the database remains active
- A *database snapshot* is identified by the value stored for the global CN at moment when the database snapshot was created

Special Values for the Transaction CN

Possible values for the transaction Commit Number include some special CN values that signify whether the transaction is active or dead, viz.:

CN_ACTIVE = 0
: Transaction is active

CN_PREHISTORIC = 1
Transaction was committed before the database started (i.e., older than OIT)

CN_PREHISTORIC < CN < CN_DEAD
Transaction was committed while the database was working

CN_DEAD = MAX_TRA_NUM - 2
Dead transaction

CN_LIMBO = MAX_TRA_NUM - 1
Transaction is in limbo

The Rule for Record Visibility

Supposing *database snapshot* is the current snapshot in use by the current transaction and *other transaction* is the transaction that created the given record version, the rule for determining the visibility of the record version works like this:

- If the state of *other transaction* is 'active', 'dead' or 'in limbo' then the given record version is not visible to the current transaction
- If the state of *other transaction* is 'committed' then the visibility of the given record version depends on the timing of the creation of *database snapshot*, so
  - if it was committed before *database snapshot* was created, it is visible to the current transaction;
  - if it was committed after *database snapshot* was created, it is not visible to the current transaction.

Thus, as long as a maintained list of all known transactions with their associated Commit Numbers is in existence, it is enough to compare the CN of *other transaction* with the CN of *database snapshot* to decide whether the given record version should be visible within the scope of *database snapshot*.

> **Note**
>
> The status of an association between a transaction and its CN can be queried using a new built-in function, RDB$GET_TRANSACTION_CN.

Implementation details

The list of all known transactions with associated Commit Numbers is maintained in shared memory. It is implemented as an array whose index is a transaction ID and its item value is the corresponding Commit Number.

The whole array is split into fixed-size blocks containing the CN's for all transactions between the OIT and Next Transaction markers. When Next Transaction moves out of the scope the highest block, a new block is allocated. An old block is released when the OIT moves out of the scope of the lowest block.

Block Size

The default size of the TIP page cache block is 4MB, providing capacity for 512 * 1024 transactions. It is configurable in `firebird.conf` and `databases.conf` using the new parameter *TipCacheBlockSize*.

Read Consistency for Statements in Read-Committed Transactions

The existing implementation of READ COMMITTED isolation for transactions suffers from an important problem: a single statement, such as a SELECT, could see different views of the same data during execution.

For example, imagine two concurrent transactions, where the first inserts 1000 rows and commits, while the second runs SELECT COUNT(*) over the same table.

If the isolation level of the second transaction is READ COMMITTED, its result is hard to predict: it could be any of:

1. the number of rows in the table before the first transaction started, or
2. the number of rows in the table after the first transaction commited, or
3. any number between those two numbers.

Which of those results is actually returned depends on how the two transactions interact:

- CASE 1 would occur if the second transaction finished counting before the first transaction was committed, since the uncommitted inserts at that point are visible only to the first transaction.
- CASE 2 would occur if the second transaction started after the first had committed all of the inserts.
- CASE 3 occurs in any other combination of the conditions: the second transaction sees some but not all of the inserts during the commit sequence of the first transaction.

CASE 3 is the problem referred to as *inconsistent read at the statement level*. It matters because, by definition, each *statement* in a READ COMMITTED transaction has its own distinct view of database state. In the existing implementation, the statement's view is not certain to remain stable for the duration of its execution: it could change between the start of execution and the completion.

Statements running in a SNAPSHOT transaction do not have this problem, since every statement runs against a consistent view of database state. Also, different statements that run within the same READ COMMITTED transaction could see different views of database state but this is “as designed” and is not a source of statement-level inconsistency.

Solving the Inconsistent Read Problem

See Tracker ticket CORE-5954.

The obvious solution to the inconsistent read problem is to have the read-committed transaction use a stable database snapshot during execution of a statement. Each new top-level statement creates its own database snapshot that sees the most recently committed data.

With snapshots based on commit order it is a very cheap operation. Nested statements (triggers, nested stored procedures and functions, dynamic statements, etc.) use the same database snapshot that was created by the top-level statement.

New Isolation Sub-Level for READ COMMITTED

A new sub-level for transactions in READ COMMITTED isolation is introduced: READ COMMITTED READ CONSISTENCY.

The existing sub-levels for READ COMMITTED isolation, RECORD VERSION and NO RECORD VERSION, are still supported but should be regarded as “legacy”, with the recommendation to avoid them.

In summary, the three variants for transactions in READ COMMITTED isolation are now:

READ COMMITTED READ CONSISTENCY
READ COMMITTED NO RECORD VERSION
READ COMMITTED RECORD VERSION

Handling of Update Conflicts

When a statement executes in a READ COMMITTED READ CONSISTENCY transaction, its database view is retained in a fashion similar to a SNAPSHOT transaction. This makes it pointless to wait for the concurrent transaction to commit, in the hope of being able to read the newly-committed record version. So, when a READ COMMITTED transaction reads the data and finds a primary record version has been created by a concurrently active transaction, it reads the next back version in the versions chain to check the state of the transaction that created the back version.

- If the state is committed then this back version is the one that is visible to the current transaction.
- If the state is active, the next backversion is read—until a backversion is found whose transaction is committed.

A READ COMMITTED transaction using NO RECORD VERSION, on the other hand, does not consider the back version. Instead, it waits for the state of the conflicting transaction to become inactive, either committed or dead.

When an update conflict occurs, the behaviour of a READ COMMITTED READ CONSISTENCY transaction is different to that of one in READ COMMITTED RECORD VERSION:

- If the concurrent transaction is active, the engine waits for the duration of the transaction lock timeout; if the concurrent transaction is then still uncommitted, an update conflict error is returned and any changes made by the statement are undone automatically.

- If the concurrent transaction is committed, then the current statement cannot continue executing because its own current snapshot would still see the committed transaction as if it were still active. Thus, the statement has to create a new snapshot to continue executing. For consistency, it must undo all the changes made so far and start everything again.

> **Note**
>
> The implementation of this restart logic, as at Beta 1, is not ideal and could be changed before the final release.

The logic is very similar to that commonly employed by user applications for handling update conflicts but it is a little more efficient as it does not entail network roundtrips between client and host.

> **Note**
>
> This restart logic is not applied to selectable stored procedures if the update conflict happens after any records are returned to the client application. In this case an `isc_update_conflict` error is returned. For historical reasons, `isc_update_conflict` is reported as a secondary error to the primary error `isc_deadlock`.

No Pre-Committed Transactions

In the existing implementation, READ COMMITTED transactions in READ ONLY mode are marked as committed when the transaction starts. This provides a benefit in that record versions in such transactions are never "interesting" from the perspective of garbage collection. It is not a problem if the transaction has no need for a database snapshot, i.e., when the isolation sub-level is RECORD VERSION or NO RECORD VERSION.

However, it would defeat statement-level snapshot consistency if the READ COMMITTED READ ONLY transaction in the READ CONSISTENCY sub-level were allowed to be pre-committed. Thus, the record versions involved in this style of transaction remain "interesting", as do those involved in READ WRITE transactions.

Syntax and Configuration

Support for the new READ COMMITTED READ CONSISTENCY isolation level is found in SQL syntax, in the API and in configuration settings.

* SQL Syntax

Where SET TRANSACTION is available in SQL, the new isolation sub-level is set as follows:

```
SET TRANSACTION READ COMMITTED READ CONSISTENCY
```

* New API Constant in the TPB

To start a READ COMMITTED READ CONSISTENCY transaction via the ISC API, use the new constant `isc_tpb_read_consistency` in the Transaction Parameter Buffer.

* Configuration Parameter ReadConsistency

Future versions of Firebird may deprecate the traditional handling of read-committed transactions. For now, existing applications can be tested with the new READ COMMITTED READ CONSISTENCY isolation level by setting the new configuration parameter **ReadConsistency**. Possible values are 1 and 0.

ReadConsistency = 1
: (Default) The engine ignores [NO] RECORD VERSION flags and makes all read-committed transactions READ COMMITTED READ CONSISTENCY.

ReadConsistency = 0
: Allows the legacy engine behaviour, with the RECORD VERSION and NO RECORD VERSION sub-levels valid to use. READ COMMITTED READ CONSISTENCY is available but needs to be be specified explicitly.

Garbage Collection

The *record version visibility rule* provides the following logic for identifying record versions as garbage:

- If snapshot CN can see some record version (RV_X) then all snapshots with numbers greater than CN can also see RV_X.
- If all existing snapshots can see RV_X then all its back-versions can be removed, OR
- If the oldest active snapshot can see RV_X then all its back-versions can be removed.

The last part of the rule reproduces the legacy rule, whereby all record versions at the tail of the versions chain start from some “mature” record version. The rule allows that mature record version to be identified so that the whole tail after it can be cut.

However, with snapshots based on commit-order, version chains can be further shortened because it enables some record versions located in intermediate positions in the versions chain to be identified as eligible for GC. Each record version in the chain is marked with the value of the oldest active snapshot that can see it. If several consecutive versions in a chain are marked with the same oldest active snapshot value, then all those following the first one can be removed.

The engine performs garbage collection of intermediate record versions during the following processes:

- sweep
- background garbage collection in SuperServer
- in every user attachment after an updated or delete record is committed

To make it work, the engine maintains in shared memory an array of all active database snapshots. When it needs to find the oldest active snapshot that can see a given record version, it just searches for the CN of the transaction that created that record version.

The default initial size of this shared memory block is 64KB but it will grow automatically when required. The initial block can be set to a custom size in `firebird.conf` and/or `databases.conf`using the new parameter `SnapshotsMemSize`.

Precision Improvement for NUMERIC and DECIMAL

Alex Peshkov

Tracker ticket CORE-4409

As a side-effect of implementing DECFLOAT as the basis for fixed-point numerics of more than 18 digits, some improvements were made to the way Firebird handles the precision of results from calculations involving NUMERIC and DECIMAL data types.

Increased Number of Formats for Views

Adriano dos Santos Fernandes

Tracker ticket CORE-5647

Views are no longer limited to 255 formats (versions) before the database requires a backup and restore. The new limit is 32,000 versions.

> **Note**
>
> This change does not apply to tables.

Optimizer Improvement for GROUP BY

Dmitry Yemanov

Tracker ticket CORE-4529

The improvement allows the use of a DESCENDING index on a column that is specified for GROUP BY.

xinetd Support on Linux Replaced

Alex Peshkov

Tracker ticket CORE-5238

On Linux, Firebird 4 uses the same network listener process (Firebird) for all architectures. For Classic, the main (listener) process now starts up via *init/systemd*, binds to the 3050 port and spawns a worker firebird process for every connection—similarly to what happens on Windows.

Support for RISC v.64 Platform

Richard Jones

Tracker ticket CORE-5779

A patch was introduced to compile Firebird 4.0 on the RISC v.64 platform.

Chapter 4

Changes to the Firebird API and ODS

ODS (On-Disk Structure) Changes

New ODS Number

Firebird 4.0 creates databases with an ODS (On-Disk Structure) version of 13.

Application Programming Interfaces

The wire protocol version for the Firebird 4.0 API is 16. Additions include

Services Cleanup

Alex Peshkov

Apart from the widely-known Services Manager (`service_mgr`), Firebird has a group of so-called “version 1” service managers. Backup and *gsec* are examples, along with a number of other services related to shared cache control and the unused journalling feature. Since at least Firebird 3 they seem to be in a semi-working state at best, so they have undergone a cleanup.

A visible effect is that the constant `service_mgr` is no longer required in the connection string for a service request. The request call will ignore anything in that field, including an empty string. The remote client will do the right thing just by processing the host name, such as localhost:, inet://localhost/ or inet://localhost.

Timeouts for Sessions & Statements

Session Timeouts

See Support for Session Timeouts at API Level in the chapter “Changes in the Firebird Engine”.

Statement Timeouts

See Support for Statement Timeouts at API Level in the chapter “Changes in the Firebird Engine”.

New Isolation Sub-level for READ COMMITTED Transactions

Provides API support for the new READ COMMITTED READ CONSISTENCY isolation sub-level for READ COMMITTED transactions. To start a READ COMMITTED READ CONSISTENCY transaction via the ISC API, use the new constant `isc_tpb_read_consistency` in the Transaction Parameter Buffer.

Support for Batch Insert and Update Operations in the API

Alex Peshkov

The OO-API in Firebird 4 supports execution of statements with more than a single set of parameters—*batch execution*. The primary purpose of the batch interface design is to satisfy JDBC requirements for batch processing of prepared statements but it has some fundamental differences:

- As with all data operations in Firebird, it is oriented on messages, not on single fields
- An important extension of our batch interface is support for inline use of BLOBs, which is especially efficient when working with small BLOBs
- The `execute()` method returns not a plain array of integers but the special `BatchCompletionState` interface which, depending on the batch creation parameters, can contain both the information about the update records and the error flag augmented by detailed status vectors for the messages that caused execution errors

The methods described below illustrate how to implement everything needed for JDBC-style prepared statement batch operations. Almost all of the methods described are used in `11.batch.cpp`. Please refer to it to see a live example of batching in Firebird.

Creating a Batch

As with `ResultSet` a batch may be created in two ways—using either the `Statement` or the `Attachment` interface. In both cases, the `createBatch()` method of appropriate interface is called.

For the `Attachment` case, the text of the SQL statement to be executed in a batch is passed directly to `createBatch()`.

Tuning of the batch operation is performed using the Batch Parameters Block (BPB) whose format is similar to DPB v.2: beginning with the tag (IBatch::CURRENT_VERSION) and followed by the set of wide clumplets: 1-byte tag, 4-byte length, length-byte value. Possible tags are described in batch interface.

The recommended (and simplest) way to create a BPB for batch creation is to use the appropriate XpbBuilder interface:

```
IXpbBuilder* pb = utl->getXpbBuilder(&status, IXpbBuilder::BATCH, NULL, 0);
pb->insertInt(&status, IBatch::RECORD_COUNTS, 1);
```

This usage of the BPB directs the batch to account for a number of updated records on per-message basis.

Creating the Batch Interface

To create the batch interface with the desired parameters, pass the BPB to a `createBatch() call`:

```
IBatch* batch = att->createBatch(&status, tra, 0, sqlStmtText, SQL_DIALECT_V6, NULL,
pb->getBufferLength(&status), pb->getBuffer(&status));
```

In this sample, the batch interface is created with the default message format because NULL is passed instead of the input metadata format.

Getting the Message Format

To proceed with the created batch interface, we need to get the format of the messages it contains, using the `getMetadata()` method:

```
IMessageMetadata* meta = batch->getMetadata(&status);
```

If you have passed your own format for messages to the batch, of course you can simply use that.

We assume here that some function is present that can fill the buffer “data” according to the passed format “metadata”. For example,

```
fillNextMessage(unsigned char* data, IMessageMetadata* metadata)
```

A Message Buffer

To work with the messages we need a buffer for our “data”:

```
unsigned char* data = new unsigned char[meta->getMessageLength(&status)];
```

Now we can add some messages full of data to the batch:

```
fillNextMessage(data, meta);
batch->add(&status, 1, data);
fillNextMessage(data, meta);
batch->add(&status, 1, data);
```

> **Note**
>
> An alternative way to work with messages is to use the `FB_MESSAGE` macro. An example of this method can be found in the batch interface example, `11.batch.cpp`.

Executing the Batch

The batch is now ready to be executed:

```
IBatchCompletionState* cs = batch->execute(&status, tra);
```

We requested accounting of the number of modified records (inserted, updated or deleted) per message. The interface `BatchCompletionState` is used to print it. The total number of messages processed by the batch

could be less than the number of messages passed to the batch if an error happened and the option enabling multiple errors during batch processing was not turned on. To determine the number of messages processed:

```
unsigned total = cs->getSize(&status);
```

Now to print the state of each message:

```
for (unsigned p = 0; p < total; ++p)
    printf("Msg %u state %d\n", p, cs->getState(&status, p));
```

A complete example of printing the contents of `BatchCompletionState` is in the function `print_cs()` in sample `11.batch.cpp`.

