E-Maj

Let your PostgreSQL data travel back in time

French acronym for

"Enregistrement des Mises A Jour"

i.e. "updates recording"

E-Maj, what is it for?

- E-Maj allows the data content to **travel back in time**, with a table level granularity
- By recording updates on sets of application tables, it is possible to
  - **Count** them (statistic function),
  - Easily **view** them (audit function),
  - **Revert** them ("rollback" function),
  - **Replay** them (script generation, or revert a revert...)
- Usable with
  - applications in test or in production
  - databases of all sizes

The gains

- In **test** environment
  - Helps the application tests management by providing a quick way to
    - Examine updates generated by the application, for debugging purpose
    - Cancel updates generated by the application in order to easily repeat tests
- In **production** environment
  - Allows to cancel processings
    - Without being obliged to save and restore the instance by `pg_dump/pg_restore` or by physical copy
    - With a finer granularity
  - Avoids to loose entire batch processing nights by helping the recovery after failure
  - Very interesting with large tables and few updates

The components

- **E-Maj,** the heart
  - A PostgreSQL extension
  - Open Source, under GPL licence
  - Download from pgxn.org - https://pgxn.org/dist/e-maj/
  - Sources available on github.com - https://github.com/dalibo/emaj
- **Emaj_web**
  - A web client - https://github.com/dalibo/emaj_web
- The online **documentation**
  - In English (or French) - https://emaj.readthedocs.io/en/latest/

The characteristics which drove the design

- **Reliability**
  - Absolute data integrity after updates cancellation
  - Management of all usual objects (tables, sequences, contraints,...)
- **Ease of use** for DBAs, production people, application developpers and testers,...
  - Easy to understand and use
  - Easy to integrate into an automatized production (thus scriptable)
- **Performance**
  - Limited log overhead
  - Acceptable “rollback” duration
- **Security**
- **Maintenability**

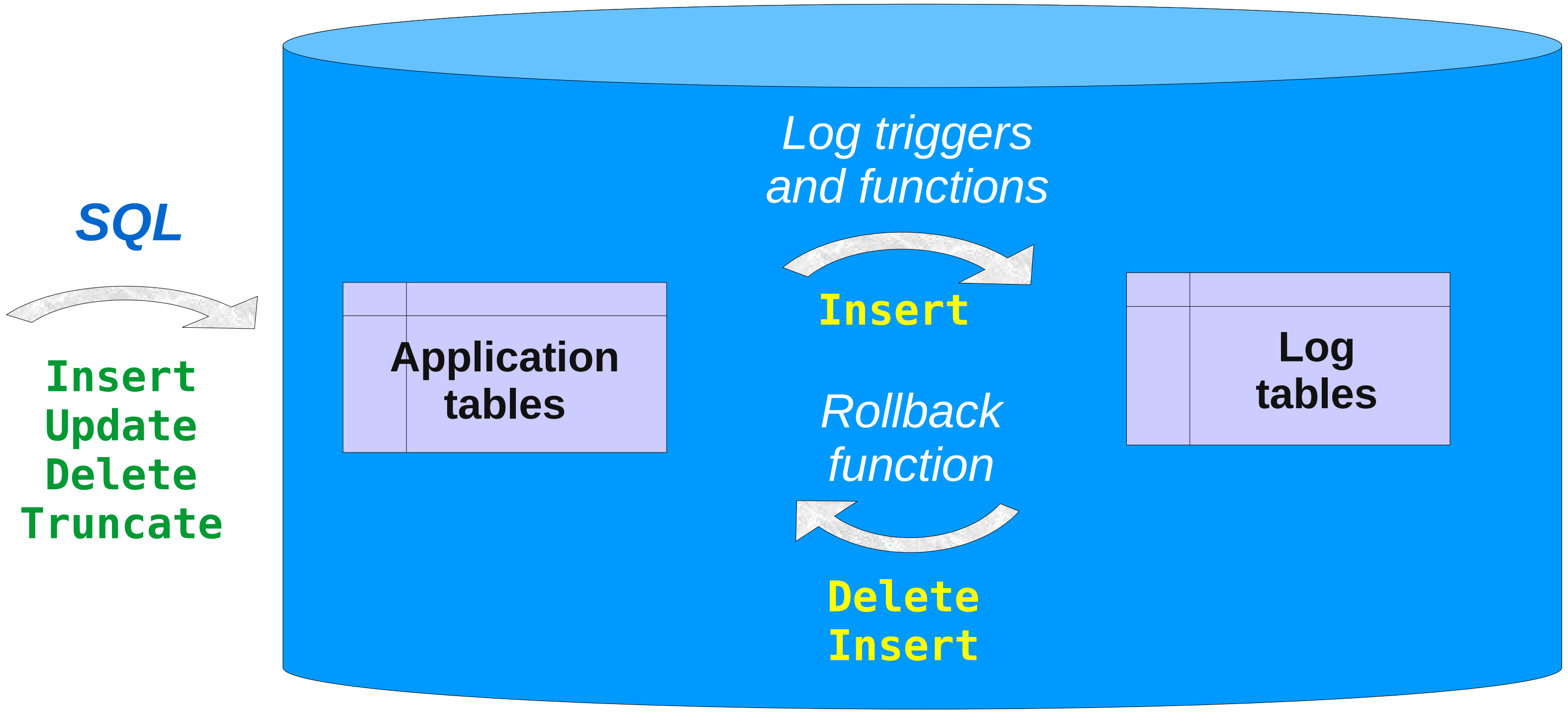
Concepts

- **Tables Group** = a set of tables and/or sequences belonging to one or several schemas and having the same life cycle ; it's the only object manipulated by users
- **Mark** = stable point in the life of a tables group, whose state can be set back ; identified by a name
- **E-Maj Rollback** = positioning of a tables group at a previously set mark state
  - NB: this concept is different from the transaction rollbacks performed by the RDBMS
    - a “RDBMS-rollback” cancels the current transaction
    - a “E-Maj rollback” cancels updates from several commited transactions

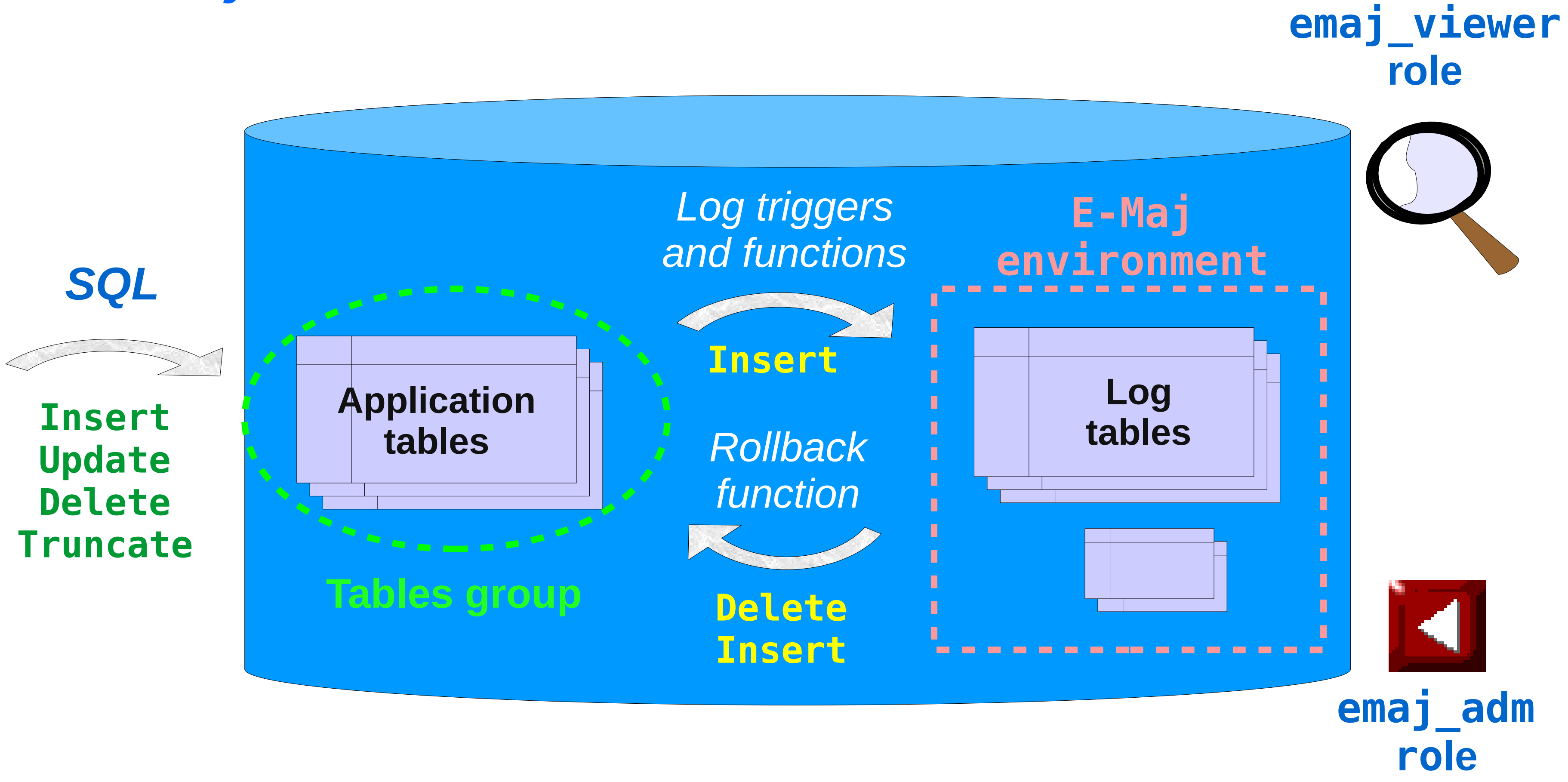
Concepts (2)