Cleaning Up

Once analysis of the completion state is finished, remember to dispose of it:

```
cs->dispose();
```

If you want to empty the batch's buffers without executing it for some reason, such as preparing for a new portion of messages to process, use the `cancel()` method:

```
batch->cancel(&status);
```

Being reference-counted, the batch does not have special method to close it—just a standard `release()` call:

```
batch->release();
```

Multiple Messages per Call

More than a single message can be added in one call to the batch. It is important to remember that messages should be appropriately aligned for this feature to work correctly. The required alignment and aligned size of the message should be obtained from the interface `MessageMetadata`. For example:

```
unsigned aligned = meta->getAlignedLength(&status);
```

Later that size will be useful when allocating an array of messages and working with it:

```
unsigned char* data = new unsigned char[aligned * N];
      // N is the desired number of messages
for (int n = 0; n < N; ++n) fillNextMessage(&data[aligned * n], meta);
batch->add(&status, N, data);
```

After that, the the batch can be executed or the next portion of messages can be added to it.

Passing In-line BLOBs in Batch Operations

As a general rule, BLOBs are not compatible with batches. Batching is efficient when a lot of small data are to be passed to the server in single step. BLOBs are treated as large objects so, as a rule, it makes no sense to use them in batches.

Nevertheless, in practice it often happens that BLOBs are not too big. When that is the case, use of the traditional BLOB API (create BLOB, pass segments to the server, close BLOB, pass BLOB's ID in the message) kills performance, especially over a WAN. Firebird's batching therefore supports passing BLOBs to the server *in-line*, along with other messages.

To use the in-line BLOB feature, first a *BLOB usage policy* has to be set up as an option in the BPB for the batch being created:

```
pb->insertInt(&status, IBatch::BLOB_IDS, IBatch::BLOB_IDS_ENGINE);
```

In this example, for the simplest and fairly common usage scenarios, the Firebird engine generates the temporary BLOB IDs needed to keep a link between a BLOB and the message where it is used. Imagine that the message is described as follows:

```
FB_MESSAGE(Msg, ThrowStatusWrapper,
(FB_VARCHAR(5), id)
(FB_VARCHAR(10), name)
(FB_BLOB, desc)
) project(&status, master);
```

Something like the following will send a message to the server containing the BLOB:

```
project->id = ++idCounter;
project->name.set(currentName);
batch->addBlob(&status, descriptionSize, descriptionText, &project->desc);
batch->add(&status, 1, project.getData());
```

Over-sized BLOBs

If some BLOB happens to be too big to fit into your existing buffer, then, instead of reallocating the buffer, you can use the `appendBlobData()` method to append more data to the last added BLOB:

```
batch->addBlob(&status, descriptionSize, descriptionText, &project->desc, bpbLength, bpb);
```

After adding the first part of the BLOB, get the next portion of data into `descriptionText`, update `descriptionSize` and then do:

```
batch->appendBlobData(&status, descriptionSize, descriptionText);
```

You can do this work in a loop but take care not to overflow the internal batch buffers. Its size is controlled by the `BUFFER_BYTES_SIZE` option when creating the batch interface. The default size is 10MB but it cannot

exceed 40MB. If you need to process a BLOB that is too big, having chosen to use batching on the basis of data involving a lot of small BLOBs, just use the standard BLOB API and the `registerBlob` method of the Batch interface.

User-Supplied BLOB IDs

Another possible choice in the BLOB policy is `BLOB_IDS_USER`, to supply a temporary BLOB_ID instead of having one generated by Firebird.

Usage is not substantially different. Before calling `addBlob()`, place the correct execution ID, which is unique per batch, into the memory referenced by the last parameter. Exactly the same ID should be passed in the data message for the BLOB.

Considering that generation of BLOB IDs by the engine is very fast. such a policy may seem useless. However, imagine a case where you get BLOBs and other data in relatively independent streams (blocks in a file, for example) and some good IDs are already present in them. Supplying the BLOB IDs can greatly simplify your code for such cases.

Streams vs Segments

Be aware that BLOBs created by the Batch interface are by default streamed, not segmented like BLOBs created by means of `createBlob()`. Segmented BLOBs provide nothing interesting compared with streamed ones—we support that format only for backward compatibility and recommend avoiding them in new development.

Overriding to Use Segmented BLOBs

If you really must have segmented BLOBs, you can override the default by calling:

```
batch->setDefaultBpb(&status, bpbLength, bpb);
```

> **Note**
>
> Of course, the passed BPB could contain other BLOB creation parameters, too. You could also pass the BPB directly to `addBlob()` but, if most of the BLOBs you are going to add have the same non-default format, it is slightly more efficient to use `setDefaultBpb()`.

A call to `addBlob()` will add the first segment to the BLOB; successive calls to `appendBlobData()` will add more segments.

> **Segment size limit!**
>
> Keep in mind that segment size is limited to 64KB -1. Attempting to pass more data in a single call will cause an error.

Multiple BLOBs Using Streams

Using the method `addBlobStream()`, it is possible to add more than one BLOB to the batch in a single call.

A blob stream is a sequence of BLOBs, each starting with a BLOB header which needs to be appropriately aligned. The Batch interface provides a special call for this purpose:

```
unsigned alignment = batch->getBlobAlignment(&status);
```

It is assumed that all components of a BLOB stream in a batch will be aligned, at least at the alignment boundary. This includes the size of stream potions passed to `addBlobStream()`, which should be a multiple of this alignment.

The header contains three fields: an 8-byte BLOB ID (must be non-zero), a 4-byte total BLOB size and a 4 byte BPB size. The total BLOB size includes the enclosed BPB, i.e. the next BLOB in the stream will always be found in the BLOB-size bytes after the header, taking the alignment into account.

The BPB is present if the BPB size is not zero and is placed immediately after the header. The BPB BLOB data goes next, its format depending upon wehether the BLOB is streamed or segmented:

- For a stream BLOB it is a plain sequence of bytes whose size is (BLOB-size - BPB-size)
- For a segmented BLOB, things are a bit more compicated: the BLOB data is a set of segments where each segment has the format: 2-bytes for the size of the segment, aligned at `IBatch::BLOB_SEGHDR_ALIGN` boundary, followed by as many bytes as are accounted for by this 2-byte segment size

Bigger BLOBS in the Stream

When a big BLOB is added to the stream, its size is not always known in advance. To avoid having too large a buffer for that BLOB (recalling that the size has to be provided in the BLOB header, before the BLOB data) a *BLOB continuation record* may be used. In the BLOB header, you leave BLOB size at a value known when creating that header and add a continuation record. The format of the continuation record is identical to the BLOB header, except that both the BLOB ID and the BPB size must always be zero.

Typically, you will want to have one continuation record per `addBlobStream()` call.

An example of this usage can be found in `sample 11.batch.cpp`.

Registering a Standard BLOB

The last method used to work with BLOBs stands apart from the first three that pass BLOB data inline with the rest of the batch data. It is required for registering in a batch the ID of a BLOB created using the standard BLOB API. This may be unavoidable if a really big BLOB has to be passed to the batch.

The ID of such BLOB cannot be used in the batch directly without causing an invalid BLOB ID error during batch execution. Instead do:

```
batch->registerBlob(&status, &realId, &msg->desc);
```

If the BLOB policy is making the Firebird engine generate BLOB IDs then this code is enough to correctly register an existing BLOB in a batch. In other cases you will have to assign to `msg>>desc` the ID that is correct from the point of view of the batch.

Batch Ops in the Legacy (ISC) API

A word or two about access to batches from the ISC API: a prepared ISC statement can be executed in batch mode. The main support for it is present in the `Util` interface, namely in the methods `getTransaction-`

`ByHandle` and `getStatementByHandle`. These methods enable access to the appropriate interfaces in the same way as to existing ISC handles.

An example of this usage can be found in `12.batch_isc.cpp`.

API Support for Time Zones

Structures (structs)

```
struct ISC_TIME_TZ
{
    ISC_TIME utc_time;
    ISC_USHORT time_zone;
};

struct ISC_TIMESTAMP_TZ
{
    ISC_TIMESTAMP utc_timestamp;
    ISC_USHORT time_zone;
};
```

API Functions

(FirebirdInterface.idl—IUtil interface)

```
void decodeTimeTz(
    Status status,
    const ISC_TIME_TZ* timeTz,
    uint* hours,
    uint* minutes,
    uint* seconds,
    uint* fractions,
    uint timeZoneBufferLength,
    string timeZoneBuffer
);

void decodeTimeStampTz(
    Status status,
    const ISC_TIMESTAMP_TZ* timeStampTz,
    uint* year,
    uint* month,
    uint* day,
    uint* hours,
    uint* minutes,
    uint* seconds,
    uint* fractions,
    uint timeZoneBufferLength,
    string timeZoneBuffer
);

void encodeTimeTz(
    Status status,
    ISC_TIME_TZ* timeTz,
```

```
    uint hours,
    uint minutes,
    uint seconds,
    uint fractions,
    const string timeZone
);

void encodeTimeStampTz(
    Status status,
    ISC_TIMESTAMP_TZ* timeStampTz,
    uint year,
    uint month,
    uint day,
    uint hours,
    uint minutes,
    uint seconds,
    uint fractions,
    const string timeZone
);
```

Chapter 5

Configuration Additions and Changes

Parameters for Timeouts

Two new parameters are available for global and per-database configuration, respectively, of server-wide and database-wide idle session and statement timeouts. They are discussed in detail elsewhere (see links).

ConnectionIdleTimeout

The value is integer, expressing minutes. Study the notes on idle session timeouts carefully to understand how this configuration fits in with related settings via SQL and the API.

See Setting the Session Timeout in the chapter “Changes to the Firebird Engine”.

StatementTimeout

The value is integer, expressing seconds. Study the notes on statement timeouts carefully to understand how this configuration fits in with related settings via SQL and the API.

See Setting a Statement Timeout in the chapter “Changes to the Firebird Engine”.

Parameters for External Connection Pooling

These parameters enable customization of aspects of pooling external connections.

ExtConnPoolSize

Configures the maximum number of idle connections allowed in the pool. It is an integer, from 0 to 1000. The installation default is 0, which disables the connection pool.

ExtConnPoolLifetime

Configures the number of seconds a connection should stay available after it has gone idle. The installation default is 7200 seconds.

Parameters to Restrict Length of Object Identifiers

Object identifiers in an ODS 13 database can be up to 63 characters in length and the engine stores them in UTF-8, not UNICODE_FSS as previously. Two new global or per-database parameters are available if you need to restrict either the byte-length or the character-length of object names in ODS 13 databases for some reason.

Longer object names are optional, of course. Reasons you might need to restrict their length could include:

- Constraints imposed by the client language interface of existing applications, such as *gpre* or Delphi
- In-house coding standards
- Interoperability for cross-database applications such as a third-party replication system or an in-house system that uses multiple versions of Firebird

This is not an exhaustive list. It is the responsibility of the developer to test usage of longer object names and establish whether length restriction is necessary.

Whether setting one or both parameters has exactly the same effect will depend on the characters you use. Any non-ASCII character requires 2 bytes or more in UTF-8, so one cannot assume that byte-length and character-length have a direct relationship in all situations.

The two settings are verified independently and if either constrains the length limit imposed by the other, use of the longer identifier will be disallowed.

> **Warning**
> If you set either parameter globally, i.e., in firebird.conf, it will affect all databases, including the security database. That has the potential to cause problems!

MaxIdentifierByteLength

Sets a limit for the number of bytes allowed in an object identifier. It is an integer, defaulting to 252 bytes, i.e., 63 characters * 4, 4 being the maximum number of bytes for each character.

To set it to the limit in previous Firebird versions, use 31.

MaxIdentifierCharLength

Sets a limit for the number of characters allowed in an object identifier. It is an integer, defaulting to 63, the new limit implemented in Firebird 4.

Parameters Supporting Read Consistency in Transactions

Firebird 4 takes a new approach to read consistency within transaction snapshots, enabling, amongst other benefits, a sustained consistent read for statements within READ COMMITTED transactions. This group of parameters allows for some customisation of the elements involved.

TipCacheBlockSize

The list of all known transactions with associated Commit Numbers is maintained in shared memory. It is implemented as an array whose index is a transaction ID and its item value is the corresponding Commit Number.

The whole array is split into fixed-size blocks containing the CN's for all transactions between the OIT and Next Transaction markers. When the “Next Transaction” marker moves out of the scope of the highest block, a new block is allocated. An old block is released when the “Oldest [Interesting] Transaction” (OIT) marker moves out of the scope of the lowest block.

The default size for a TIP page cache block is 4MB, providing capacity for 512 * 1024 transactions. Use this parameter to configure a custom TIP page cache block size in `firebird.conf` and/or `databases.conf`.

ReadConsistency

For now, existing applications can be tested with and without the new READ COMMITTED READ CONSISTENCY isolation level by setting this parameter. Possible values are 1 and 0.

ReadConsistency = 1
: (Default) The engine ignores [NO] RECORD VERSION flags and makes all read-committed transactions READ COMMITTED READ CONSISTENCY.

ReadConsistency = 0
: Allows the legacy engine behaviour, with the RECORD VERSION and NO RECORD VERSION sublevels valid to use. READ COMMITTED READ CONSISTENCY is available but needs to be be specified explicitly.

SnapshotsMemSize

To handle garbage collection of record versions younger than the Oldest Snapshot, (“intermediate record versions”) the engine maintains in shared memory an array that it can search for the Commit Number (CN) of a particular record version. See the Garbage Collection topic the chapter *Changes in the Firebird Engine*.

The default initial size of this shared memory block is 64KB but it will grow automatically when required. The initial block can be set to a custom size in `firebird.conf` and/or `databases.conf`.

TempCacheLimit at Database Level

Dmitry Yemanov

See Tracker ticket CORE-5718

`TempCacheLimit`, for setting the maximum amount of temporary space that can be cached in memory, can now be configured at database level, i.e., in `databases.conf`. Previously, it was available only as a global setting for all databases.

Chapter 6

Security

Security enhancements in Firebird 4 include:

Enhanced System Privileges

Alex Peshkov

Tracker ticket CORE-5343

This feature enables granting and revoking some special privileges for regular users to perform tasks that have been historically limited to SYSDBA only, for example:

- Run utilities such as gbak, gfix, nbackup and so on
- Shut down a database and bring it online
- Trace other users' attachments
- Access the monitoring tables
- Run management statements

The implementation involved creating a set of SYSTEM PRIVILEGES, analogous to object privileges, from which lists of privileged tasks could be assigned to roles.

List of Valid System Privileges

The following table lists the names of the valid system privileges that can be granted and revoked to and from roles.

USER_MANAGEMENT	Manage users
READ_RAW_PAGES	Read pages in raw format using Attachment::getInfo()
CREATE_USER_TYPES	Add/change/delete non-system records in RDB$TYPES
USE_NBACKUP_UTILITY	Use nbackup to create database copies
CHANGE_SHUTDOWN_MODE	Shut down database and bring online
TRACE_ANY_ATTACHMENT	Trace other users' attachments
MONITOR_ANY_ATTACHMENT	Monitor (tables MON$) other users' attachments
ACCESS_SHUTDOWN_DATABASE	Access database when it is shut down
CREATE_DATABASE	Create new databases (given in security.db)
DROP_DATABASE	Drop this database
USE_GBAK_UTILITY	Use appropriate utility

USE_GSTAT_UTILITY	...
USE_GFIX_UTILITY	...
IGNORE_DB_TRIGGERS	Instruct engine not to run DB-level triggers
CHANGE_HEADER_SETTINGS	Modify parameters in DB header page
SELECT_ANY_OBJECT_IN_DATABASE	Use SELECT for any selectable object
ACCESS_ANY_OBJECT_IN_DATABASE	Access (in any possible way) any object
MODIFY_ANY_OBJECT_IN_DATABASE	Modify (up to drop) any object
CHANGE_MAPPING_RULES	Change authentication mappings
USE_GRANTED_BY_CLAUSE	Use GRANTED BY in GRANT and REVOKE operators
GRANT_REVOKE_ON_ANY_OBJECT	GRANT and REVOKE rights on any object in database
GRANT_REVOKE_ANY_DDL_RIGHT	GRANT and REVOKE any DDL rights
CREATE_PRIVILEGED_ROLES	Use SET SYSTEM PRIVILEGES in roles
MODIFY_EXT_CONN_POOL	Use command ALTER EXTERNAL CONNECTIONS POOL

New Grantee Type SYSTEM PRIVILEGE

At a lower level, a new grantee type SYSTEM PRIVILEGE enables the SYSDBA to grant and revoke specific access privileges on database objects to a named system privilege. For example,

```
GRANT ALL ON PLG$SRP_VIEW TO SYSTEM PRIVILEGE USER_MANAGEMENT
```

grants to users having USER_MANAGEMENT privilege all rights to the view that is used in the SRP user management plug-in.