- By default, a tables group is created as “**rollbackable**”
- A tables group may be created as “**audit-only**”
  - E-Maj rollbacks are not possible
  - But
    - A table may have no declared PRIMARY KEY
    - A table may have been created as UNLOGGED

An updates recording based on triggers



Main objects



Management of application sequences

- Sequence increments are not individually recorded
- At set mark time
  - The state of each sequence of the group is stored into an internal table
- At E-Maj rollback time
  - Each sequence is reset to its state recorded at the targeted mark

Install E-Maj

- Download and unzip the extension
- Standart install
  - Copy emaj.control and sql/*.sql files into $SHAREDIR/extension
  - Log on the target database as super-user and execute
    - `CREATE EXTENSION emaj CASCADE;`
- Install on DBaaS cloud environment
  - `psql … -f sql/emaj-<version>.sql`
- This adds to the database
  - the extensions `dblink` et `btree_gist` if needed
  - 1 schema, named 'emaj', with about 180 functions, 16 technical tables, 11 types, 1 view, 1 sequence, 3 event triggers
  - 2 roles

Initialization

- For each group:
  - 1) Create an empty group
    `SELECT emaj_create_group (`*`group`*`, is_`*`rollbackable`*`);`
  - 2) Add tables and sequences
    `SELECT emaj_assign_tables (schema, inclusion regexp, exclusion regexp, group);`
    `SELECT emaj_assign_sequences (schema, inclusion regexp, exclusion regexp, group);`
    - Ex: all tables of a schema except those suffixed by sav:
      `'.*', 'sav$'`
    - Create for each application table: 1 log table, 1 log sequence, 1 log trigger and its function
- NB: `SELECT emaj_drop_group (`*`group`*`)`
  - … drop an existing group

The 3 main functions to manage groups

- “Starting” a group
  - `emaj_start_group (`*`group`*`, `*`mark`*`)`
    activates the log triggers and sets a first mark
- Setting a mark
  - `emaj_set_mark_group (`*`group`*`, `*`mark`*`)`
    sets an intermediate mark
- “Stopping” a group
  - `emaj_stop_group (`*`group`*` [,`*`mark`*`])`
    deactivates the log triggers => a rollback is not possible anymore
- The % character in a mark name represents the current date and time

Examine logs

- Examining log tables may largely help the application debuging
- Each application table has its own log table
  - `emaj_<schema>.<table>_log`
- A log table contains
  - The same columns as its related application table
  - And some technical columns
- A single row change in an application table generates
  - 1 log row for an `INSERT` (image of the new row)
  - 1 log row for a `DELETE` or a `TRUNCATE` (image of the old row)
  - 2 log rows for an `UPDATE` (image of the old and the new rows)
- A `TRUNCATE` generates also a single log row

Log tables technical columns

- 6 technical columns at the end of each log row
  - `emaj_verb` : SQL statement type - INS/UPD/DEL/TRU
  - `emaj_tuple` : row type - OLD/NEW
  - `emaj_gid` : internal sequence number
  - `emaj_changed` : time of the update - `clock_timestamp()`
  - `emaj_txid` : transaction identifier - `txid_current()`
  - `emaj_user` : connection role of the client - `session_user`
- … and some others can be added
- It is possible to identify clients and transactions, and analyze the timing of the program execution

Counting updates

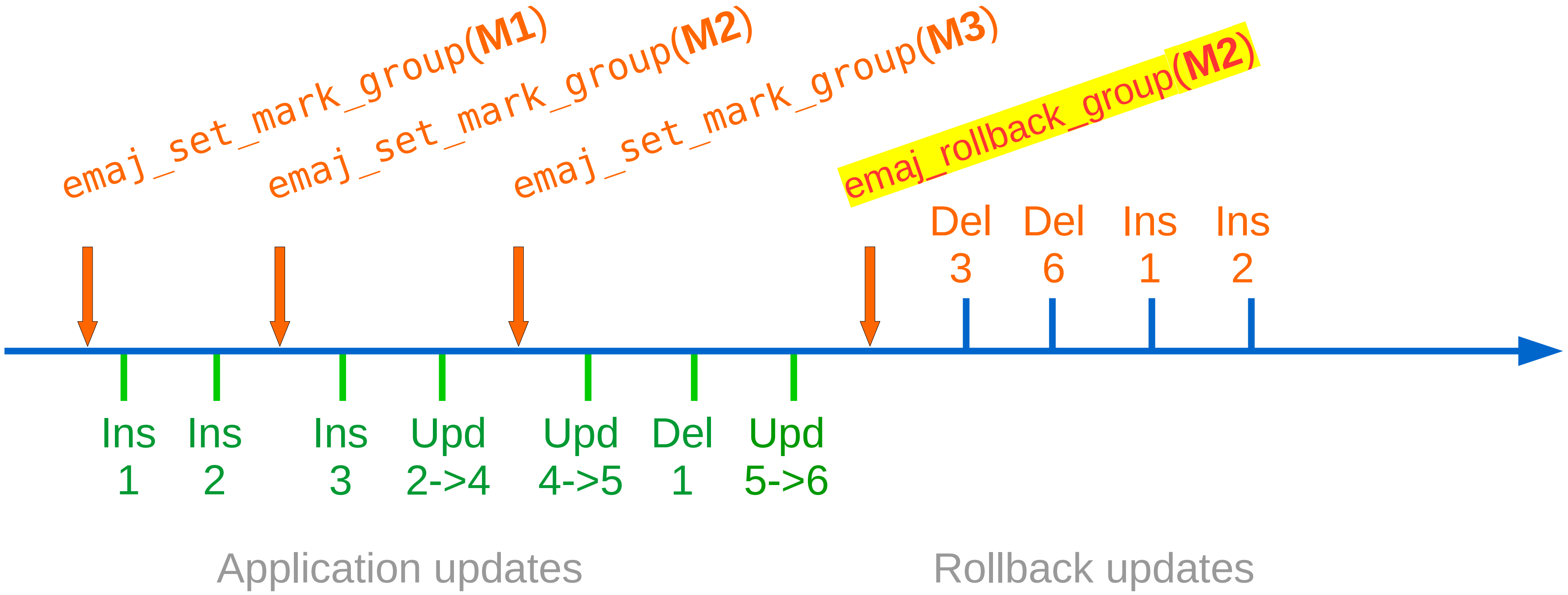
- 2 statistical functions
  - `emaj_log_stat_group (`*`group`*`, `*`start_mark`*`, `*`end_mark`*`)`
    quickly returns an estimate of recorded updates
    - by table
    - between 2 marks (or between 1 mark and the current state)
  - `emaj_detailed_log_stat_group (`*`group`*`, `*`start_mark`*`, `*`end_mark`*`)`
    scans log tables and returns precise statistics on their content
    - by table
    - by statement type (INSERT / UPDATE / DELETE / TRUNCATE)
    - by ROLE
    - between 2 marks (or between 1 mark and the current state)

Cancel updates : the “simple” rollback

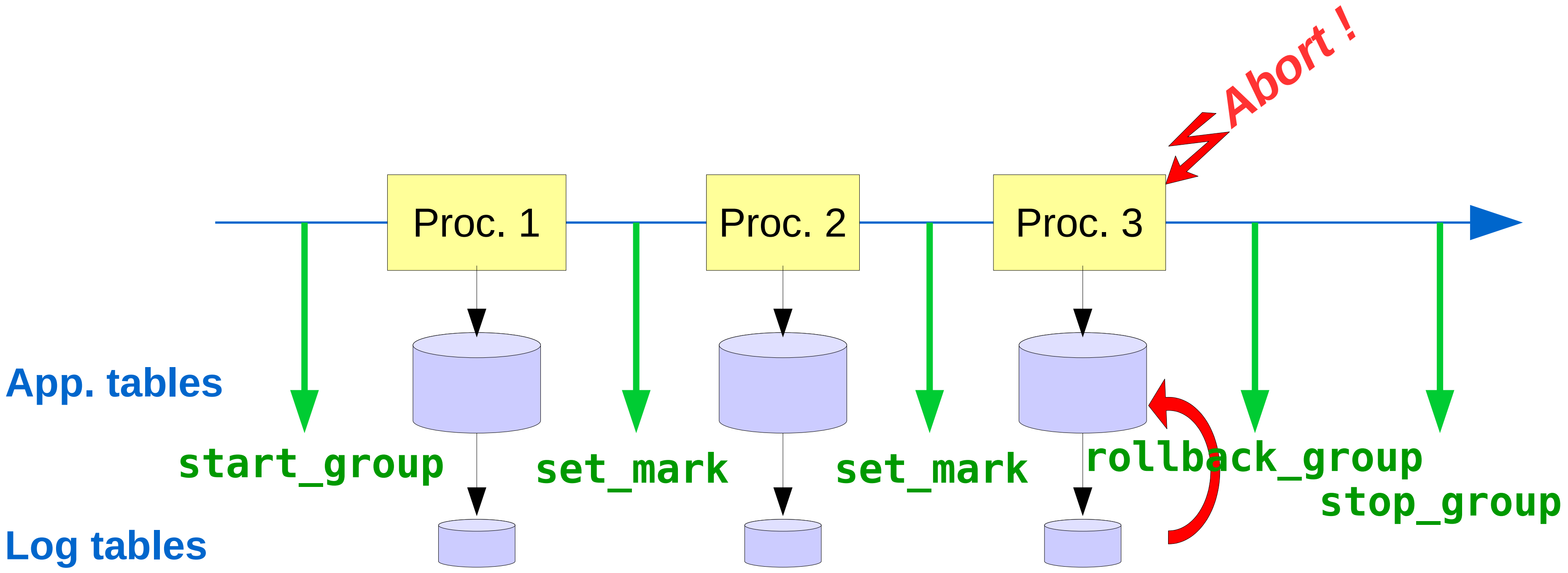
- A “rollback” function allows to reset a tables group in the state it had at a given mark
  - `emaj_rollback_group (`*`group, mark [, false [, comment]]`*`)`
- How this works
  - Log triggers are deactivated during the operation
  - Each table is reset to its mark state using an optimised algorithm
  - Application sequences are reset to their mark state
  - Takes into account the foreign keys, if any
  - The canceled logs and marks are deleted
    => all what is after the rollback mark is forgotten

An optimised rollback algorithm

- It processes each primary key value only once



A typical E-Maj usage (production batch processing)

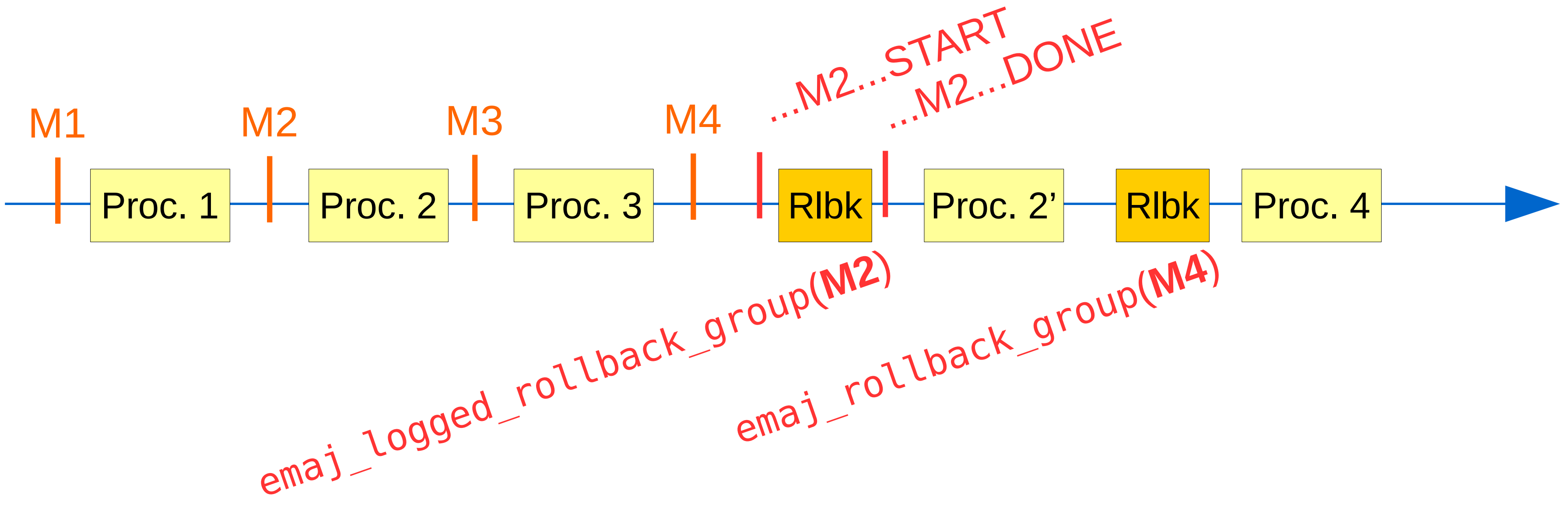


Cancelling updates : the “logged” rollback

- `emaj_logged_rollback_group (`*`group, mark[, false [, comment]]`*`)`
- Different from the “simple” rollback
  - Log triggers are NOT deactivated during the operation
    => the updates generated by the rollback are recorded
  - Cancelled logs et marks are NOT deleted
- So we can revert an E-Maj rollback ! And more generally let a tables group travel back and forth in time !
- 2 marks are automatically set before and after the rollback
  - `RLBK_<marque cible>_<HH.MI.SS.MS>_START`
  - `RLBK_<marque cible>_<HH.MI.SS.MS>_DONE`
- During the rollback, tables remain accessible in read mode

A typical E-Maj usage in test environment

- 4 processings to test in sequence
- After test 3, a new version of processing 2 must be re-tested
- Then perform the remaining tests



Estimating an E-Maj rollback duration

- In order to know if we have enough time to perform the operation or if another way to recover would be more efficient
- A function estimates the time needed to rollback a group to a given mark
  - `emaj_estimate_rollback_group (`*`group`*`, `*`mark`*`)`

Executing a parallel E-Maj rollback

- A php or perl client performs rollbacks with parallelism
  - `emajParallelRollback.php -d <database> -h <host> -p <port> -U <user> -W <password> -g <group_name or groups_list> -m <mark> -s <nb_sessions> [-l] [-c comment>]`
- Automatically spreads the tables to process into a given number of parallel sessions
- All sessions belong to a single transaction (2PC)