Assigning System Privileges to a Role

To put all this to use, we have some new clauses in the syntax of the CREATE ROLE and ALTER ROLE statements for attaching a list of the desired system privileges to a new or existing role.

The SET SYSTEM PRIVILEGES Clause

Tracker ticket CORE-2557

The syntax pattern for setting up or changing these special roles is as follows:

```
CREATE ROLE <name> SET SYSTEM PRIVILEGES TO <privilege1> {, <privilege2> {, ...  <privilegeN> }}
ALTER ROLE <name> SET SYSTEM PRIVILEGES TO <privilege1> {, <privilege2> {, ...  <privilegeN> }}
```

Both statements assign a non-empty list of system privileges to role <name>. The ALTER ROLE statement clears privileges previously assigned to the named role, before constructing the new list.

> **Important**
> Be aware that each system privilege provides a very thin level of control. For some tasks it may be necessary to give the user more than one privilege to perform some task. For example, add IGNORE_DB_TRIGGERS to USE_GSTAT_UTILITY because gstat needs to ignore database triggers.

Note that this facility provides a solution to an old Tracker request (CORE-2557) to implement permissions on the monitoring tables:

```
CREATE ROLE MONITOR SET SYSTEM PRIVILEGES TO MONITOR_ANY_ATTACHMENT;
GRANT MONITOR TO ROLE MYROLE;
```

Dropping System Privileges from a Role

This statement is used to clear the list of system privileges from the named role:

```
ALTER ROLE <name> DROP SYSTEM PRIVILEGES
```

The role <name> is not dropped, just the list attached to it.

Function RDB$SYSTEM_PRIVILEGE

To accompany all this delegation of power is a new built-in function, RDB$SYSTEM_PRIVILEGE(). It takes a valid system privilege as an argument and returns True if the current attachment has the given system privilege.

Format:

```
    RDB$SYSTEM_PRIVILEGE( <privilege> )
```

Example

```
select rdb$system_privilege(user_management) from rdb$database;
```

Granting a Role to Another Role

Roman Simakov

Tracker ticket CORE-1815

Firebird 4 allows a role to be granted to another role—a phenomenon that has been nicknamed “cumulative roles”. If you hear that term, it is referring to roles that are embedded within other roles by way of `GRANT ROLE a TO ROLE b`, something Firebird would not allow before.

Important

Take careful note that the GRANT ROLE syntax has been extended, along with its effects.

Syntax Pattern

```
GRANT [DEFAULT] <role name> TO [USER | ROLE] <user/role name> [WITH ADMIN OPTION];
REVOKE [DEFAULT] <role name> FROM [USER | ROLE] <user/role name> [WITH ADMIN OPTION];
```

The DEFAULT Keyword

If the optional DEFAULT keyword is included, the role will be used every time the user logs in, even if the role is not specified explicitly in the login credentials. During attachment, the user will get the privileges of all roles that have been granted to him/her with the DEFAULT property. This set will include all the privileges of all the embedded roles that have been granted to the <role name> role with the DEFAULT property.

Setting (or not setting) a role in the login does not affect the default role. The set of rights, given (by roles) to the user after login is the union of the login role (when set), all default roles granted to the user and all roles granted to this set of roles.

Note
A user still cannot acquire any privileges associated with a base role that has not been granted to his account or has been revoked.

WITH ADMIN OPTION Clause

If a user is to be allowed to grant a role to another user or to another role, the WITH ADMIN OPTION should be included. Subsequently the user will be able to grant any role in the sequence of roles granted to him, provided every role in the sequence has WITH ADMIN OPTION.

Example Using a Cumulative Role

```
CREATE DATABASE 'LOCALHOST:/TMP/CUMROLES.FDB';
CREATE TABLE T(I INTEGER);
CREATE ROLE TINS;
CREATE ROLE CUMR;
GRANT INSERT ON T TO TINS;
GRANT DEFAULT TINS TO CUMR WITH ADMIN OPTION;
GRANT CUMR TO USER US WITH ADMIN OPTION;
CONNECT 'LOCALHOST:/TMP/CUMROLES.FDB' USER 'US' PASSWORD 'PAS';
INSERT INTO T VALUES (1);
GRANT TINS TO US2;
```

Revoking the DEFAULT Property of a Role Assignment

To remove the DEFAULT property of a role assignment without revoking the role itself, include the DEFAULT keyword in the REVOKE statement:

```
REVOKE DEFAULT ghost FROM USER henry
REVOKE DEFAULT ghost FROM ROLE poltergeist
```

Otherwise, revoking a role altogether from a user is unchanged. However, now a role can be revoked from a role. For example,

```
REVOKE ghost FROM USER henry
REVOKE ghost FROM ROLE poltergeist
```

Function RDB$ROLE_IN_USE

Roman Simakov

Tracker ticket CORE-2762

A new built-in function lets the current user check whether a specific role is available under his/her current credentials. It takes a single-quoted role name as a string argument of arbitrary length and returns a Boolean result.

Format

```
RDB$ROLE_IN_USE(<role_name>)
```

List Currently Active Roles

Tracker ticket CORE-751

To get a list of currently active roles you can run:

```
SELECT * FROM RDB$ROLES WHERE RDB$ROLE_IN_USE(RDB$ROLE_NAME)
```

SQL SECURITY Feature

Roman Simakov

Tracker ticket CORE-5568

This new feature in Firebird 4 enables executable objects (triggers, stored procedures, stored functions) to be defined to run in the context of an SQL SECURITY clause, as defined in the SQL standards (2003, 2011).

The SQL SECURITY scenario has two contexts: INVOKER and DEFINER. The INVOKER context corresponds to the privileges currently available to the CURRENT_USER or the calling object, while DEFINER corresponds to those available to the owner of the object.

The SQL SECURITY property is an optional part of an object's definition that can be applied to the object with DDL statements. The property cannot be dropped but it can be changed from INVOKER to DEFINER and vice versa.

It is not the same thing as SQL privileges, which are applied to **users** and some database object types to give them various types of access to database objects. When an executable object in Firebird needs access to a table, a view or another executable object, the target object is not accessible if the invoker does not have the necessary privileges on it. That has been the situation in previous Firebird versions and remains so in Firebird 4. That is, by default, all executable objects have the SQL SECURITY INVOKER property in Firebird 4. Any caller lacking the necessary privileges will be rejected.

If a routine has the SQL SECURITY DEFINER property applied to it, the invoking user or routine will be able to execute it if the required privileges have been granted to its owner, without the need for the caller to be granted those privileges specifically.

In summary:

- If INVOKER is set, the access rights for executing the call to an executable object are determined by checking the current user's active set of privileges
- If DEFINER is set, the access rights of the object owner will be applied instead, regardless of the current user's active privilege set

Syntax Patterns

```
CREATE TABLE <table-name> (...) [SQL SECURITY {DEFINER | INVOKER}]
ALTER TABLE <table-name> ... [{ALTER SQL SECURITY {DEFINER | INVOKER} | DROP SQL SECURITY}]
CREATE [OR ALTER] FUNCTION <function-name> ... [SQL SECURITY {DEFINER | INVOKER}] AS ...
CREATE [OR ALTER] PROCEDURE <procedure-name> ... [SQL SECURITY {DEFINER | INVOKER}] AS ...
CREATE [OR ALTER] TRIGGER <trigger-name> ... [SQL SECURITY {DEFINER | INVOKER} | DROP SQL SECURI
CREATE [OR ALTER] PACKAGE <package-name> [SQL SECURITY {DEFINER | INVOKER}] AS ...

ALTER DATABASE SET DEFAULT SQL SECURITY {DEFINER | INVOKER}
```

Packaged Routines

An explicit SQL SECURITY clause is not valid for procedures and functions defined in a package and will cause an error.

Triggers

Triggers inherit the setting of the SQL SECURITY property from the table, but it can be overriden explicitly. If the property is changed for a table, triggers that do not carry the overridden property will not see the effect of the change until next time the trigger is loaded into the metadata cache.

To remove an explicit SQL SECURITY option from a trigger, e.g. one named tr_ins, you can run

```
alter trigger tr_ins DROP SQL SECURITY;
```

To set it again to SQL SECURITY INVOKER, run

```
alter trigger tr_ins sql security invoker;
```

Examples Using the SQL SECURITY Property

1. With DEFINER set for table t, user US needs only the SELECT privilege on it. If it were set for INVOKER, the user would need also the EXECUTE privilege on function f.

```
set term ^;
create function f() returns int
as
begin
    return 3;
end^
set term ;^
create table t (i integer, c computed by (i + f())) SQL SECURITY DEFINER;
insert into t values (2);
grant select on table t to user us;

commit;

connect 'localhost:/tmp/7.fdb' user us password 'pas';
select * from t;
```

2. With DEFINER set for function f, user US needs only the EXECUTE privilege on it. If it were set for INVOKER, the user would need also the INSERT privilege on table t.

```
set term ^;
create function f (i integer) returns int SQL SECURITY DEFINER
as
begin
  insert into t values (:i);
  return i + 1;
end^
set term ;^
grant execute on function f to user us;

commit;

connect 'localhost:/tmp/59.fdb' user us password 'pas';
select f(3) from rdb$database;
```

3. With DEFINER set for procedure p, user US needs only the EXECUTE privilege on it. If it were set for INVOKER, either the user or the procedure would need also the INSERT privilege on table t.

```
set term ^;
create procedure p (i integer) SQL SECURITY DEFINER
as
begin
  insert into t values (:i);
end^
set term ;^

grant execute on procedure p to user us;
commit;
```

```
connect 'localhost:/tmp/17.fdb' user us password 'pas';
execute procedure p(1);
```

4. With DEFINER set for trigger tr, user US needs only the INSERT privilege on it. If it were set for INVOKER, either the user would need also the INSERT privilege on table t.

```
create table tr (i integer);
create table t (i integer);
set term ^;
create trigger tr_ins for tr after insert SQL SECURITY DEFINER
as
begin
  insert into t values (NEW.i);
end^
set term ;^
grant insert on table tr to user us;

commit;

connect 'localhost:/tmp/29.fdb' user us password 'pas';
insert into tr values(2);
```

   The result would be the same if SQL SECURITY DEFINER were specified for table TR:

```
create table tr (i integer) SQL SECURITY DEFINER;
create table t (i integer);
set term ^;
create trigger tr_ins for tr after insert
as
begin
  insert into t values (NEW.i);
end^
set term ;^
grant insert on table tr to user us;

commit;

connect 'localhost:/tmp/29.fdb' user us password 'pas';
insert into tr values(2);
```

5. With DEFINER set for package pk, user US needs only the EXECUTE privilege on it. If it were set for INVOKER, either the user would need also the INSERT privilege on table t.

```
create table t (i integer);
set term ^;
create package pk SQL SECURITY DEFINER
as
begin
    function f(i integer) returns int;
end^

create package body pk
as
begin
    function f(i integer) returns int
```

```
    as
    begin
      insert into t values (:i);
      return i + 1;
    end
end^
set term ;^
grant execute on package pk to user us;

commit;

connect 'localhost:/tmp/69.fdb' user us password 'pas';
select pk.f(3) from rdb$database;
```

Built-in Cryptographic Functions

Alex Peshkov

Tracker ticket CORE-5970

Firebird 4 introduces eight new built-in functions supporting cryptographic tasks; also two (non-cryptographic) functions for encoding and decoding between string and Base-64 data and another for getting a CRC32 code for a block of data.

ENCRYPT() and DECRYPT()

For encrypting/decrypting data using a symmetric cipher.

Format

```
{ENCRYPT | DECRYPT} ( <string | blob> USING <algorithm> [MODE <mode>] KEY <string>
   [IV <string>] [<endianness>] [CTR_LENGTH <smallint>] [COUNTER <bigint>])

algorithm ::= { block_cipher | stream_cipher }
block_cipher ::= { AES | ANUBIS | BLOWFISH | KHAZAD | RC5 | RC6 | SAFER+ | TWOFISH | XTEA }
stream_cipher ::= { CHACHA20 | RC4 | SOBER128 }
mode ::= { CBC | CFB | CTR | ECB | OFB }
endianness ::= { CTR_BIG_ENDIAN | CTR_LITTLE_ENDIAN }
```

Important

- Mode should be specified for block ciphers
- Initialization vector (IV) should be specified for block ciphers in all modes except ECB and all stream ciphers except RC4
- Endianness may be specified only in CTR mode, default is little endian counter
- Counter length (CTR_LENGTH, bytes) may be specified only in CTR mode, default is the size of IV
- Initial counter value (COUNTER) may be specified only for CHACHA20 cipher, default is 0
- Sizes of data strings passed to these functions are in accordance with the selected algorithm and mode requirements
- Functions return BLOB when the first argument is blob and varbinary for all text types.

Examples

```
select encrypt('897897' using sober128 key 'AbcdAbcdAbcdAbcd' iv '01234567')
    from rdb$database;
select decrypt(x'0154090759DF' using sober128 key 'AbcdAbcdAbcdAbcd' iv '01234567')
    from rdb$database;
select decrypt(secret_field using aes mode ofb key '0123456701234567' iv init_vector)
    from secure_table;
```

RSA_PRIVATE()

Returns an RSA private key of specified length (in bytes) in PKCS#1 format as a VARBINARY string.

Format

```
RSA_PRIVATE ( <smallint> )
```

Example

```
select rdb$set_context('USER_SESSION', 'private_key', rsa_private(256))
    from rdb$database;
```

RSA_PUBLIC()

Returns the RSA public key for a specified RSA private key. Both keys are in PKCS#1 format.

Format

```
RSA_PUBLIC ( <private key> )
```

Example

> **Tip**
>
> Run your samples one by one from the RSA_PRIVATE function forward.

```
select rdb$set_context('USER_SESSION', 'public_key',
    rsa_public(rdb$get_context('USER_SESSION', 'private_key'))) from rdb$database;
```

RSA_ENCRYPT()

Pads data using OAEP padding and encrypts it using an RSA public key. Normally used to encrypt short symmetric keys which are then used in block ciphers to encrypt a message.

Format

```
RSA_ENCRYPT ( <string> KEY <public key> [LPARAM <string>] [HASH <hash>] )
```

KEY should be a value returned by the RSA_PUBLIC function. LPARAM is an additional system-specific tag that can be applied to identify which system encoded the message. Its default value is NULL.

```
hash ::= { MD5 | SHA1 | SHA256 | SHA512 }
```

Default is SHA256.

Example

> **Tip**
>
> Run your samples one by one from the RSA_PRIVATE function forward.

```
select rdb$set_context('USER_SESSION', 'msg', rsa_encrypt('Some message'
    key rdb$get_context('USER_SESSION', 'public_key'))) from rdb$database;
```

RSA_DECRYPT()

Decrypts using the RSA private key and OAEP de-pads the resulting data.