  => max_prepared_transactions >= nb sessions
- Needs php or perl with its PostgreSQL extension

Monitoring E-Maj rollbacks in execution

- A function
  - `SELECT * FROM emaj.emaj_rollback_activity ();`
  - returns
    - The characteristics of rollbacks (group, mark...)
    - Their state
    - Their current duration
    - An estimate of the remaining duration and the already executed %
- Needs to setup the value of the "`dblink_user_password`" parameter in the `emaj_param` table

Monitoring E-Maj rollbacks

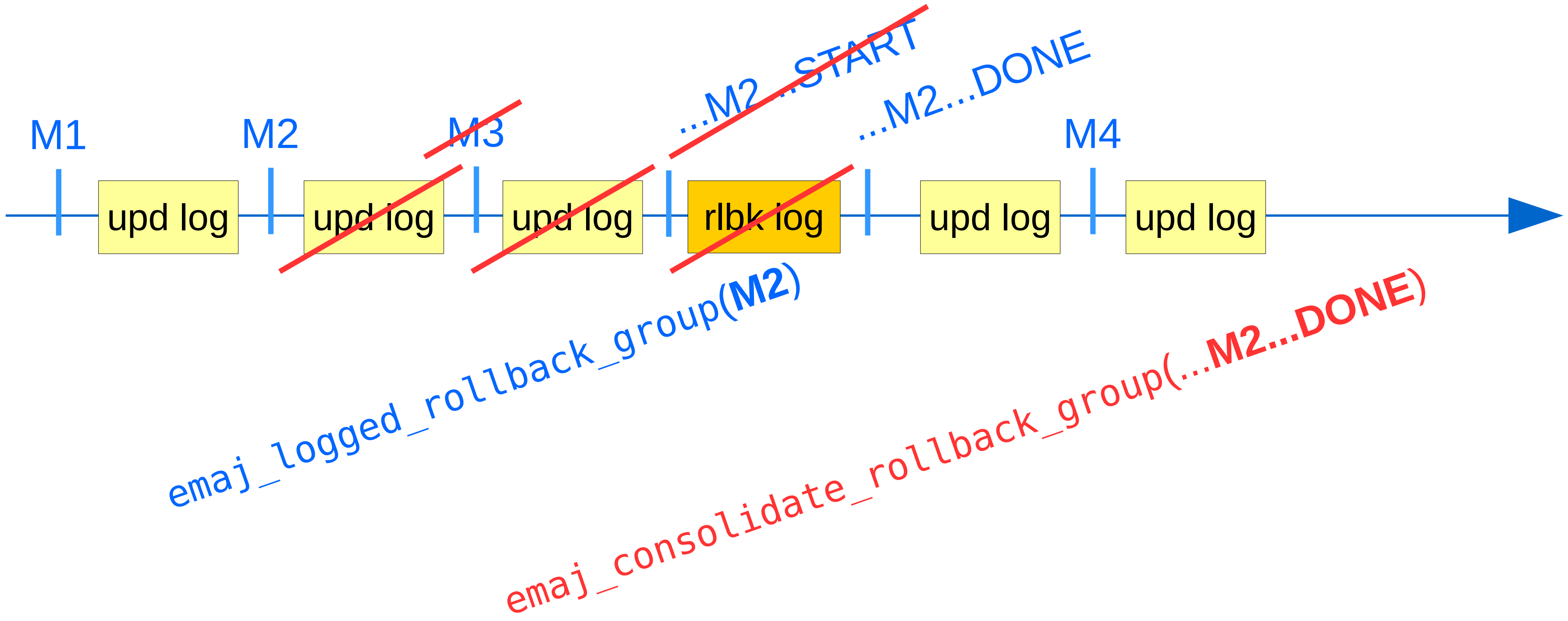
- A php or perl client to monitor the executing or completed rollbacks
  - `emajRollbackMonitor.php -d <database> -h <host> -p <port> -U <user> -W <password> -n <nb_iterations> -i <refresh_rate_in_seconds> -l <nb_completed rollbacks> -a <completed_rollbacks_history_depth_in_hours>`

```
 E-Maj (version 4.2.0) - Monitoring rollbacks activity
---------------------------------------------------------------
21/03/2023 - 08:31:23
** rollback 34 started at 2023-03-21 08:31:16.777887+01 for groups {myGroup1}
   status: COMMITTED ; ended at 2023-03-21 08:31:16.9553+01
** rollback 35 started at 2023-03-21 08:31:17.180421+01 for groups {myGroup1}
   status: COMMITTED ; ended at 2023-03-21 08:31:17.480194+01
-> rollback 36 started at 2023-03-21 08:29:26.003502+01 for groups {group20101}
   status: EXECUTING ; completion 85 %; 00:00:20 remaining
```

Consolidate a “logged” rollback

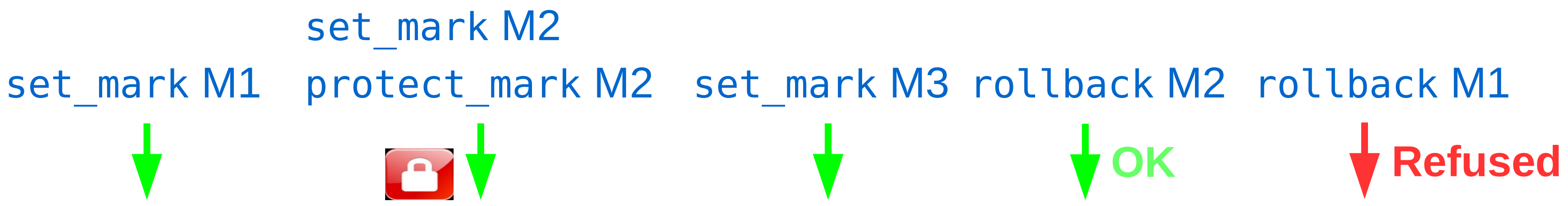
- “Consolidate” a rollback means transform a “logged rollback” into a “simple rollback”
- Intermediate logs and marks are deleted, recovering some place in the logs
  - `emaj_consolidate_rollback_group (`*`groups, end_rollback_mark`*`)`
- Tables can be updated during the consolidation
- A function returns the list of consolidable rollbacks
  - `emaj_get_consolidable_rollbacks ()`

Example of E-Maj rollback consolidation



Being protected against unattended E-Maj rollbacks

- 2 functions to manage the protection of a tables group
  - `emaj_protect_group (`*`group`*`)`
  - `emaj_unprotect_group (`*`group`*`)`
- 2 functions to manage the protection of a mark
  - `emaj_protect_mark_group (`*`group, mark`*`)` blocks any attempt to rollback to a mark prior the protected mark
  - `emaj_unprotect_mark_group (`*`group, mark`*`)`



Analyse recorded data changes

- Dump on files, by `COPY`, in a given directory, a log tables extracts and sequences of a group
  - `emaj_dump_changes_group (group, start_mark, end_mark, options_list, tables/seq_array, directory)`
- Generate SQL to extract recorded changes between 2 marks for all or some tables or sequences of a group
  - In the instance disk space : `emaj_gen_sql_dump_changes_group (group, start_mark, end_mark, options_list, tables/seq_array, file)`
  - In an `emaj_temp_sql` temporary table, for any use by any client : `emaj_gen_sql_dump_changes_group (group, start_mark, end_mark, options_list, tables/seq_array)`

Analyse data changes: the options

- Common to emaj_dump_changes_group() and emaj_gen_sql_dump_changes_group()
  - **CONSOLIDATION** = NONE (default) | PARTIAL | FULL
  - **EMAJ_COLUMNS** = ALL | MIN | (list) : selects E-Maj technical columns
  - **COLS_ORDER** = TABLE_LOG | PK : sets the order of delivered columns
  - **ORDER_BY** = PK | TIME : sets the order of delivered rows, by PK or emaj_gid
  - **SEQUENCES_ONLY** : excludes tables
  - **TABLES_ONLY** : excludes sequences
- For emaj_dump_changes_group()
  - **COPY_OPTIONS** = (options list) : for the COPY TO generation
  - **NO_EMPTY_FILES** : removes empty files (tables without changes)
- For emaj_gen_sql_dump_changes_group()
  - **PSQL_COPY_DIR** = directory : generates a \copy for each statement, with this directory
  - **PSQL_COPY_OPTIONS** = (liste options) : sets the \copy options
  - **SQL_FORMAT** = RAW | PRETTY : formats each statement on 1 or several lines

Analyse data changes: the consolidated vision of changes

- The consolidated vision of changes provides a net outcome of recorded changes, for a given time range and for each primary key
  - At most: 1 “OLD” row (the initial state) and 1 “NEW” row (the final state)
  - Ex: if UPDATE ‘A’→’B’ then UPDATE ‘B’→’C’, row OLD = ‘A’ and row NEW = ‘C’
- Therefore each examined table must have an explicit PK
- 2 consolidation kinds
  - “Partial consolidation”: without taking into account the columns content
  - “Full consolidation”: examining the changed data
    - For a given PK, no change is reported if all columns of both “OLD” and “NEW” rows are equal
    - Ex: no change reported for a given PK if UPDATE ‘A’→’B’ then UPDATE ‘B’→’A’, or if INSERT then DELETE
- Sequences
  - 1 “OLD” row and 1 “NEW” row for the initial and final sequence’s characteristics
  - In “Full consolidation” mode, no row is returned if the sequence has not been changed

Analyse data changes: emaj_temp_sql temporary table structure

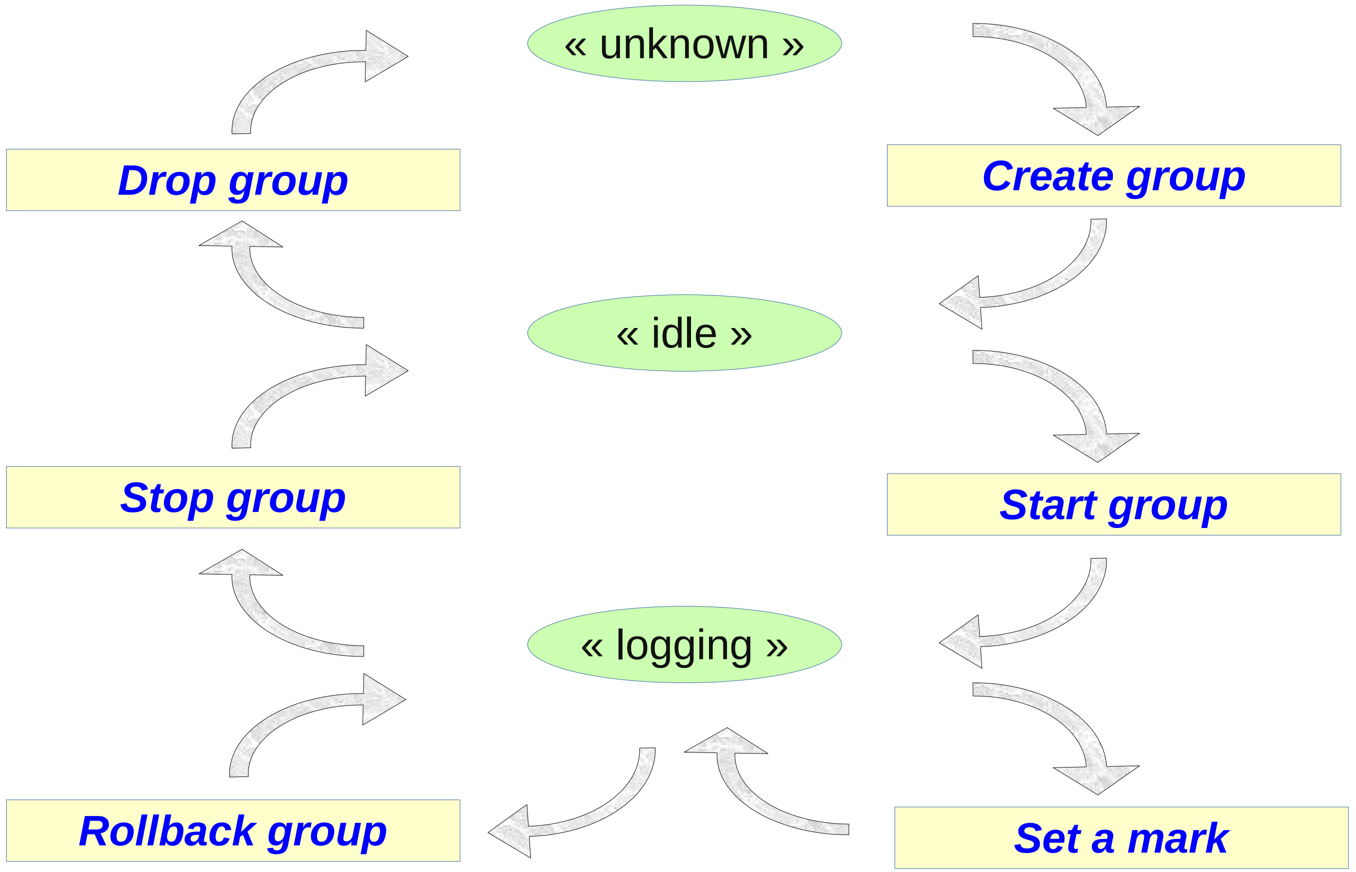
```
CREATE TEMP TABLE emaj_temp_sql (
  sql_stmt_number        INT,         -- Statement number
                                      --    (0 for the initial comment)
  sql_line_number        INT,         -- Line number within the statement
                                      --    (0 for the initial comment of the statement)
  sql_rel_kind           TEXT,        -- Relation kind: "table" or "sequence"
  sql_schema             TEXT,        -- Schema name
  sql_tblseq             TEXT,        -- Table or sequence name
  sql_first_mark         TEXT,        -- Fist mark name (for the table/sequence)
  sql_last_mark          TEXT,        -- Last mark name (for the table/sequence)
  sql_group              TEXT,        -- Tables group owning the relation
  sql_nb_changes         BIGINT,      -- Estimated number of changes to process
  sql_file_name_suffix   TEXT,        -- File name suffix
  sql_text               TEXT,        -- SQL statement text
  sql_result             BIGINT       -- Column dedicated to the caller for its operations
                                      --    (some other can be added with ALTER TABLE)
);
```

An index on the 2 first columns

Replay data changes

- Generate a sql script replaying the elementary recorded changes between 2 marks, for some or all tables and sequences of a group
  - In the instance disk space:
    emaj_gen_sql_group (*group*, *start_mark*, *end_mark*, *dest_file* [,*tables/seq_list*])
  - Anywhere, with psql:
    SELECT emaj_gen_sql_group (*group*, *start_mark*, *end_mark*, *NULL* [,*tables/seq_list*])
    \copy (SELECT * FROM emaj_sql_script) TO ‘*dest_file*’
- Useful in test environment to “replicate” the changes produced by a processing

The tables group life cycle



Tables groups dynamic adjustment

- To add one or several tables
  - `emaj_assign_table(schema, table, group, properties [, mark])`
  - `emaj_assign_tables(schema, tables list, group, properties [, mark])`
  - `emaj_assign_tables(schema, selection filter, exclusion filter, group, properties [, mark])`
- Properties:
  - JSON format
  - To define the priority and the tablespaces for log data and index
- Selection and exclusion filters: RegExp

Tables groups dynamic adjustment

- Example
  - `emaj_assign_tables(‘myschema’, ‘tbl.*’,’_sav$’, ‘mygroup’, ‘{“priority”:1}’::json)`
    assigns to the group ‘mygroup’ and with the priority 1 all tables of the schema ‘myschema’ whose name starts with ‘tbl’ and doesn’t end with ‘_sav’