Format

```
RSA_DECRYPT ( <string> KEY <private key> [LPARAM <string>] [HASH <hash>] )
```

KEY should be a value returned by the RSA_PRIVATE function. LPARAM is the same variable passed to RSA_ENCRYPT. If it does not match what was used during encoding, RSA_DECRYPT will not decrypt the packet.

```
hash ::= { MD5 | SHA1 | SHA256 | SHA512 } Default is SHA256.
```

Example

> **Tip**
>
> Run your samples one by one from the RSA_PRIVATE function forward.

```
select rsa_decrypt(rdb$get_context('USER_SESSION', 'msg')
    key rdb$get_context('USER_SESSION', 'private_key')) from rdb$database;
```

RSA_SIGN()

Performs PSS encoding of the message digest to be signed and signs using the RSA private key.

> **PSS encoding**
>
> Probabilistic Signature Scheme (PSS) is a cryptographic signature scheme specifically developed to allow modern methods of security analysis to prove that its security directly relates to that of the RSA problem. There is no such proof for the traditional PKCS#1 v1.5 scheme.

Format

```
RSA_SIGN ( <string> KEY <private key> [HASH <hash>] [SALT_LENGTH <smallint>] )
```

KEY should be a value returned by the RSA_PRIVATE function.

```
  hash ::= { MD5 | SHA1 | SHA256 | SHA512 }
```

Default is SHA256.

SALT_LENGTH indicates the length of the desired salt, and should typically be small. A good value is between 8 and 16.

Example

> **Tip**
>
> Run your samples one by one from the RSA_PRIVATE function forward.

```
  select rdb$set_context('USER_SESSION', 'msg', rsa_sign(hash('Test message' using sha256)
    key rdb$get_context('USER_SESSION', 'private_key'))) from rdb$database;
```

RSA_VERIFY()

Performs PSS encoding of message digest to be signed and verifies its digital signature using the RSA public key.

Format

```
RSA_VERIFY ( <string> SIGNATURE <string>
                          KEY <public key>
                          [HASH <hash>] [SALT_LENGTH <smallint>] )
```

SIGNATURE should be a value returned by the RSA_SIGN function. KEY should be a value returned by RSA_PUBLIC function.

```
hash ::= { MD5 | SHA1 | SHA256 | SHA512 }
```

Default is SHA256.

SALT_LENGTH indicates the length of the desired salt, and should typically be small. A good value is between 8 and 16.

Example

> **Tip**
>
> Run your samples one by one from the RSA_PRIVATE function forward.

```
select rsa_verify(hash('Test message' using sha256)
                  signature rdb$get_context('USER_SESSION', 'msg')
                  key rdb$get_context('USER_SESSION', 'public_key'))
              from rdb$database;
```

BASE64_ENCODE() and BASE64_DECODE()

These two functions are for encoding and decoding input data between string and BASE64 representation. They operate with character strings and BLOBs. Considered useful when working with binary objects—with keys, for example.

Format

```
BASE64_ENCODE( <binary data> )
BASE64_DECODE( <base64 data> )
```

Example

```
select base64_encode(public_key) from clients;
```

CRC32()

Accepts an argument than can be a field, variable or expression of any type recognised by DSQL/PSQL and returns a CRC-32 code calculated from the input data with the polynomial 0x04C11DB7. A constant, such as a file name passed as a string, returns the CRC for only the input.

Format

```
CRC32( <any value> )
```

Example

```
select crc32(job_title) from job;

select crc32('Firebird-4.0.0.716-Alpha1.amd64.tar.gz') from rdb$database;
```

> **Note**
>
> Initially CRC codes were designed as a tool to detect accidental changes to raw data when transferred over the wire or stored somewhere.
>
> It can be used as a very fast and rather efficient hash function. If the risk of collisions is not critical, its 32-bit integer output bestows a significant advantage over the widely-used SHA family of hashes in that it is easier to use later in various calculations if needed.

Improvements to Security Features

The following improvements were made to existing security features:

User Managing Other Users

Alex Peshkov

Tracker ticket CORE-5770

A user that was created with user account administration privileges in the security database (via the `... GRANT ADMIN ROLE` clause) no longer has to hold the `RDB$ADMIN` role in the connected database and pass it explicitly in order to create, alter or drop other users.

> **Note**
>
> This improvement is also backported to Firebird 3.0.5.

Chapter 7

Management Statements

Over the more recent releases of Firebird a new class of DSQL statement has emerged in Firebird's SQL lexicon, usually for administering aspects of the client/server environment. Typically, such statements commence with the verb `SET`, especially those introduced in Firebird 4.

> **Note**
>
> Some statements of this class, introduced earlier, use the verb `ALTER`, although management statements should not be confused with DDL `ALTER` statements that modify database objects like tables, views, procedures, roles, et al.

Use of Management Statements

Management statements can run anywhere DSQL can run but, typically, the developer will want to run a management statement in a database trigger. In past releases, management statements were treated in PSQL like DDL, precluding them from running directly inside a PSQL module. From Firebird 4 forward, a pre-determined set of them can be used directly in PSQL modules without the need to wrap them in an `EXECUTE STATEMENT` block. For more details of the current set, see Allow Management Statements in PSQL Blocks in the PSQL chapter.

Authorization

Most of the management statements introduced in Firebird 4 affect the current connection ("session") only, and do not require any authorization over and above the login privileges of a current user without elevated privileges.

Some management statements operate beyond the scope of the current session. Examples are the `ALTER DATABASE ..` statements to control *nBackup* or the `ALTER EXTERNAL CONNECTIONS POOL` statements introduced in Firebird 4 to manage connection pooling. A new set of *system privileges*, analogous with SQL privileges granted for database objects, is provided for assignment to a role, to enable the required authority to run a specific management statement in this category. For details, refer to Enhanced System Privileges in the Security chapter.

Management Statements for Use with Connections Pooling

A group of management statements for use with connections pooling.

> **Authorization**
>
> A role carrying the new system privilege `MODIFY_EXT_CONN_POOL` is required to run the statements.

ALTER EXTERNAL CONNECTIONS POOL Statement

The new statement `ALTER EXTERNAL CONNECTIONS POOL` has been added to the repertoire for managing the external connections pool.

The syntax is:

```
ALTER EXTERNAL CONNECTIONS POOL { <parameter variants> }
```

When prepared it is described like a DDL statement but its effect is immediate—it is executed immediately and completely, without waiting for transaction commit.

The statements can be issued from any connection and changes are applied to the in-memory instance of the pool in the current Firebird process. If the process is a Classic one, a change submitted there does not affect other Classic processes.

Changes made with `ALTER EXTERNAL CONNECTIONS POOL` are not persistent: after a restart, Firebird will use the pool settings configured in `firebird.conf` by `ExtConnPoolSize` and `ExtConnPoolLifeTime`.

Full Syntax

Full syntax for the variants follows.

To set the maximum number of idle connections:

```
ALTER EXTERNAL CONNECTIONS POOL SET SIZE <int>
```

Valid values are from 0 to 1000. Setting it to zero disables the pool. The default value is set using the parameter `ExtConnPoolSize` in `firebird.conf`.

To set the lifetime of an idle connection:

```
ALTER EXTERNAL CONNECTIONS POOL SET LIFETIME <int> <time_part>
```

where `<time_part>` is `SECOND | MINUTE | HOUR`. Valid values are from `1 SECOND` to `24 HOUR`. The default value (in seconds) is set using the parameter `ExtConnPoolLifetime` in `firebird.conf`.

To close all idle connections and instigate dissociation of all active connections immediately they become unused:

```
ALTER EXTERNAL CONNECTIONS POOL CLEAR ALL
```

To close expired idle connections:

```
ALTER EXTERNAL CONNECTIONS POOL CLEAR OLDEST
```

ALTER SESSION RESET Statement

The statement `ALTER SESSION RESET` is used to attempt a reset of an unused connection in the pool. For details, see How the Connection Pool Works in the Engine chapter.

Management Statements Pertaining to Time Zone Support

Statement syntax has been added to support management of the timezone features for the current connection.

SET TIME ZONE

Changes the session time zone.

Syntax

```
SET TIME ZONE { <time zone string> | LOCAL }
```

Examples

```
set time zone '-02:00';
set time zone 'America/Sao_Paulo';
set time zone local;
```

SET TIME ZONE BIND

Changes the session time zone bind format for compatibility with old clients. The default is configured as `NATIVE`, which means that `TIME WITH TIME ZONE` and `TIMESTAMP WITH TIME ZONE` expressions are returned to the client with the new data types.

Old clients may not understand the new data types, so the bind can be configured as `LEGACY` to make the appropriate conversion and return the expressions as `TIME WITHOUT TIME ZONE` and `TIMESTAMP WITHOUT TIME ZONE`, respectively.

> **Note**
>
> The bind configuration is also applicable to input parameters.

Syntax

```
SET TIME ZONE BIND { NATIVE | LEGACY }
```

Examples

```
set time zone bind native;
set time zone bind legacy;
```

Management Statements Pertaining to Timeouts

The timeout periods for session and statement timeouts can be managed at session level using the management statements `SET SESSION IDLE TIMEOUT` and `SET STATEMENT TIMEOUT`, respectively.

Statements to Set DECFLOAT Properties

Management statements of the form

```
SET DECFLOAT <property-name> [TO] <value>
```

are available for controlling the properties of the `DECFLOAT` data type for the current session. For details, see the topic Session Control Operator SET DECFLOAT in the DDL chapter.

Chapter 8

Data Definition Language (DDL)

Quick Links

Extended Length for Object Names

Adriano dos Santos Fernandes

Tracker ticket CORE-749

The maximum length of objects names from this version forward is 63 characters, up from the previous maximum of 31 bytes.

Multi-byte identifiers can also be long now. For example, the previous limit allowed only 15 Cyrillic characters; now, they could be up to 63.

> **Note**
> Double quotes are not counted.

Restricting the Length

If, for some reason, you need to restrict the maximum size of object names, either globally or for individual databases, two new configuration parameters are available in `firebird.conf` and/or `databases.conf`: see Parameters to Restrict Length of Object Identifiers in the Configuration chapter for further details.

New Data Types

New data types implemented in Firebird 4.0:

Data type DECFLOAT

Alex Peshkov

Tracker ticket CORE-5525

DECFLOAT is an SQL:2016 standard-compliant numeric type that stores floating-point numbers precisely, unlike FLOAT or DOUBLE PRECISION that provide a binary approximation of the purported precision. Firebird 4 accords with the IEEE 754-1985 standard types DECIMAL64 and DECIMAL128 by providing both 16-digit and 34-digit precision for this type.

All intermediate calculations are performed with 34-digit values.

> **16-digit and 34-digit**
>
> The “16” and “34” refer to the maximum precision in Base-10 digits. See https://en/wikipedia.org/wiki/iEEE_754#Basic_and_interchange_formats for a comprehensive table.

Syntax Rules

```
DECFLOAT(16)
DECFLOAT(34)
DECFLOAT
```

The default precision is 34 digits, i.e., if DECFLOAT is declared with no parameter, it will be defined as DECFLOAT(34). Storage complies with IEEE 754, storing data as 64 and 128 bits, respectively.

Examples

```
DECLARE VARIABLE VAR1 DECFLOAT(34);
--
CREATE TABLE TABLE1 (FIELD1 DECFLOAT(16));
```

Aspects of DECFLOAT Usage

Length of Literals

The length of DECFLOAT literals cannot exceed 1024 characters. Scientific notation is required for longer values. For example, **0.0<1020 zeroes>11** cannot be used as a literal, the equivalent in scientific notation, **1.1E-1022** is valid. Similarly, **10<1022 zeroes>0** can be presented as **1.0E1024**.

Use with Standard Functions

A number of standard scalar functions can be used with expressions and values of the DECFLOAT type. They are:

ABS	EXP	LN	LOG10	SIGN
CEILING	FLOOR	LOG	POWER	SQRT

The aggregate functions SUM, AVG, MAX and MIN work with DECFLOAT data, as do all of the statistics aggregates (like but not limited to STDDEV or CORR).

Special Functions for DECFLOAT

Firebird supports four functions, designed to support DECFLOAT data specifically:

- COMPARE_DECFLOAT—compares two DECFLOAT values to be equal, different or unordered
- NORMALIZE_DECFLOAT—takes a single DECFLOAT argument and returns it in its simplest form
- QUANTIZE— takes two DECFLOAT arguments and returns the first argument scaled using the second value as a pattern
- TOTALORDER—performs an exact comparison on two DECFLOAT values

Detailed descriptions are in the DML chapter, in the topic Special Functions for DECFLOAT.

Session Control Operator SET DECFLOAT

Firebird supports the session control operator SET DECFLOAT which has three forms, as follows:

- SET DECFLOAT ROUND <mode> controls the rounding mode used in operations with DECFLOAT values. Valid modes are:

CEILING	towards +infinity
UP	away from 0
HALF_UP	to nearest, if equidistant, then up
HALF_EVEN	to nearest, if equidistant, ensure last digit in the result will be even
HALF_DOWN	to nearest, if equidistant, then down
DOWN	towards 0
FLOOR	towards -infinity
REROUND	up if digit to be rounded is 0 or 5, down in other cases

  The default rounding mode is `HALF-UP`.

- SET DECFLOAT TRAPS TO <comma-separated traps list which may be empty> controls which exceptional conditions cause a trap. Valid traps are:

Division_by_zero	(set by default)
Inexact	---
Invalid_operation	(set by default)
Overflow	(set by default)
Underflow	---

- SET DECFLOAT BIND <bind-type> controls how DECFLOAT values are represented externally, i.e. in messages or in the XSQLDA. The range of bindings is useful if one plans to use DECFLOAT values with some old client that does not support the native format. One can choose between strings (ideal precision, but poor support for further processing), floating point values (ideal support for further processing but poor

precision) or scaled integers (good support for further processing and the required precision but having a very limited range of values). CHAR binding is a satisfactory choice for most general purpose GUI client tools.

Valid binding types are:

NATIVE	Use IEEE754 binary representation
CHAR/CHARACTER	Use ASCII string
DOUBLE PRECISION	Use the same 8-byte floating-point representation as is used for DOUBLE PRECISION fields
BIGINT	As BIGINT, with optional comma-separated SCALE clause, e.g., `BIGINT,3`

Further notes

1. A bound ASCII string will be CHAR(23) for DECFLOAT(16) or CHAR(42) for DECFLOAT(34). The lengths are simple to verify using *isql* or some other SQL client tool.
2. The string representation depends on the DECFLOAT value: if it is exponential and precision requirements make it possible to display a value without using scientific notation, the fully written out format is used; it will be in scientific notation otherwise.
3. Any overflow or underflow will be treated appropriately according to the TRAPS setting.

Note

The precision of the `DECFLOAT` column or domain is stored in the system table `RDB$FIELDS`, in `RDB$FIELD_PRECISION`.

DDL Enhancements

Enhancements have been added to the SQL data definition language lexicon in Firebird 4 include a new, high-precision floating-point data type and more extensions for the IDENTITY type.

New and extended DDL statements supporting the new security features are described in the Security chapter.

Increased Precision for NUMERIC and DECIMAL Types

Alex Peshkov

Fixed decimal types NUMERIC and DECIMAL can now be defined with up to 34 digits precision. Any value with precision higher than 18 digits will be stored as a 34-digit number.

Syntax rules

```
NUMERIC ( P [, S] )
DECIMAL ( P [, S] )
```

where P is precision (P <= 34, previously limited to 18 digits) and the optional S is scale, as previously, i.e., the number of digits after the decimal separator.

Storage is 128-bit, format according to IEEE 754.

Examples

1. Declare a variable of 25 digits to behave like an integer:

```
DECLARE VARIABLE VAR1 DECIMAL(25);
```

2. Define a column to accommodate up to 34 digits, with 17 decimal places:

```
CREATE TABLE TABLE1 (FIELD1 NUMERIC(34, 17));
```

> **Note**
>
> Numerics with precision less than 19 digits use SMALLINT, INTEGER, BIGINT or DOUBLE PRECISION as the base datatype, depending on the number of digits and SQL dialect. When precision is between 19 and 34 digits DECFLOAT(34) is used as the base and the actual precision is always extended to the full 34 digits.
>
> For complex calculations, those digits are cast internally, in a trivial way, to DECFLOAT(34). The result of various mathematical operations, such as LOG(), EXP() and so on, and aggregate functions using a high precision numeric argument, will be DECFLOAT(34).

Data Type Extensions for Time Zone Support

The syntax for declaring the data types `TIMESTAMP` and `TIME` has been extended to include arguments defining whether the column, domain, parameter or variable should be defined with or without time zone adjustments, i.e.,

```
```
TIME [{ WITHOUT | WITH } TIME ZONE]

TIMESTAMP [{ WITHOUT | WITH } TIME ZONE]
```
```

> **Important**
>
> For a summary of the effects of time zone support on existing data and application code, refer to Changes in DDL and DML Due to Timezone Support in the Compatibility chapter.

Storage

Data of types `TIME/TIMESTAMP WITH TIME ZONE` are stored respectively with the same storage as `TIME/TIMESTAMP WITHOUT TIME ZONE` plus two extra bytes for the time zone identifier or displacement.

- The time/timestamp parts, translated from the informed time zone, are stored in UTC.
- Time zone identifiers (from regions) are put directly in the time_zone bytes. They start from 65535, for the GMT code, decreasing as new time zones are added.

  The time zone literals, together with their time zone identifiers, are listed in the Appendix Time Zone Regions at the end of these release notes.

- Time zone displacements (`+/- HH:MM`) are encoded with (`sign * (HH * 60 + MM)) + 1439`.

  For example, a `00:00` displacement is encoded as `(1 * (0 * 60 + 0)) + 1439 = 1439` and `-02:00` as `(-1 * (2 * 60 + 0)) + 1439 = 1319`
  .

The default for both `TIME` and `TIMESTAMP` is `WITHOUT TIME ZONE`.

See also Management Statements Pertaining to Time Zone Support in the *Management Statements* chapter.

Aliases for Binary String Types

Dimitry Sibiryakov

Tracker ticket CORE-5064

Data types named BINARY(n), VARBINARY(n) and BINARY VARYING(n) have been added to the lexicon as optional aliases for defining string columns in CHARACTER SET OCTETS.

BINARY(n) is an alias for CHAR(n) CHARACTER SET OCTETS, while VARBINARY(n) and BINARY VARYING(n) are aliases for VARCHAR(n) CHARACTER SET OCTETS and for each other.

Extensions to the IDENTITY Type

Adriano dos Santos Fernandes

An IDENTITY column is one that is formally associated with an internal sequence generator and has its value set automatically when omitted from an INSERT statement.

The IDENTITY sub-type was introduced in Firebird 3 and has undergone a number of extensions in V.4, including implementation of DROP IDENTITY, the GENERATED ALWAYS and OVERRIDE directives and the INCREMENT BY option.

Extended Syntax for Managing IDENTITY Columns

```
<column definition> ::=
  <name> <type> GENERATED { ALWAYS | BY DEFAULT } AS IDENTITY [ ( <identity column option>... ) ]

<identity column option> ::=
  START WITH <value> |  INCREMENT [ BY ] <value>

<alter column definition> ::=
  <name> <set identity column generation clause> [ <alter identity column option>... ] |
  <name> <alter identity column option>... |
  <name> DROP IDENTITY

 <set identity column generation clause> ::=
  SET GENERATED { ALWAYS | BY DEFAULT }

<alter identity column option> ::=
  RESTART [ WITH <value> ] | SET INCREMENT [ BY ] <value>
```

Rules and Characteristics

- The type of an identity column must be an exact number type with zero scale, comprising SMALLINT, INTEGER, BIGINT, NUMERIC(s,0) and DECIMAL(s,0).
- Identity columns cannot have a DEFAULT value or be defined as COMPUTED BY <expr>
- A regular column cannot be altered to be an identity column
- Identity columns cannot be defined or made non-nullable
- The engine does not enforce uniqueness automatically. A unique constraint or index of the required kind must be defined explicitly.
- An INCREMENT value cannot be zero

The Firebird 4 Extensions to IDENTITY

The Firebird 3 implementation was minimal, effectively formalizing the traditional way of implementing generated keys in Firebird, without many options. Firebird 4 puts some meat on those bones.

The GENERATED ALWAYS and BY DEFAULT Directives

Tracker ticket CORE-5463

The earlier implementation behaved like the traditional Firebird setup for generating integer keys automatically when the column was omitted from the insert operation's column list. If the column was not listed, the IDENTITY generator would supply the value.

A GENERATED BY clause is mandatory. The GENERATED BY DEFAULT directive, present in the Firebird 3 syntax, implemented this behaviour formally without the alternative GENERATED ALWAYS option, :

```
create table objects (
  id integer generated BY DEFAULT as
     identity primary key,
  name varchar(15)
);

insert into objects (name) values ('Table');
insert into objects (name) values ('Book');
insert into objects (id, name) values (10, 'Computer');

select * from objects order by id;

commit;
```

```
          ID NAME
============ ===============
           1 Table
           2 Book
          10 Computer
```

The GENERATED ALWAYS directive introduces alternative behaviour that enforces the use of the identity generator, whether or not the user supplies a value.

Overriding the defined behaviour

For one-off cases this enforcement can be overridden in DML by including an OVERRIDING SYSTEM VALUE clause.

On the other hand, for one-off cases where you want to override the defined action for a column defined with the GENERATED BY DEFAULT directive to behave as though it were defined as GENERATED ALWAYS and ignore any DML-supplied value, the clause OVERRIDING USER VALUE is available.

For more details, see OVERRIDING Clause for IDENTITY Columns in the DML chapter.

Changing the Defined Behaviour

The ALTER COLUMN clause of ALTER TABLE now has syntax for changing the default GENERATED behaviour from BY DEFAULT to ALWAYS, or vice versa:

```
alter table objects
  alter id
  SET GENERATED ALWAYS;
```

DROP IDENTITY Clause

Tracker ticket CORE-5431

For a situation where you want to drop the IDENTITY property from a column but retain the data, the DROP IDENTITY clause is available to the ALTER TABLE statement:

```
alter table objects
  alter id
  DROP IDENTITY;
```

INCREMENT BY Option for IDENTITY Columns

Tracker ticket CORE-5430

By default, identity columns start at 1 and increment by 1. The INCREMENT BY option can now be used to set the increment for some positive step, i.e., 1 or more:

```
create table objects (
  id integer generated BY DEFAULT as
     identity (START WITH 10000 INCREMENT BY 10)
     primary key,
  name varchar(15)
);
```

Changing the Increment (Step) Value

For changing the step value of the sequence produced by an IDENTITY generator, the SET INCREMENT clause is available in the latest ALTER TABLE statement syntax:

```
alter table objects
  alter id SET INCREMENT BY 5;
```

Note

1. Changing the step value does not affect existing data.
2. It is not necessary to specify SET INCREMENT BY 1 for a new column, nor for one that has not been altered previously, as the default step is 1.

Implementation

Two columns have been inserted in RDB$RELATION_FIELDS: RDB$GENERATOR_NAME and RDB $IDENTITY_TYPE. RDB$GENERATOR_NAME stores the automatically created generator for the column.

In RDB$GENERATORS, the value of RDB$SYSTEM_FLAG of that generator will be 6. RDB $IDENTITY_TYPE stores the value 0 for GENERATED ALWAYS, 1 for GENERATED BY DEFAULT, and NULL for non-identity columns.

Chapter 9

Data Manipulation Language (DML)

In this chapter are the additions and improvements that have been added to the SQL data manipulation language subset in Firebird 4.0.

Quick Links

DEFAULT Context Value for Inserting and Updating

Adriano dos Santos Fernandes

Tracker ticket CORE-5449

Support has been implemented to enable the declared default value for a column or domain to be included directly in INSERT, UPDATE, MERGE and UPDATE OR INSERT statements by use of the keyword DEFAULT in the column's position. If DEFAULT appears in the position of a column that has no default value defined, the engine will attempt to write NULL to that column.

The feature is defined in (SQL:2011): 6.5 <contextually typed value specification>.

Simple Examples

```
insert into sometable (id, column1)
values (DEFAULT, 'name')
--
update sometable
  set column1 = 'a', column2 = default
```

Notes

If id is an identity column, the identity value will be generated, even if there is an UPDATE ... SET command associated with the column.

If DEFAULT is specified on a computed column, the parser will allow it but it will have no effect.

In columns populated by triggers in the traditional way, the value from DEFAULT enters the NEW context variable of any BEFORE INSERT or BEFORE UPDATE trigger.

DEFAULT vs DEFAULT VALUES

Since v.2.1, Firebird has supported the DEFAULT VALUES clause. The two clauses are not the same. The DEFAULT VALUES clause is an alternative to the VALUES clause and can be used only when all of the colums specified in the column list have been defined with default values.

OVERRIDING Clause for IDENTITY Columns

Adriano dos Santos Fernandes

Tracker ticket CORE-5463

Identity columns defined with the BY DEFAULT attibute can be overriden in statements that insert rows (INSERT, UPDATE OR INSERT, MERGE ... WHEN NOT MATCHED) just by specifying the value in the values list. For identity columns defined with the GENERATE ALWAYS attribute, that kind of override is not allowed.

Making the value passed in the INSERT statement for an ALWAYS column acceptable to the engine requires use of the OVERRIDING clause with the SYSTEM VALUE sub-clause, as illustrated below:

```
insert into objects (id, name)
  OVERRIDING SYSTEM VALUE values (11, 'Laptop');
```

OVERRIDING supports another sub-clause, USER VALUE, for use with BY DEFAULT columns to direct the engine to ignore the value passed in INSERT and use the sequence defined for the identity column:

```
insert into objects (id, name)
  OVERRIDING USER VALUE values (12, 'Laptop');  -- 12 is not used
```

Extension of SQL Windowing Features

Adriano dos Santos Fernandes

The OVER clause for Window functions in Firebird now supports not just the sub-clauses PARTITION and ORDER subclauses but also *frames* and *windows with names* that can be re-used in the same query.

Syntax Pattern

The pattern for Firebird 4 windowing syntax is as follows:

```
<window function> ::=
<window function name>([<expr> [, <expr> ...]])
    OVER {<window specification> | <existing window name>}

<window specification> ::=
  ([<existing window name>] [<window partition>] [<window order>] [<window frame>])

<window partition> ::=
  PARTITION BY <expr> [, <expr> ...]

<window order> ::=
  ORDER BY <expr> [<direction>] [<nulls placement>] [, <expr> [<direction>] [<nulls placement>]]

<window frame> ::=
  {RANGE | ROWS} <window frame extent>

<window frame extent> ::=
  {<window frame start> | <window frame between>}

<window frame start> ::=
  {UNBOUNDED PRECEDING | <expr> PRECEDING | CURRENT ROW}

<window frame between> ::=
  BETWEEN {UNBOUNDED PRECEDING | <expr> PRECEDING | <expr> FOLLOWING | CURRENT ROW} AND
          {UNBOUNDED FOLLOWING | <expr> PRECEDING | <expr> FOLLOWING | CURRENT ROW}

<direction> ::=
  {ASC | DESC}

<nulls placement> ::=
  NULLS {FIRST | LAST}

<query spec> ::=
  SELECT
    [<limit clause>]
    [<distinct clause>]
    <select list>
    <from clause>
    [<where clause>]
    [<group clause>]
    [<having clause>]
    [<named windows clause>]
    [<plan clause>]

<named windows clause> ::=
  WINDOW <window definition> [, <window definition>] ...

<window definition> ::=
  <new window name> AS <window specification>
```

Frames for Window Functions

Tracker ticket CORE-3647

A *frame* can be specified, within which certain window functions are to work.

Syntax Elements for Frames

The following extract from the syntax pattern above explains the elements that affect frames:

```
<window frame> ::=
  {RANGE | ROWS} <window frame extent>

<window frame extent> ::=
  {<window frame start> | <window frame between>}

<window frame start> ::=
  {UNBOUNDED PRECEDING | <expr> PRECEDING | CURRENT ROW}

<window frame between> ::=
  BETWEEN {UNBOUNDED PRECEDING | <expr> PRECEDING | <expr> FOLLOWING | CURRENT ROW} AND
          {UNBOUNDED FOLLOWING | <expr> PRECEDING | <expr> FOLLOWING | CURRENT ROW}
```

The frame comprises three pieces: unit, start bound and end bound. The unit can be RANGE or ROWS and defines how the bounds will work. The bounds are:

<expr> PRECEDING
<expr> FOLLOWING
CURRENT ROW

- With RANGE, the ORDER BY should specify only one expression, and that expression should be of a numeric, date, time or timestamp type. For <expr> PRECEDING and <expr> FOLLOWING bounds, <expr> is subtracted from the order expression in the case of PRECEDING and added to it in the case of FOLLOWING. For CURRENT ROW, the order expression is used as-is.

  All rows inside the partition that are between the bounds are considered part of the resulting window frame.

- With ROWS, order expressions are not limited by number or type. For this unit, <expr> PRECEDING, <expr> FOLLOWING and CURRENT ROW relate to the row position under the partition, and not to the values of the ordering keys.

UNBOUNDED PRECEDING and UNBOUNDED FOLLOWING work identically with RANGE and ROWS. UNBOUNDED PRECEDING looks for the first row and UNBOUNDED FOLLOWING the last one, always inside the partition.

The frame syntax with <window frame start> specifies the start frame, with the end frame being CURRENT ROW.

Some window functions discard frames:

- ROW_NUMBER, LAG and LEAD always work as ROWS BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW
- DENSE_RANK, RANK, PERCENT_RANK and CUME_DIST always work as RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW.
- FIRST_VALUE, LAST_VALUE and NTH_VALUE respect frames, but the RANGE unit behaviour is identical to ROWS.

Navigational Functions with Frames

Navigational functions, implemented in Firebird 3, get the simple (non-aggregated) value of an expression from another row that is within the same partition. They can operate on frames. These are the syntax patterns:

```
  <navigational window function> ::=
```

```
    FIRST_VALUE(<expr>) |
    LAST_VALUE(<expr>) |
    NTH_VALUE(<expr>, <offset>) [FROM FIRST | FROM LAST] |
    LAG(<expr> [ [, <offset> [, <default> ] ] ) |
    LEAD(<expr> [ [, <offset> [, <default> ] ] )
```

The default frame is `RANGE BETWEEN UNBOUNDED PRECEDING AND CURRENT ROW` which might produce strange results when a frame with these properties is operated on by `FIRST_VALUE`, `NTH_VALUE` or, particularly, `LAST_VALUE`.

Example Using Frames

When the ORDER BY window clause is used but a frame clause is omitted, the default frame just described causes the query below to produce weird behaviour for the `sum_salary` column. It sums from the partition start to the current key, instead of summing the whole partition.

```
select
    id,
    salary,
    sum(salary) over (order by salary) sum_salary
  from employee
  order by salary;
```

Result:

```
| id | salary | sum_salary |
|---:|-------:|-----------:|
|  3 |   8.00 |       8.00 |
|  4 |   9.00 |      17.00 |
|  1 |  10.00 |      37.00 |
|  5 |  10.00 |      37.00 |
|  2 |  12.00 |      49.00 |
```

A frame can be set explicitly to sum the whole partition, as follows:

```
select
    id,
    salary,
    sum(salary) over (
      order by salary
      ROWS BETWEEN UNBOUNDED PRECEDING AND UNBOUNDED FOLLOWING
                    ) sum_salary
  from employee
  order by salary;
```

Result:

```
| id | salary | sum_salary |
|---:|-------:|-----------:|
|  3 |   8.00 |      49.00 |
|  4 |   9.00 |      49.00 |
|  1 |  10.00 |      49.00 |
|  5 |  10.00 |      49.00 |
|  2 |  12.00 |      49.00 |
```

This query “fixes” the weird nature of the default frame clause, producing a result similar to a simple `OVER ()` clause without `ORDER BY`.