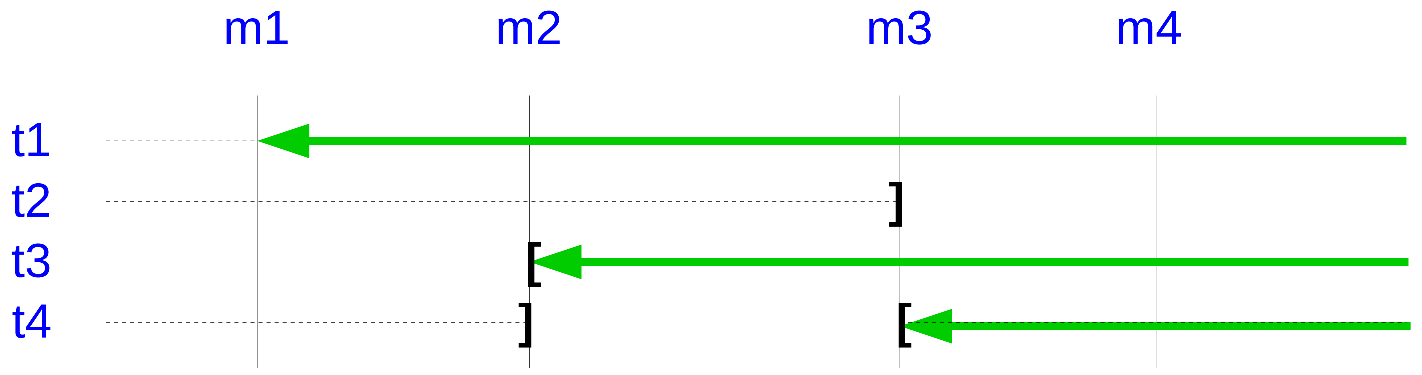
Tables groups dynamic adjustment

- Similarly:
  - `emaj_assign_sequence()` and `emaj_assign_sequences()`
  - `emaj_modify_table()` and `emaj_modify_tables()`
  - `emaj_move_table()` and `emaj_move_tables()`
  - `emaj_move_sequence()` and `emaj_move_sequences()`
  - `emaj_remove_table()` and `emaj_remove_tables()`
  - `emaj_remove_sequence()` and `emaj_remove_sequences()`

Impact of logging group structure changes on rollbacks

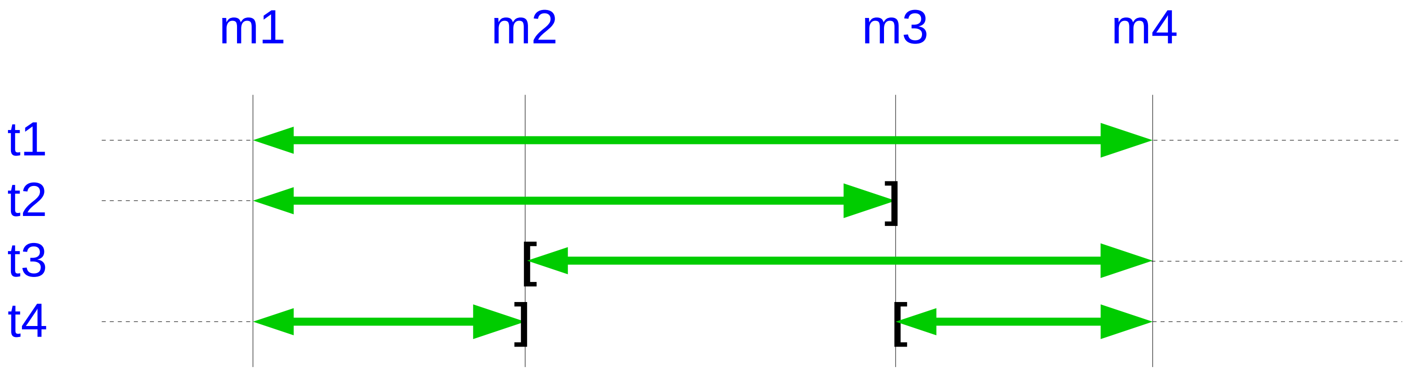
Table t2 removed at mark m3, t3 added at m2, t4 removed at m2 and added at m3

emaj_rollback_group(<groupe>,'m1', true) would pr



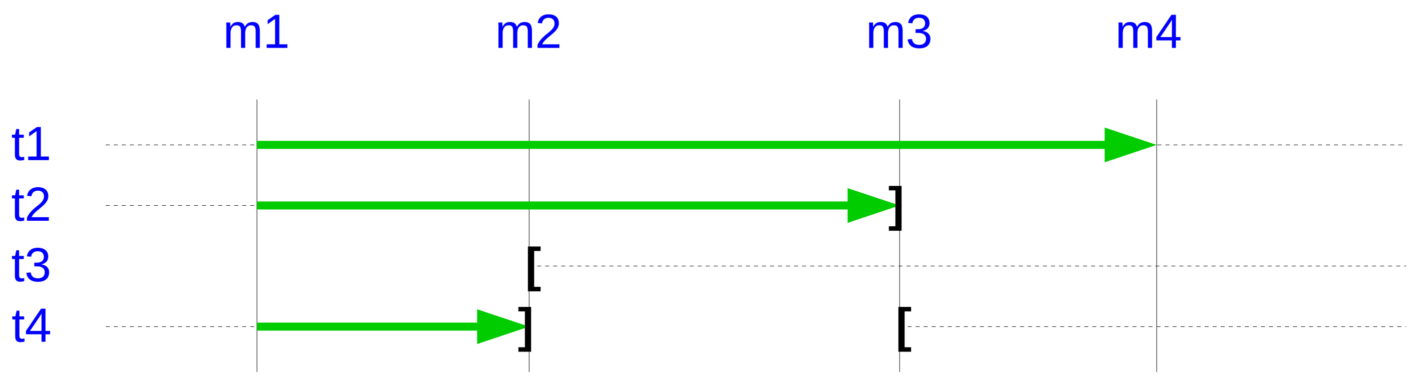
Impact of logging group structure changes on statistics and content changes extracts

emaj_log_stat_group(<groupe>,’m1’,’m4’) and
emaj_dump_changes_group(<groupe>,’m1’,’m4’,...) would report:



Impact of logging group structure changes on the SQL scripts generation

emaj_gen_sql_group(<group>,'m1','m4') would process:



Modify the structure of a table in a LOGGING group

- For actions like: rename the table, change its schema, add/drop/rename a column, change a column type
- The log table structure is impacted
- 3 steps
  - Remove the table from its tables group
  - ALTER TABLE
  - Add the table into its tables group
- Constraint: an E-Maj rollback to a prior mark will not be able to go beyond the structure change
- Idem to rename a sequence of change its schema

Processing several groups in a single operation

- Some “multi-groups” variants of functions
  - `emaj_start_groups (`*`groups_array`*`, … )`
  - `emaj_stop_groups (`*`groups_array`*`, … )`
  - `emaj_set_mark_groups (`*`groups_array`*`, … )`
  - `emaj_rollback_groups (`*`groups_array`*`, … )`
  - `emaj_logged_rollback_groups (`*`groups_array`*`, … )`
  - `emaj_log_stat_groups (`*`groups_array`*`, … )`
  - `emaj_gen_sql_groups (`*`groups_array`*`, … )`
- Allows to get marks shared by several groups
- Both PostgreSQL syntaxes for groups arrays
  - `ARRAY['`*`group 1`*`', '`*`group 2`*`', … ]`
  - `'{"`*`group 1`*`", "`*`group 2`*`", … }'`

Managing marks

- Comment a mark for a group (add/modify/suppress)
  - `emaj_comment_mark_group (`*`group, mark, comment`*`)`
- Rename a mark
  - `emaj_rename_mark_group (`*`group, old_name, new_name`*`)`
- Delete a mark
  - `emaj_delete_mark_group (`*`group, mark`*`)`
  - If the deleted mark is the first one, logs prior the second one are deleted
- Delete all marks prior a given mark
  - `emaj_delete_before_mark_group (`*`group, mark`*`)`
  - Deletes logs prior the mark (it may take a long time...)