We can use a range frame to compute the count of employees with salaries between (an employee's salary - 1) and (his salary + 1) with this query:

```
select
    id,
    salary,
    count(*) over (
      order by salary
      RANGE BETWEEN 1 PRECEDING AND 1 FOLLOWING
    ) range_count
  from employee
  order by salary;
```

Result:

```
| id | salary | range_count |
|---:|-------:|------------:|
|  3 |   8.00 |           2 |
|  4 |   9.00 |           4 |
|  1 |  10.00 |           3 |
|  5 |  10.00 |           3 |
|  2 |  12.00 |           1 |
```

Named Windows

Tracker ticket CORE-5346

In a query with the WINDOW clause, a window can be explicitly named to avoid repetitive or confusing expressions.

A named window can be used

1. in the OVER element to reference a window definition, e.g. OVER <window-name>
2. as a base window of another named or inline (OVER) window, if it is not a window with a frame (ROWS or RANGE clauses).

> **Note**
> a window with a base window cannot have PARTITION BY, nor override the ordering (ORDER BY sequence) of a base window.

In a query with multiple SELECT and WINDOW clauses (for example, with subqueries), the scope of the window name is confined to its query context. That means a window name from an inner context cannot be used in an outer context, nor vice versa. However, the same window name definition can be used independently in different contexts.

Example Using Named Windows

```
select
    id,
    department,
    salary,
    count(*) over w1,
    first_value(salary) over w2,
```

```
    last_value(salary) over w2
  from employee
  window w1 as (partition by department),
         w2 as (w1 order by salary)
  order by department, salary;
```

More Window Functions

Adriano dos Santos Fernandes
Hajime Nakagami

Tracker ticket CORE-1688

More ANSI SQL:2003 window functions—the ranking functions PERCENT_RANK, CUME_DIST and NTILE.

Ranking Functions

```
<ranking window function> ::=
    DENSE_RANK() |
    RANK() |
    PERCENT_RANK() |
    CUME_DIST() |
    NTILE(<expr>) |
    ROW_NUMBER()
```

Ranking functions compute the ordinal rank of a row within the window partition. The basic functions in this category, present since Firebird 3, are DENSE_RANK, RANK and ROW_NUMBER. These function enable creation of various types of incremental counters to generate sets in ways that are analogous with operations such as SUM(1) OVER (ORDER BY SALARY).

The new functions implemented in Firebird 4 are:

- PERCENT_RANK is a ratio of RANK to group count.
- CUME_DIST is the cumulative distribution of a value in a group.
- NTILE takes an argument and distributes the rows into the specified number of groups. The argument is restricted to integral positive literal, variable (:var) and DSQL parameter (?).

Simple Example

The following example illustrates the behaviour of ranking functions. SUM is included for comparison.

```
select
    id,
    salary,
    dense_rank() over (order by salary),
    rank() over (order by salary),
    percent_rank() over (order by salary),
    cume_dist() over (order by salary),
    ntile(3) over (order by salary),
    row_number() over (order by salary),
    sum(1) over (order by salary)
  from employee
  order by salary;
```

The result set looks something like the following, although trailing zeroes have been truncated here in order to fit the lines to the document page:

```
id  salary   dense_rank   rank   percent_rank   cume_dist   ntile   row_number   sum
3     8.00            1      1      0.0000000  0.20000000       1            1     1
4     9.00            2      2      0.2500000  0.40000000       1            2     2
1    10.00            3      3      0.5000000  0.80000000       2            3     4
5    10.00            3      3      0.5000000  0.80000000       2            4     4
2    12.00            4      5      1.0000000  1.00000000       3            5     5
```

FILTER Clause for Aggregate Functions

Adriano dos Santos Fernandes

Tracker ticket CORE-5768

The FILTER clause extends aggregate functions (sum, avg, count, etc.) by an additional WHERE clause. The set returned is the aggregate of the rows that satisfy the conditions of both the main WHERE clause and those inside the FILTER clause(s).

It can be thought of as a shortcut for situations where one would use an aggregate function with some condition (decode, case, iif) to ignore some of the values that would be considered by the aggregation.

The clause can be used with any aggregate functions in aggregate or windowed (OVER) statements, but not with window-only functions like DENSE_RANK.

Example

Suppose you have a query where you want to count the number of status = 'A' and the number of status = 'E' as different columns. The old way to do it would be:

```
select count(decode(status, 'A', 1)) status_a,
       count(decode(status, 'E', 1)) status_e
  from data;
```

The FILTER clause lets you express those conditions more compactly:

```
select count(*) filter (where status = 'A') status_a,
       count(*) filter (where status = 'E') status_e
  from data;
```

> **Tip**
>
> You can use more than one FILTER modifier in an aggregate query. You could, for example, use 12 filters on totals aggregating sales for a year to produce monthly figures for a pivot set

Syntax for FILTER Clauses

```
aggregate_function [FILTER (WHERE <condition>)] [OVER (<window>)]
```

Optional AUTOCOMMIT for SET TRANSACTION

Dmitry Yemanov

Tracker ticket CORE-5119

Autocommit mode is now supported in the SET TRANSACTION statement syntax.

Example

```
SET TRANSACTION SNAPSHOT NO WAIT AUTO COMMIT;
```

Expressions and Built-in Functions

Additions and changes to the sets of built-in functions and expressions in Firebird 4.

New Functions and Expressions

Built-in functions and expressions added in Firebird 4.0.

Functions & Expressions for Timezone Operations

Adriano dos Santos Fernandes

Expressions and built-in functions for timezone operations.

AT Expression

Translates a time/timestamp value to its corresponding value in another time zone. If `LOCAL` is used, the value is converted to the session time zone.

Syntax

```
<at expr> ::= <expr> AT { TIME ZONE <time zone string> | LOCAL }
```

Examples

```
select time '12:00 GMT' at time zone '-03' from rdb$database;
select current_timestamp at time zone 'America/Sao_Paulo' from rdb$database;
select timestamp '2018-01-01 12:00 GMT' at local from rdb$database;
```

LOCALTIME Expression

Returns the current time as a `TIME WITHOUT TIME ZONE`, i.e., in the session time zone.

Example

```
select localtime from rdb$database;
```

LOCALTIMESTAMP Expression

Returns the current timestamp as a `TIMESTAMP WITHOUT TIME ZONE`, i.e., in the session time zone.

Example

```
select localtimestamp from rdb$database;
```

Two New Date/Time Functions

Adriano dos Santos Fernandes

FIRST_DAY

Returns a date or timestamp (as appropriate) with the first day of the year | month | week of a given date or timestamp value.

Format:

```
FIRST_DAY( OF { YEAR | MONTH | WEEK } FROM <date_or_timestamp> )
```

1. The first day of the week is considered as Sunday, following the same rules as for EXTRACT with WEEKDAY
2. When a timestamp is passed the return value preserves the time part

Examples

```
select first_day(of month from current_date) from rdb$database;
select first_day(of year from current_timestamp) from rdb$database;
select first_day(of week from date '2017-11-01') from rdb$database;
```

LAST_DAY

Returns a date or timestamp (as appropriate) with the last day of the year | month | week of a given date or timestamp value.

Format:

```
LAST_DAY( OF { YEAR | MONTH | WEEK } FROM <date_or_timestamp> )
```

1. The lastt day of the week is considered as Saturday, following the same rules as for EXTRACT with WEEKDAY
2. When a timestamp is passed the return value preserves the time part

Examples

```
select last_day(of month from current_date) from rdb$database;
select last_day(of year from current_timestamp) from rdb$database;
select last_day(of week from date '2017-11-01') from rdb$database;
```

Security Functions

Two new built-in functions were added to support the new security features. They are not described here—the descriptions are located in the Security chapter. They are:

- RDB$SYSTEM_PRIVILEGE
- RDB$ROLE_IN_USE

A number of cryptographic functions was added, viz.,

- ENCRYPT() and DECRYPT()
- RSA_PRIVATE()
- RSA_PUBLIC()
- RSA_ENCRYPT()
- RSA_DECRYPT()
- RSA_SIGN()
- RSA_VERIFY()

Also, three related non-cryptographic functions:

- BASE64_ENCODE() and BASE64_DECODE
- CRC32()

Special Functions for DECFLOAT

Firebird supports four functions, designed to support DECFLOAT data specifically:

- COMPARE_DECFLOAT—compares two DECFLOAT values to be equal, different or unordered. Returns a SMALLINT value, one of:

0	Values are equal
1	First value is less than second
2	First value is greater than second
3	Values are unordered, i.e., one or both is NAN / SNAN

Unlike the comparison operators ('<', '=', '>', etc.) comparison is exact: `COMPARE_DECFLOAT(2.17, 2.170)` returns 2, not 0.

- NORMALIZE_DECFLOAT—takes a single DECFLOAT argument and returns it in its simplest form. That means that for any non-zero value, trailing zeros are removed with appropriate correction of the exponent.

  For example, `NORMALIZE_DECFLOAT(12.00)` returns 12 and `NORMALIZE_DECFLOAT(120)` returns 1.2E+2.

- QUANTIZE— takes two DECFLOAT arguments. The returned value is the first argument scaled using the second value as a pattern.

  For example, `QUANTIZE(1234, 9.999)` returns 1234.000.

  There are almost no retrictions on the pattern. However, in almost all usages, SNaN will produce an exception, NULL will make the function return NULL, and so on.

```
SQL> select v, pic, quantize(v, pic) from examples;

                     V                    PIC QUANTIZE
====================== ==================== ==================
                  3.16 0.001                  3.160
                  3.16 0.01                   3.16
                  3.16 0.1                    3.2
                  3.16 1                      3
                  3.16 1E+1                   0E+1
                  -0.1 1                     -0
                     0 1E+5                   0E+5
                   316 0.1                  316.0
                   316 1                    316
                   316 1E+1                 3.2E+2
                   316 1E+2                   3E+2
```

Note

1. If scaling like the example produces a result that would exceed the precision, the error “Decimal float invalid operation” is returned.
2. A known bug (CORE-5697), can sometimes cause the use of literals in QUANTIZE to produce strange results. A workaround in Beta 1 is to use a string literal, i.e., enclose the DECFLOAT number in single quotes.

- TOTALORDER—compares two DECFLOAT values including any special value. The comparison is exact. Returns a SMALLINT value, one of:

-1	First value is less than second
0	Values are equal
1	First value is greater than second

For TOTALORDER comparisons, DECFLOAT values are ordered as follows:

```
-nan < -snan < -inf < -0.1 < -0.10 < -0 < 0 < 0.10 < 0.1 < inf < snan < nan
```

Function RDB$GET_TRANSACTION_CN

Supporting Snapshots Based on Commit Order

Vlad Khorsun

See Tracker ticket CORE-5921. For the background, see Commit Order for Capturing the Database Snapshot in the Engine chapter.

Returns the commit number (“CN”)of the supplied transaction. Result type is BIGINT.

Format

```
RDB$GET_TRANSACTION_CN( <transaction number> )
```

If the value returned is greater than 1, it will be the actual CN of the transaction if it was committed after the database was started.

The function could return one of the following results instead, indicating the commit status of the transaction:

- -2 —Transaction is dead (rolled back)
- -1 —Transaction is in limbo
- 0 —Transaction is still active
- 1 —Transaction committed before the database started or less than the Oldest Interesting Transaction for the database
- NULL—Transaction number supplied is NULL or greater than Next Transaction for the database

> **Note about the numerics**
>
> Internally, the engine uses unsigned 8-byte integer for commit numbers and unsigned 6-byte integer for transaction numbers. Thus, although the SQL language has no unsigned integers and RDB $GET_TRANSACTION_CN returns a signed BIGINT, a negative commit number will never be returned except for the special values returned for uncommitted transactions.

Examples

```
select rdb$get_transaction_cn(current_transaction) from rdb$database;
select rdb$get_transaction_cn(123) from rdb$database;
```

Cryptographic Functions

Alex Peshkov

Eight new functions are introduced supporting cryptographic operations. Follow the links to the Security chapter for syntax and usage details.

ENCRYPT() and DECRYPT()
For encrypting/decrypting data using a symmetric cipher.

RSA_PRIVATE()
Returns an RSA private key of specified length (in bytes) in PKCS#1 format as a VARBINARY string.

RSA_PUBLIC()
Returns the RSA public key for a specified RSA private key. Both keys are in PKCS#1 format.

RSA_ENCRYPT()
Pads data using OAEP padding and encrypts it using an RSA public key. Normally used to encrypt short symmetric keys which are then used in block ciphers to encrypt a message.

RSA_DECRYPT()
Decrypts using the RSA private key and OAEP de-pads the resulting data.

RSA_SIGN()
Performs PSS encoding of message digest to be signed and signs using the RSA private key.

RSA_VERIFY()
Performs PSS encoding of message digest to be signed and verifies its digital signature using the RSA public key.

Changes to Built-in Functions and Expressions

Functions changed or extended in this release:

Changes Arising from Timezone Support

EXTRACT Expressions

Two new arguments have been added to the `EXTRACT` expression:

- `TIMEZONE_HOUR`: extracts the time zone hours displacement
- `TIMEZONE_MINUTE`: extracts the time zone minutes displacement

Examples

```
select extract(timezone_hour from current_time) from rdb$database;
select extract(timezone_minute from current_timestamp) from rdb$database;
```

Changes in CURRENT_TIME and CURRENT_TIMESTAMP

In version 4.0, `CURRENT_TIME` and `CURRENT_TIMESTAMP` are changed: they now return `TIME WITH TIME ZONE` and `TIMESTAMP WITH TIME ZONE`, with the time zone set by the session time zone. In previous versions, `CURRENT_TIME` and `CURRENT_TIMESTAMP` returned the respective types according to the system clock, i.e., without any time zone.

To ease the transition, `LOCALTIME` and `LOCALTIMESTAMP` were added at v3.0.4, allowing developers to adjust application code without any functional changes, before migrating to Firebird 4.

> **Important**
>
> See also Changes in DDL and DML Due to Timezone Support in the Compatibility chapter.

HASH()

Adriano dos Santos Fernandes

Tracker ticket CORE-4436

Returns a hash for a string using a specified algorithm. Format is:

```
HASH( <string> [ USING <algorithm> ] )

algorithm ::= { MD5 | SHA1 | SHA256 | SHA512 }
```

The syntax with the optional USING clause is introduced in FB 4.0 and returns VARCHAR strings in character set OCTETS.

> **Important**
>
> The syntax without the USING clause is still supported. It uses the 64-bit variation of the non-cryptographic PJW hash function (also known as ELF64):
>
> https://en.wikipedia.org/wiki/PJW_hash_function
>
> which is very fast and can be used for general purposes (hash tables, etc), but its collision quality is sub-optimal. Other hash functions (specified explicitly in the USING clause) should be used for more reliable hashing.

Examples

```
select hash(x using sha256) from y;
--
select hash(x) from y; -- not recommended
```

SUBSTRING()

A SUBSTRING start position smaller than 1 is now allowed. It has some properties that need to be taken into consideration for predicting the end of the string value returned.

Examples

```
  select substring('abcdef' from 0) from rdb$database
```

Expected result: 'abcdef'

```
select substring('abcdef' from 0 for 2) from rdb$database
```

Expected result: 'a' (and NOT 'ab', because there is “nothing” at position 0)

```
select substring('abcdef' from -5 for 2) from rdb$database
```

Expected result: ''

Those last two examples might not be what you expect. The `for <length>` is considered from the specified `from <start>` position, not the start of the string, so the string returned could be shorter than the specified <length>, or even empty.

UDF Changes

Many of the UDFs in previous versions became built-in functions. The UDF feature itself is heavily deprecated in Firebird 4—see External Functions (UDFs) Feature Deprecated in the Engine chapter. Most of the remaining UDFs in the `ib_udf` and `fbudf` libraries now have analogs, either as UDRs in the new library `udf_compat` or as precompiled PSQL functions.

A script in the `/misc/upgrade/4.0/` sub-directory of your installation provides an easy way to upgrade existing UDF declarations to the safe form that is available for each respective UDF. For details and instructions, see Deprecation of External Functions (UDFs) in the Compatibility chapter.

New UDR GetExactTimestampUTC

The new UDR `GetExactTimestampUTC`, in the `udf_compat` library, takes no input argument and returns the TIMESTAMP WITH TIME ZONE value at the moment the function is called.

The older function, `GetExactTimestamp` has been refactored as a stored function, returning, as before, the TIMESTAMP WITHOUT TIME ZONE value at the moment the function is called.

Miscellaneous DML Improvements

Improvements to behaviour and performance in DML include:

Improve Error Message for an Invalid Write Operation

Adriano dos Santos Fernandes

See Tracker ticket CORE-5874.

When a read-only column is incorrectly targeted in an `UPDATE ... SET xxx` operation, the error message now provides the name of the affected column.

Improved Failure Messages for Expression Indexes

Adriano dos Santos Fernandes

Tracker ticket CORE-5606

If computation of an expression index fails, the exception message will now include the name of the index.

RETURNING * Now Supported

Adriano dos Santos Fernandes

Tracker ticket CORE-3808

The engine now supports `RETURNING *` syntax, and variants, to return a complete set of field values after committing a row that has been inserted, updated or deleted. The syntax and semantics of`RETURNING *` are similar to `SELECT *`.

Examples

```
INSERT INTO T1 (F1, F2) VALUES (:F1, :F2) RETURNING *

DELETE FROM T1 WHERE F1 = 1 RETURNING *

UPDATE T1 SET F2 = F2 * 10 RETURNING OLD.*, NEW.*
```

Chapter 10

Procedural SQL (PSQL)

Recursion is now supported in sub-routines. A few improvements have been implemented to help in logging exceptions from the various error contexts supported in PSQL.

Recursion for subroutines

Adriano dos Santos Fernandes

Tracker ticket CORE-5380

Starting in FB 4, subroutines may be recursive or call other subroutines.

Examples

A couple of recursive sub-functions in EXECUTE BLOCK:

```
execute block returns (i integer, o integer)
as
    -- Recursive function without forward declaration.
    declare function fibonacci(n integer) returns integer
    as
    begin
      if (n = 0 or n = 1) then
       return n;
     else
       return fibonacci(n - 1) + fibonacci(n - 2);
    end
    begin
      i = 0;

      while (i < 10)
      do
      begin
        o = fibonacci(i);
        suspend;
        i = i + 1;
      end
   end

-- With forward declaration and parameter with default values.

execute block returns (o integer)
as
    -- Forward declaration of P1.
    declare procedure p1(i integer = 1) returns (o integer);

    -- Forward declaration of P2.
    declare procedure p2(i integer) returns (o integer);
```

```
    -- Implementation of P1 should not re-declare parameter default value.
    declare procedure p1(i integer) returns (o integer)
    as
    begin
        execute procedure p2(i) returning_values o;
    end

    declare procedure p2(i integer) returns (o integer)
    as
    begin
        o = i;
    end
begin
    execute procedure p1 returning_values o;
    suspend;
end
```

A Helper for Logging Context Errors

A new system function enables the module to pass explicit context information from the error block to a logging routine.

System Function RDB$ERROR()

Dmitry Yemanov

Tracker tickets CORE-2040 and CORE-1132

The function RDB$ERROR() takes a PSQL error context as input and returns the specific context of the active exception. Its scope is confined to the context of the exception-handling block in PSQL. Outside the exception handling block, RDB$ERROR always returns NULL.

The type of the return value depends on the context.

Syntax Rules

```
RDB$ERROR ( context )
context ::= { GDSCODE | SQLCODE | SQLSTATE | EXCEPTION | MESSAGE }
```

Contexts

GDSCODE	INTEGER	Context variable: refer to documentation
SQLCODE	INTEGER	Context variable: refer to documentation
SQLSTATE	CHAR(5) CHARACTER SET ASCII	Context variable: refer to documentation

EXCEPTION	VARCHAR(63) CHARACTER SET UTF8	Returns name of the active user-defined exception or NULL if the active exception is a system one
MESSAGE	VARCHAR(1024) CHARACTER SET UTF8	Returns interpreted text for the active exception

> **Note**
>
> For descriptions of the context variables GDSCODE, SQLCODE and SQLSTATE, refer to the Context Variables topic in the *Firebird 2.5 Language Reference*.

Example

```
BEGIN
  ...
WHEN ANY DO
  EXECUTE PROCEDURE P_LOG_EXCEPTION(RDB$ERROR(MESSAGE));
END
```

Allow Management Statements in PSQL Blocks

Adriano dos Santos Fernandes

See Tracker ticket CORE-5887.

In prior Firebird versions, management statements were not allowed inside PSQL blocks. They were allowed only as top-level SQL statements, or as the top-level statement of an EXECUTE STATEMENT embedded in a PSQL block.

Now they can be used directly in PSQL blocks (triggers, procedures, EXECUTE BLOCK), which is especially helpful for applications that need some management statements to be issued at the start of a session, specifically in ON CONNECT triggers.

The management statements permitted for this usage are:

```
ALTER SESSION RESET
SET DECFLOAT ROUND
SET DECFLOAT TRAPS TO
SET DECFLOAT BIND
SET ROLE
SET SESSION IDLE TIMEOUT
SET STATEMENT TIMEOUT
SET TIME ZONE
SET TIME ZONE BIND
SET TRUSTED ROLE
```

Example

```
create or alter trigger on_connect on connect
as
begin
    set decfloat bind double precision;
    set time zone 'America/Sao_Paulo';
end
```

Chapter 11

Monitoring & Command-line Utilities

Improvements and additions to the Firebird utilities continue.

Monitoring

Additions to MON$ATTACHMENTS and MON$STATEMENTS to report on timeouts and wire status. Refer to Timeouts at Two levels in the chapter “Changes in the Firebird Engine” for details.

New columns in the tables:

- In MON$ATTACHMENTS:

MON$IDLE_TIMEOUT	Connection level idle timeout
MON$IDLE_TIMER	Idle timer expiration time
MON$STATEMENT_TIMEOUT	Connection level statement timeout
MON$WIRE_COMPRESSED	Wire compression enabled = 1, disabled = 0
MON$WIRE_ENCRYPTED	Wire encryption enabled = 1, disabled = 0

- In MON$STATEMENTS:

MON$STATEMENT_TIMEOUT	Connection level statement timeout
MON$STATEMENT_TIMER	Timeout timer expiration time

nBackup: UUID-based Backup and In-Place Merge

Roman Simakov
Vlad Khorsun

Tracker ticket CORE-2216

The *nBackup* utility in Firebird 4 can perform a physical backup that uses the GUID (UUID) of the most recent backup of a read-only standby database to establish the backup target file. Increments from the <source database> can be applied continuously to the standby database, eliminating the need to keep and apply all increments since the last full backup.

The new style of “warm” backup and merge to a standby database can be run without affecting an existing multilevel backup scheme on the live database.

Making Backups

The syntax pattern for this form of backup with *nBackup* is as follows:

```
nbackup -B[ACKUP] <level> | <GUID> <source database> [<backup file>]
```

Merging-in-Place from the Backup

The syntax pattern for an in-place “restore” to merge the incremental backup file with the standby database is:

```
nbackup -I[NPLACE] -R[ESTORE] <standby database> <backup file>
```

> **Note**
>
> “Restore” here means merging the increment from the backup file with the standby database.
>
> *Switch names may change before the final release.*

Example of an On-line Backup and Restore

1. Use *gstat* to get the UUID of the standby database:

```
  gstat -h <standby database>
...
    Variable header data:
        Database backup GUID: {8C519E3A-FC64-4414-72A8-1B456C91D82C}
```

2. Use the backup UUID to produce an incremental backup:

```
  nbackup -B {8C519E3A-FC64-4414-72A8-1B456C91D82C} <source database> <backup file>
```

3. Apply increment to the standby database:

```
  nbackup -I -R <standby database> <backup file>
```

isql: Support for Statement Timeouts

A new command has been introduced in *isql* to enable an execution timeout in milliseconds to be set for the next statement. The syntax is:

```
SET LOCAL_TIMEOUT <int>
```

After statement execution, the timer is automatically reset to zero.

gbak

Alex Peshkov

Backup and Restore with Encryption

Tracker ticket CORE-5808

With an encrypted database, sooner or later it will need to be backed up and restored. It is not unreasonable to want the database backup to be encrypted as well. If the encryption key is delivered to the plug-in by some means that does not require input from the client application, it is not a big problem. However, if the server expects the key to be delivered from the client side, that could become a problem.

The introduction of keys to *gbak* in Firebird 4 provides a solution.

Prerequisites

A *keyholder plug-in* is required, that is able to load keys from some external source, such as a configuration file, and deliver them using the call

```
ICryptKeyCallback* IKeyHolderPlugin::chainHandle(IStatus* status)
```

That key holder and the dbcrypt plug-ins that work with it should be installed on the workstation that will be used to perform backups.

New Switches for Encrypted Backups & Restores

With the prerequisites in place, the following new switches are available for use. They are case-insensitive.

Table 11.1. Switches for Encrypted Backups/Restores

Switch	What it Does
-KEYHOLDER	This is the main switch necessary for *gbak* to access an encrypted database.
-KEYNAME	Available to name the key explicitly, in place of the default key specified in the original database (when backing up) or in the backup file (when restoring).
-CRYPT	Available to name the plug-in to use to encrypt the backup file or restored database in place of the default plug-in. It can also be used in combination with the -KEYNAME switch to encrypt the backup of a non-encrypted database or to encrypt a database restored from a non-encrypted backup. See example below.
-ZIP	Only for a backup, to compress the backup file before encrypting it. The switch is necessary because the usual approach of compressing the backup file with some favoured compression routine after *gbak*, perhaps using pipe, does not work with encrypted backups because they are not compressible. The -ZIP switch is unnecessary for a restore because the format is detected automatically.

Usage and Examples

To back up an encrypted database do something like this:

```
gbak -b -keyholder MyKeyHolderPlugin host:dbname backup_file_name
```

The backup file will be encrypted using the same crypt plug-in and key that are used for database encryption. This ensures that it will not be any easier to steal data from your backup file than from the database.

To restore a database that was previously backed up encrypted:

```
gbak -c -keyholder MyKeyHolderPlugin backup_file_name host:dbname
```

The restored database will be encrypted using the same plug-in and key as the backup file. Using the backup example above, of course this means the same plug-in and key as the original database.

> **Note**
>
> The database is first encrypted right after creation and only after the encryption data are restored into the header. This is a bit faster than a “restore-then-encrypt” approach but, mainly, it is to avoid having non-encrypted data on the server during the restore process.

The next example will either

- restore the database from a backup file made using non-default Crypt and Keyholder plug-ins, using the same Keyname as was used for the backup; OR
- restore a non-encrypted backup as an encrypted database

```
gbak -c -keyholder MyKeyHolderPlugin -crypt MyDbCryptPlugin
   -keyname SomeKey non_encrypted_backup_file host:dbname
```

The restored database will encrypted by MyDbCryptPlugin using SomeKey.

To make an encrypted backup of a non-encrypted database:

```
gbak -b -keyholder MyKeyHolderPlugin -crypt MyDbCryptPlugin
   -keyname SomeKey host:dbname encrypted_backup_file
```

> **Take note:**
>
> Attempts to create a non-encrypted backup of an encrypted database or to restore an encrypted backup to a non-encrypted database will fail. Such operations are intentionally disallowed to avoid foolish operator errors that would expose critcal data in non-encrypted form.

To create a compressed, encrypted backup:

```
gbak -b -keyholder MyKeyHolderPlugin -zip host:dbname backup_file_name
```

The backup file will be compressed after it is encrypted, using the same crypt plug-in and same key that are used for the database encryption. ZLib is used to compress the backup file content and the appropriate record is added to its header.

> **Compressing Non-Encrypted Databases**
>
> The -ZIP switch is also available for compressing a non-encrypted database. It is important to understand that the format of a backup file thus created is not the same as one created by compressing a backup file with a utility such as 7Zip. It can be decompressed only by a *gbak* restore.

> **Note**
>
> At this point (Beta 1), this feature is not supported in the Services API.

Enhanced Restore Performance

Tracker ticket CORE-5952

The new Batch API is used to enhance the performance of restoring from backup.

Friendlier "-fix_fss_*" Messages

Tracker ticket CORE-5741

The messages in the verbose output from a restore using the "-fix_fss_*" switches now use the word "adjusting" instead of "fixing".

The same change was backported to V. 3.0.5.

gfix

The *gfix* repertoire now includes the new `-replica` switch for configuring and managing Firebird replication. For more detail, see the topic Creating a Replica Database. It takes one of three arguments (case-insensitive):

- *read-only* Sets the database copy as a read-only replica, usually for a high-availability solution.
- *read-write* Sets the database copy as a read-write replica, for asynchronous replication.
- *none* Converts the replica to a regular database, "switching off" replication to a read-write replica when conditions call for replication flow to be discontinued for some reason. Typically, it would be used to promote the replica to become the master database after a failure; or to make physical backup copies from the replica.

Chapter 12

Compatibility Issues

In this section are features and modifications that might affect the way you have installed and used Firebird in earlier releases.

SQL

Changes that may affect existing SQL code:

Deprecation of External Functions (UDFs)

Support for the external function (UDF) feature is deprecated in Firebird 4. Its immediate effect, out of the box, is that UDFs cannot be used with the default configuration, where the parameter `UdfAccess` in `firebird.conf` is set to `NONE`) and the UDF libraries `ib_udf` and `fbudf` are withdrawn from the distribution.

Most of the functions in those libraries were already deprecated in previous Firebird versions and replaced with built-in analogs. Safe replacements for a few of the remaining functions are now available, either in a new library of user-defined routines (UDRs) named `[lib]udf_compat.[dll/so/dylib]`, or as scripted conversions to PSQL stored functions. They are listed below; those marked with asterisks (*) are the UDR conversions.

ADDDAY()	*DOW()	ROUND()
ADDDAY2()	DPOWER()	RTRIM()
ADDHOUR()	GETEXACTTIMESTAMP	*SDOW()
ADDMILLISECOND()	*GETEXACTTIMESTAMPUTC	SNULLIF()
ADDMINUTE()	I64NULLIF()	SNVL()
ADDMONTH()	I64NVL()	SRIGHT()
ADDSECOND()	I64ROUND()	STRING2BLOB()
ADDWEEK()	I64TRUNCATE()	STRLEN()
ADDYEAR()	INULLIF()	SUBSTR()
*DIV()	INVL()	SUBSTRLEN()
DNULLIF()	ISLEAPYEAR()	TRUNCATE()
DNVL()	LTRIM(	*UDF_FRAC() or *FRAC()

The Firebird 4 distribution contains a script to migrate all (or any) of those UDF declarations. You can edit and extract from it to suit, if you wish, but you must keep the respective re-declarations and conversions intact as scripted.

The UDF Migration Script

The SQL script that you can use to upgrade the declarations for the UDFs listed above to the analog UDRs or stored functions is located beneath the Firebird root, in `misc/upgrade/v4.0/udf_replace.sql`.

How to Work with the Script

During the restore of your Firebird 3 backup, *gbak* will issue warnings about any UDFs that are affected but the restore will proceed. It would be useful to output the `-verbose` reporting to a file if you want a list of the affected function declarations. You will note items like

```
gbak: WARNING:function UDF_FRAC is not defined
gbak: WARNING:    module name or entrypoint could not be found
```

It means you have a UDF that is declared in the database but whose library is missing—which, of course, we know is true.

Running the Script

From the command shell:

```
isql -user sysdba -pas masterkey -i udf_replace.sql {your-database}
```

> **REMINDER**
>
> This script will have no effect on declarations for UDFs from third-party libraries!

What If You MUST Use a UDF?

In the short term, if you absolutely cannot avoid retaining the use of a UDF, you must configure the `UdfAccess` parameter to `Restrict <path-list>`. The default `<path-list>` points to the `UDF` sub-directory beneath the Firebird root. The (uncommented!) line in firebird.conf should be:

```
UdfAccess = Restrict UDF
```

The libraries `[lib]ib_udf.[dll/so/dylib]` and `[lib]fbudf.[dll/so/dylib]` that were distributed with Firebird 3 were tested to work with Firebird 4. No tests were done for any third-party or custom UDF libraries but, considering that nothing changed in the way Firebird works with UDFs, other than the default value for `UdfAccess`, they should also work.