Managing mark (2)

- Search for marks
  - `emaj_find_previous_mark_group (`*`group`*`, `*`date-time`*`)` returns the mark immediately preceeding a given date and time
  - `emaj_find_previous_mark_group (`*`group`*`, `*`mark`*`)` returns the mark immediately preceeding a given mark
- "`EMAJ_LAST_MARK`" represents the last set mark for a group
  - Usable for all parameters defining an existing mark

Other actions on groups

- Comment a group (add/modify/suppress)
  - `emaj_comment_group (`*`group`*`, `*`comment`*`)`
- Purge log tables of a stopped group (anticipating its next restart)
  - `emaj_reset_group (`*`group`*`)`
- Export / import tables groups configurations
  - `emaj_export_groups_configuration ()`
  - `emaj_import_groups_configuration ()`
- Force a group stop (in case of problem with the normal stop function)
  - `emaj_force_stop_group (`*`group`*`)`
- Snap on files in a given directory, by COPY, all tables and sequences of a group
  - `emaj_snap_group (group, directory, copy_options)`

Other actions

- Verify the good health of the E-Maj installation
  - `emaj_verify_all ()`
- Get the current log table of a given application table
  - `emaj_get_current_log_table ()`
- Manualy purge obsoletes traces
  - `emaj_purge_histories ()`
- Create/modify/delete a comment on a rollback
  - `emaj_comment_rollback ()`
- Export/import parameters configuration
  - `emaj_export_parameters_configuration ()`
  - `emaj_import_parameters_configuration ()`

Temporary or permanent logging?

- **Temporary logging** = steps like
  - `emaj_start_group()`
  - repeat
    - processiong
    - `emaj_set_mark()`
  - `emaj_stop_group()`
- At next start, old logs are purged
- But stops and starts set very heavy locks

- **Permanent logging** = no repeated group stop/restart
  - Obsolete data in log tables must be regularly deleted, using the `emaj_delete_before_mark()` function
- The deletion can be costly if the volume of log to delete is big

For large databases...

- Log tables and indexes can be stored into **tablespaces**
  - 2 optional properties set when assigning tables to groups

To ensure the reliability

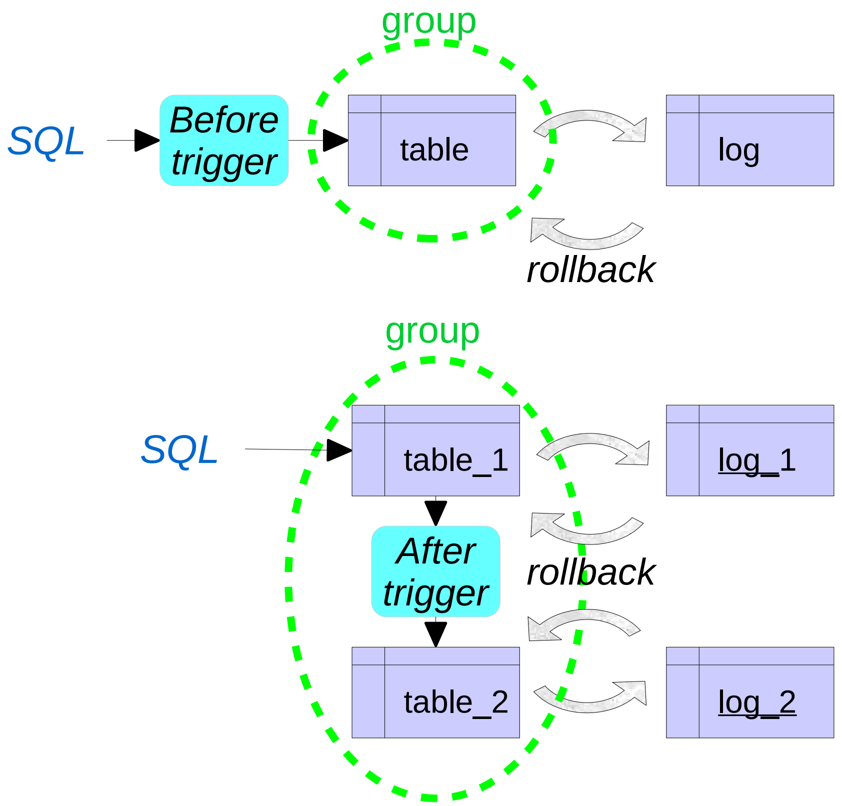
- No change in the PostgreSQL engine
- Many systematic **checks**, in particular at group start, mark set or rollback times:
  - Do all required tables, sequences, functions and triggers exist?
  - Consistency of columns between the application tables and the related log tables (existence, type)?
- Heavy **locks** on tables at `start_group`, `set_mark_group` and `rollback_group`, to be sure that no transaction is currently updating application tables
  - The order of lock setting can be influence by a priority level defined for each table
- Rollback all tables and sequences by a single **transaction**

To ensure the reliability (2)

- “**event triggers**” block unintentional drops or some component changes (tables, sequences, functions...)
  - 2 functions to deactivate/reactivate the lock-in
  - `emaj_disable_protection_by_event_triggers ()`
  - `emaj_enable_protection_by_event_triggers ()`

Impact of application triggers on E-Maj rollbacks

- Triggers of type *BEFORE* on a table belonging to a tables group
  - Values really inserted into the database are recorded into the log
  - => to be disabled at E-Maj rollback
- Triggers of type *AFTER* updating a table belonging to the same tables group
  - The rollback will reset both tables with the right content
  - => to be disabled at E-Maj rollback
- Other cases : study the impacts



Impact of application triggers on E-Maj rollbacks

- By default, application triggers are automatically disabled by E-Maj rollbacks
- A trigger may be left in its state at rollback time if it is registered as is
- 2 properties for `emaj_assign_table()`, `emaj_assign_tables()`, `emaj_modify_table()` and `emaj_modify_tables()` functions to specify the triggers that must be ignored by the E-Maj rollback processing
  - `"ignored_triggers": ["trg1","trg2",…]` lists trigger names
  - `"ignored_triggers_profiles": ["regexp1","regexp2",…]` lists regular expressions that select trigger names

To contribute to the security

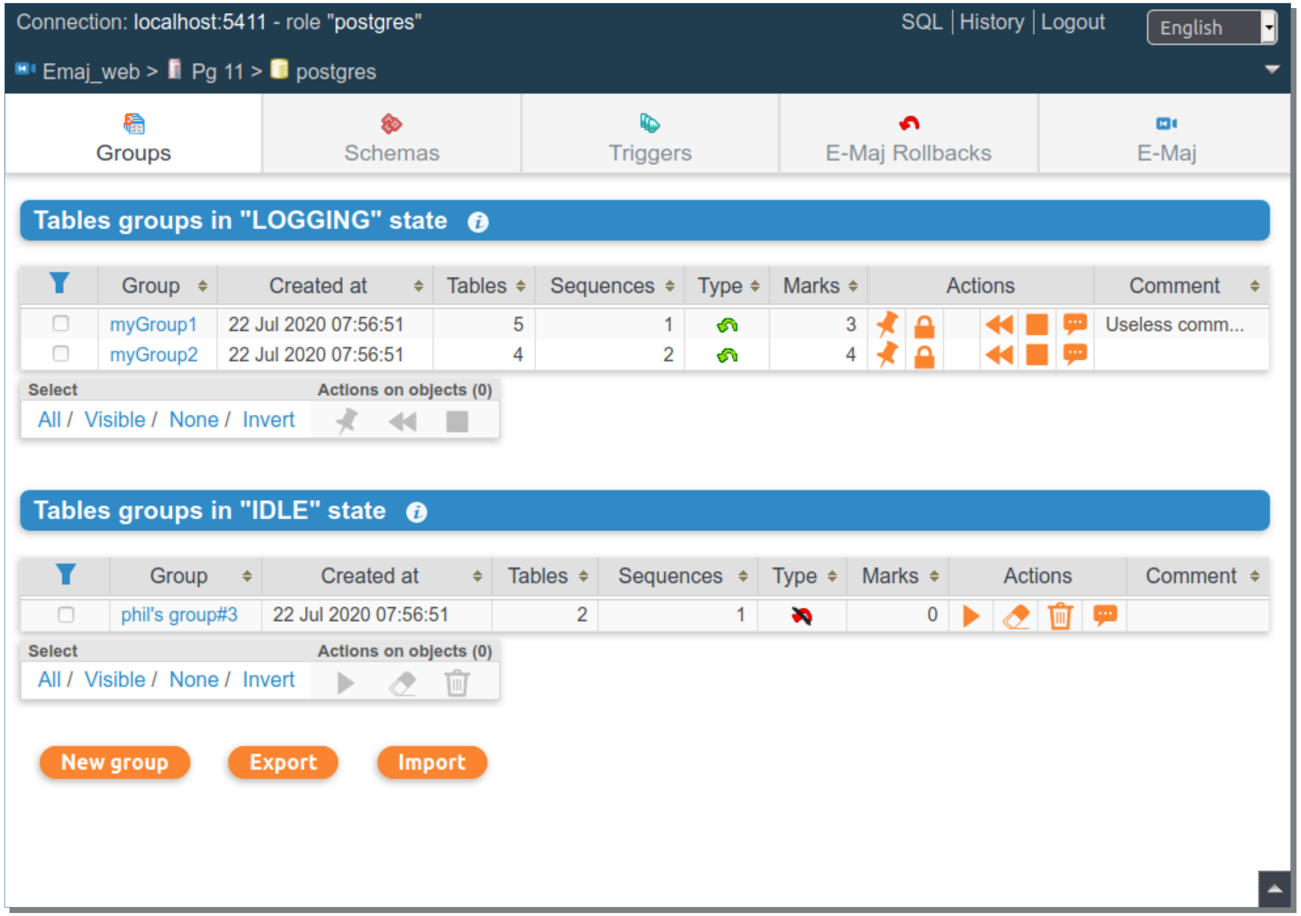
- 2 `NOLOGIN` roles whose rigths may be granted:
  - `emaj_adm` for the E-Maj administration
  - `emaj_viewer` to just look at E-Maj objects (logs, marks, statistics)
- E-Maj objects are only created and handled by a super-user or a member of the `emaj_adm` role
- No other right has to be granted on E-Maj schemas, tables and functions
- Log triggers are created with the “`SECURITY DEFINER`” attribute
- No need to give additional rights to application tables or sequences