> **Important**
>
> The recommended long-term solution for any UDFs which you absolutely *must* use is to replace them with UDRs or stored functions.

Changes in DDL and DML Due to Timezone Support

Timezone support introduces some changes in DDL and DML which could affect compatibility with existing databases and applications.

Changes to Data Types TIMESTAMP and TIME

The syntax for declaring the data types TIMESTAMP and TIME has been extended to include arguments defining whether the column, domain, parameter or variable should be defined with or without time zone adjustments, i.e.,

```
TIME [ { WITHOUT | WITH } TIME ZONE ]

TIMESTAMP [ { WITHOUT | WITH } TIME ZONE ]
```

The default in both cases is WITHOUT TIME ZONE. If you are shifting migrated databases and/or applications to use the zoned date/time features, it is advisable to run reality checks on any calculations, computed fields, domains, query sets ordered or grouped by dates or timestamps, etc.

For more details, see Data Type Extensions for Time Zone Support in the DDL chapter.

CURRENT_TIME and CURRENT_TIMESTAMP

In version 4.0, CURRENT_TIME and CURRENT_TIMESTAMP are changed: they now return TIME WITH TIME ZONE and TIMESTAMP WITH TIME ZONE, with the time zone set by the session time zone. In previous versions, CURRENT_TIME and CURRENT_TIMESTAMP returned the respective types according to the system clock, i.e., without any time zone.

The expressions LOCALTIMESTAMP and LOCALTIME now replace the former functionality of CURRENT_TIMESTAMP and CURRENT_TIME, respectively.

> **Firebird 3.0.4 LOCALTIME and LOCALTIMESTAMP**
>
> To ease the transition, LOCALTIME and LOCALTIMESTAMP were added at v3.0.4, allowing developers to adjust application and PSQL code without any functional changes, before migrating to Firebird 4.

Prefaced Implicit Date/Time Literals Now Rejected

The literal date/time preface syntax (DATE, TIME or TIMESTAMP prefacing the quoted value) used together with the implict date/time literal expressions ('NOW', 'TODAY', etc.) was known to evaluate those expressions in ways that would produce unexpected results, often undetected:

- In stored procedures and functions, evaluation would occur at compile time but not during the procedure or function call, storing the result in BLR and retrieving that stale value at runtime
- In DSQL, this style of usage in DSQL causes the evaluation to occur st prepare time, not at each iteration of the statement as would be expected with correct usage of the implicit date/time literals. The time difference between statement preparation and execution may be too small to discover the issue, particularly with 'NOW', which is a timestamp. Users could have been misled thinking the expression was evaluated at each iteration of the statement at runtime, when in fact it happened at prepare time.

If something like TIMESTAMP 'NOW' has been used in DSQL queries in application code or in migrated PSQL, there will be a compatibility issue with Firebird 4.

The behaviour was considered undesirable—the Firebird 4.0 engine and above will now reject such expressions in both PSQL and DSQL.

Example of such usage that will now be rejected:

```
..
DECLARE VARIABLE moment TIMESTAMP;
  ..
  SELECT TIMESTAMP('NOW') FROM RDB$DATABASE INTO :moment;
/* here, the variable :moment will 'frozen' as the timestamp at the moment
   the procedure or function was last compiled */
  ..
```

`TIMESTAMP '<constant>'` is for explict date/time literals, e.g. `DATE '2019.02.20'` is legal. The implicit date/time literals, such as 'NOW' or 'YESTERDAY' are for use in expressions. Enforcemnt of the appropriate usage means that attempting to combine both becomes explicitly invalid syntax.

Existing code where usage does not break the rule remains unaffected. Both `'NOW'` and `CAST('NOW' AS TIMESTAMP)` continue to work as before, as well as code that correctly uses the date/time prefaces with explicit literals, like `DATE '2019.02.20'`.

Chapter 13

Bugs Fixed

Firebird 4.0 Beta 1 Release: Bug Fixes

The following bug-fixes since the Alpha release are noted:

Core Engine

(CORE-5986) Evaluation of NULL IS [NOT] FALSE | TRUE was incorrect. Same fix was backported to Firebird 3.0.5.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5985) Regression: ROLE was not being passed to ES/EDS: specifying it in the statement was ignored. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

(CORE-5982) An error involving read permission for a BLOB field was being thrown when the BLOB was an input or output parameter for a procedure. Same fix was backported to Firebird 3.0.5.

fixed by D. Starodubov

~ ~ ~

(CORE-5974) SELECT DISTINCT with a decfloat/timezone/collated column was producing wrong results.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5973) Improvement: Fixed-point overflow in a DOUBLE PRECISION value converted from DECFLOAT is now handled properly.

fixed by A. Peshkov

~ ~ ~

(CORE-5965) The optimizer was choosing a less efficient plan in Fb4 and Fb3 than the FB2.5 optimizer. Same fix was backported to Firebird 3.0.5.

fixed by D. Yemanov

~ ~ ~

(CORE-5959) Firebird would return the wrong time after a change of time zone. Same fix was backported to Firebird 3.0.5.

fixed by V. Khorsun

~ ~ ~

(CORE-5950) Deadlock could occur when attaching to a bugchecked database. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

(CORE-5949) Bugcheck could happen when a read-only database with non-zero linger was set to read-write mode. Same fix was backported to Firebird 3.0.5.

fixed by V. Khorsun

~ ~ ~

(CORE-5935) Bugcheck 165 (cannot find TIP page). Same fix was backported to Firebird 3.0.5.

fixed by V. Khorsun

~ ~ ~

(CORE-5930) Bugcheck with message “incorrect snapshot deallocation - too few slots”.

fixed by V. Khorsun

~ ~ ~

(CORE-5918) Memory pool statistics were inaccurate. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

(CORE-5896) A NOT NULL constraint was not being synchronized after the column was renamed.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5785) An ORDER BY clause on a compound index could disable usage of other indices. Same fix was backported to Firebird 3.0.5.

fixed by D. Yemanov

~ ~ ~

(CORE-5871) Incorrect caching of the result of a subquery result in a procedure call from a SELECT query.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5862) RDB$CHARACTER_LENGTH in RDB$FIELDS was not being populated when the column was a computed VARCHAR without an explicit type.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5750) Date-time parsing needed strengthening.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5728) The field subtype of DEC_FIXED columns was not being returned by `isc_info_sql_sub_type`.

fixed by A. Peshkov

~ ~ ~

(CORE-5726) The error message when inserting a value exceeding the maximum value of DEC_FIXED decimal was unclear.

fixed by A. Peshkov

~ ~ ~

(CORE-5717) The literal date/time preface syntax (DATE, TIME or TIMESTAMP prefix before the quoted value) used together with the implict date/time literal expressions ('NOW', 'TODAY', etc.) was known to evaluate those expressions in ways that would produce unexpected results, often undetected. This behaviour was considered undesirable—the Firebird 4.0 engine and above will now reject them everywhere.

For details, see Prefaced Implicit Date/Time Literals Now Rejected in the Compatibility chapter.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5710) Data type declaration DECFLOAT without precision should be using a default precision.

fixed by A. Peshkov

~ ~ ~

(CORE-5700) DECFLOAT underflow should yield zero instead of an error.

fixed by A. Peshkov

~ ~ ~

(CORE-5699) DECFLOAT should not throw exceptions when +/-NaN, +/-sNaN and +/-Infinity is used in comparisons.

fixed by A. Peshkov

~ ~ ~

(CORE-5646) A parse error when compiling a statement would cause a memory leak until the attachment was disconnected.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5612) View operations (create, recreate or drop) were exhibiting gradual slow-down.

fixed by D. Yemanov

~ ~ ~

(CORE-5611) Memory consumption for prepared statements was higher.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5593) and also CORE-5518 The system function `RDB$ROLE_IN_USE` could not take long role names.

fixed by A. Peshkov

~ ~ ~

(CORE-5480) A SUBSTRING start position smaller than 1 should be allowed.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-1592) Altering procedure parameters could lead to an unrestorable database.

fixed by A. dos Santos Fernandes

~ ~ ~

Server Crashes/Hang-ups

(CORE-5980) Firebird would crash due to concurrent operations with expression indices. Same fix was backported to Firebird 3.0.5.

fixed by V. Khorsun

~ ~ ~

(CORE-5972) External engine trigger could crash the server if the table had a computed field.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5943) The server could crash while preparing a query with both DISTINCT/ORDER BY and a non-field expression in the select list. Same fix was backported to Firebird 3.0.5.

fixed by D. Yemanov

~ ~ ~

(CORE-5936) The server could segfault at the end of a database backup.

fixed by V. Khorsun

~ ~ ~

Security

(CORE-5927) With some non-standard authentication plugins, traffic would remain unencrypted despite providing the correct crypt key. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

(CORE-5926) An attempt to create a mapping with a non-ASCII user name that was encoded in a SINGLE-BYTE codepage (WIN1251) would lead to a 'Malformed string' error. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

(CORE-5861) New objects and some old objects in a database could not be granted the GRANT OPTION via role privileges.

fixed by R. Simakov

~ ~ ~

(CORE-5657) Attended to various UDF-related security vulnerabilities, resulting in aggressive deprecation of support for the use of UDFs as external functions. See also External Functions (UDFs) Feature Deprecated in the the chapter Changes to the Firebird Engine and Deprecation of External Functions (UDFs) in the Compatibility chapter.

fixed by A. Peshkov

~ ~ ~

(CORE-5639) Mapping rule using WIN_SSPI plugin: Windows user group conversion to Firebird role was not working.

fixed by A. Peshkov

~ ~ ~

(CORE-5518) Firebird UDF `string2blob()` could allow remote code execution.

fixed by A. Peshkov

~ ~ ~

Utilities

gbak

(CORE-5855) A database with generators containing space characters in their names could not be backed up.

fixed by A. Peshkov

~ ~ ~

(CORE-5800) After backup/restore, expression indexes on computed fields would not work properly. Same fix was backported to Firebird 3.0.5.

fixed by D. Yemanov

~ ~ ~

(CORE-5637) A string right truncation error was occurring on restore of the security database.

fixed by A. Peshkov

~ ~ ~

gpre

(CORE-5834) `gpre_boot` was failing to link using `cmake`, giving undefined reference 'dladdr' and 'dlerror'. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

trace

(CORE-5907) Regression: Trace could not be launched if its 'database' section contained a regular expression pattern with curvy brackets to enclose a quantifier. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

Build Issues

(CORE-5989) Some build issues involving iconv / libiconv 1.15 vs libc / libiconv_open | common/isc_file.cpp. Same fix was backported to Firebird 3.0.5.

fixed by A. Peshkov

~ ~ ~

(CORE-5955) Static linking problem with ld >= 2.31. Same fix was backported to Firebird 3.0.5.

fixed by R. Simakov

~ ~ ~

Firebird 4.0 Alpha 1 Release: Bug Fixes

The following fixes to pre-existent bugs are noted:

(CORE-5545) Using the POSITION parameter with the [RE]CREATE TRIGGER syntax would cause an "unknown token" error if POSITION was written in the logically correct place, i.e., after the main clauses of the statement. For example, the following should work because POSITION comes after the other specifications:

```
RECREATE TRIGGER T1
BEFORE INSERT
ON tbl
POSITION 1 AS
BEGIN
  --
END
```

However, it would exhibit the error, while the following would succeed:

```
RECREATE TRIGGER T1
BEFORE INSERT
POSITION 1
ON tbl
AS
BEGIN
  --
END
```

The fix makes the first example correct and the second should throw the error.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5454) Inserting into an updatable view without an explicit column list would fail.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5408) The result of a Boolean expression could not be concatenated with a string literal.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5404) Inconsistent column and line references were being returned in error messages for faulty PSQL definitions.

fixed by A. dos Santos Fernandes

~ ~ ~

(CORE-5237) Processing of the *include* clause in configuration files was mishandling dot (.) and asterisk (*) characters in the file name and path of the included file.

fixed by D. Sibiryakov

~ ~ ~

(CORE-5223) Double dots in file names for databases were prohibited if the *DatabaseAccess* configuration parameter was set to restrict access to a list of directories.

fixed by D. Sibiryakov

~ ~ ~

(CORE-5141) Field definition would allow multiple NOT NULL clauses. For example,

```
create table t (a integer not null not null not null)
```

The fix makes the behaviour consistent with CREATE DOMAIN behaviour and the example will return the error “Duplicate specification of NOT NULL - not supported”.

fixed by D. Sibiryakov

~ ~ ~

(CORE-4985) A non-privileged user could implicitly count records in a restricted table.

fixed by D. Yemanov

~ ~ ~

(CORE-4701) Garbage collection for indexes and BLOBs was not taking data in the Undo log into account.

fixed by D. Sibiryakov

~ ~ ~

(CORE-4483) In PSQL, data changed by executing a procedure was not visible to the WHEN handler if the exception occurred in the called procedure.

fixed by D. Sibiryakov

~ ~ ~

(CORE-4424) In PSQL, execution flow would roll back to the wrong savepoint if multiple exception handlers were executed at the same level.

fixed by D. Sibiryakov

~ ~ ~

Chapter 14

Firebird 4.0 Project Teams

Table 14.1. Firebird Development Teams

Developer	Country	Major Tasks
Dmitry Yemanov	Russian Federation	Full-time database engineer/implementor, core team leader
Alex Peshkov	Russian Federation	Full-time security features coordinator; buildmaster; porting authority
Vladyslav Khorsun	Ukraine	Full-time DB engineer, SQL feature designer/implementor
Adriano dos Santos Fernandes	Brazil	International character-set handling; text and text BLOB enhancements; new DSQL features; code scrutineering
Roman Simakov	Russian Federation	Engine contributions
Paul Beach	France	Release Manager; HP-UX builds; MacOS Builds; Solaris Builds
Pavel Cisar	Czech Republic	QA tools designer/coordinator; Firebird Butler coordinator; Python driver developer
Pavel Zotov	Russian Federation	QA tester and tools developer
Philippe Makowski	France	QA tester and maintainer of EPEL kits
Paul Reeves	France	Windows installers and builds
Mark Rotteveel	The Netherlands	Jaybird implementer and co-coordinator
Jiri Cincura	Czech Republic	Developer and coordinator of .NET providers
Martin Koeditz	Germany	Developer and coordinator of PHP driver
Alexander Potapchenko	Russian Federation	Developer and coordinator of ODBC/JDBC driver for Firebird
Alexey Kovyazin	Russian Federation	Website coordinator
Paul Vinkenoog	The Netherlands	Coordinator, Firebird documentation project; documentation writer and tools developer/implementor
Norman Dunbar	U.K.	Documentation writer

Developer	Country	Major Tasks
Tomneko Hayashi	Japan	Documentation translator
Martin Koeditz	Germany	Documentation translator
Helen Borrie	Australia	Release notes editor; Chief of Thought Police

Appendix A: Licence Notice

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The Initial Writer of the Original Documentation is: Helen Borrie. Persons named in attributions are Contributors.

Appendix B: Time Zone Regions

The following lists the time zone region names and their IDs. Quick links:

Africa | America | Antarctica | Arctic | Asia | Atlantic | Australia | BET | BST | Brazil | CAT | CET | CNT | CST | CST6CDT | CTT | Canada | Chile | Cuba | EST | ECT | EET | EST | EST5EDT | Egypt | Etc | Europe | GB | GMT | Greenwich | HST | Hong Kong | IET | IST | Iceland | Indian | Iran | Israel | JST | Jamaica | Kwajalein | Libya | MET | MIT | MST | MST7MDT | Mexico | NET | NST | New Zealand & Chatham Is. | Navajo | PLT | PNT | PRC | PRT | PST | PST8PDT | Pacific | Poland | Portugal | ROC | SST | Singapore | SystemV | Turkey | UCT | US | UTC | Universal | VST | W-SU | WET | Zulu

GMT (65535)
ACT (65534)
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