Performances

- Log overhead
  - Highly depends on hardware and on the application read/write SQL ratio
  - Typically a few % on elapse times
  - But can be much higher on pure data loading
- Rollback duration
  - Of course depends on the number of updates to cancel
  - Also highly depends on
    - The hardware configuration
    - Tables structure (row sizes, indexes, foreign keys, other constraints…)
  - But almost always shorter than a logical restore

Emaj_web

- For administrators and users
- All E-Maj objects (groups, marks...) and their attributes
- (almost) all possible actions on E-Maj objects


Connection: localhost:5411 - role "postgres"
SQL | History | Logout
English
Emaj_web > Pg 11 > postgres
Groups
Schemas
Triggers
E-Maj Rollbacks
E-Maj

Tables groups in "LOGGING" state

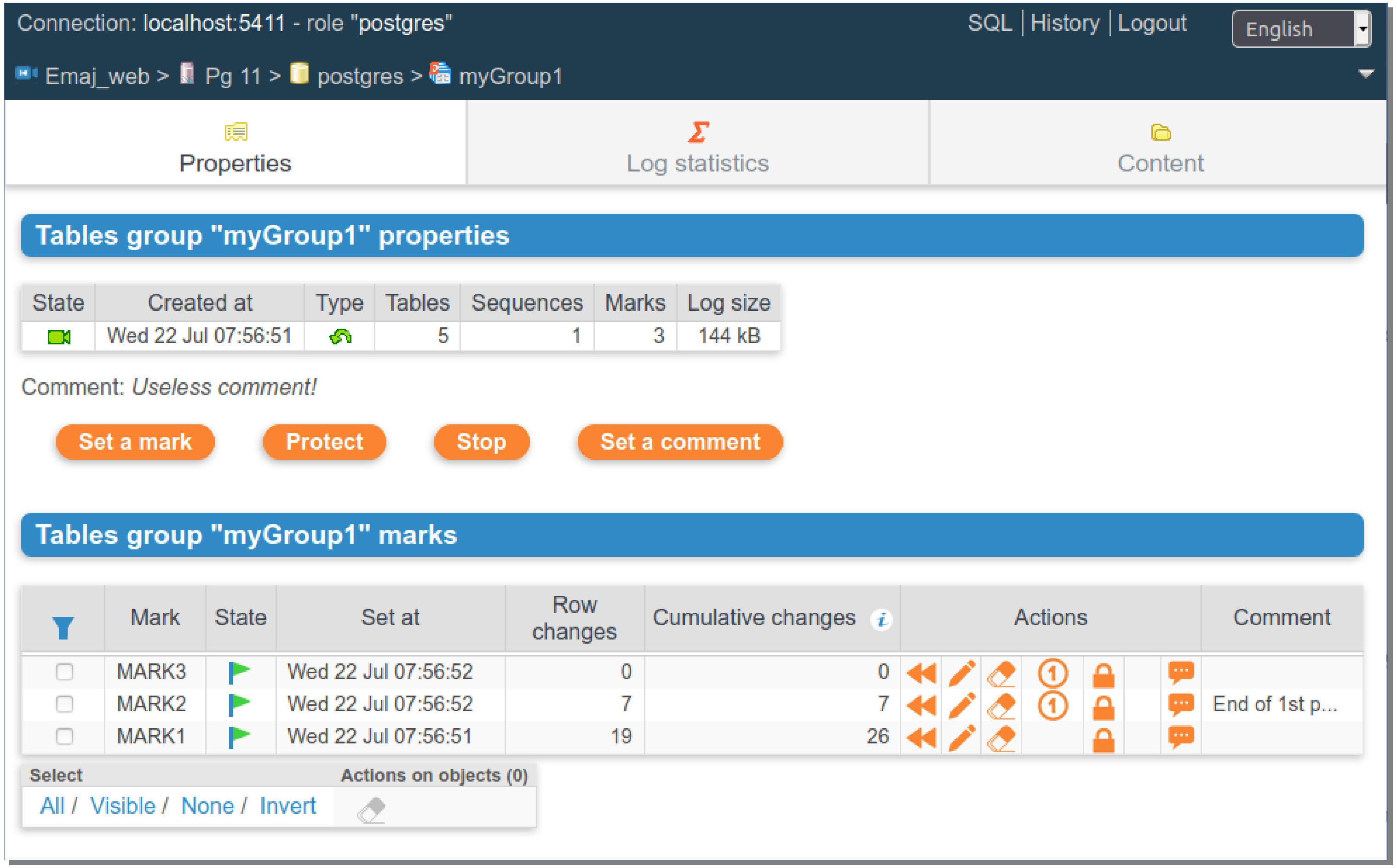
	Group	Created at	Tables	Sequences	Type	Marks	Actions	Comment
☐	myGroup1	22 Jul 2020 07:56:51	5	1		3		Useless comm...
☐	myGroup2	22 Jul 2020 07:56:51	4	2		4		

Tables groups in "IDLE" state

	Group	Created at	Tables	Sequences	Type	Marks	Actions	Comment
☐	phil's group#3	22 Jul 2020 07:56:51	2	1		0		

Tables groups list

Emaj_web : tables group details



Connection: localhost:5411 - role "postgres"   SQL | History | Logout   English

Emaj_web > Pg 11 > postgres > myGroup1

Tables group "myGroup1" properties

State	Created at	Type	Tables	Sequences	Marks	Log size
	Wed 22 Jul 07:56:51		5	1	3	144 kB

Comment: *Useless comment!*

Tables group "myGroup1" marks

	Mark	State	Set at	Row changes	Cumulative changes	Actions	Comment
☐	MARK3		Wed 22 Jul 07:56:52	0	0		
☐	MARK2		Wed 22 Jul 07:56:52	7	7		End of 1st p...
☐	MARK1		Wed 22 Jul 07:56:51	19	26		

Current limitations

- Since E-Maj 4.2, the minimum required PostgreSQL version is **11**
- Every application table belonging to a rollbackable group needs a **`PRIMARY KEY`**
- **DDL** statements cannot be logged or cancelled by E-Maj

To conclude...

- Many more **informations** in
  - the documentation:
    https://emaj.readthedocs.io/en/latest/index.html
  - the `README` et `CHANGES` files
- Many thanks to all contributors and users
- Feel free to give any **feedback** through github or email (phb.emaj@free.fr)