E-Maj

-

With this PostgreSQL extension, let your 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/beaud76/emaj
- 2 **web clients**
  - The Emaj_web application - https://github.com/beaud76/emaj_web
  - A plug-in for phpPgAdmin - https://github.com/beaud76/emaj_ppa_plugin
- The online **documentation**
  - In English (or French) - https://emaj.readthedocs.io/en/stable/

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**

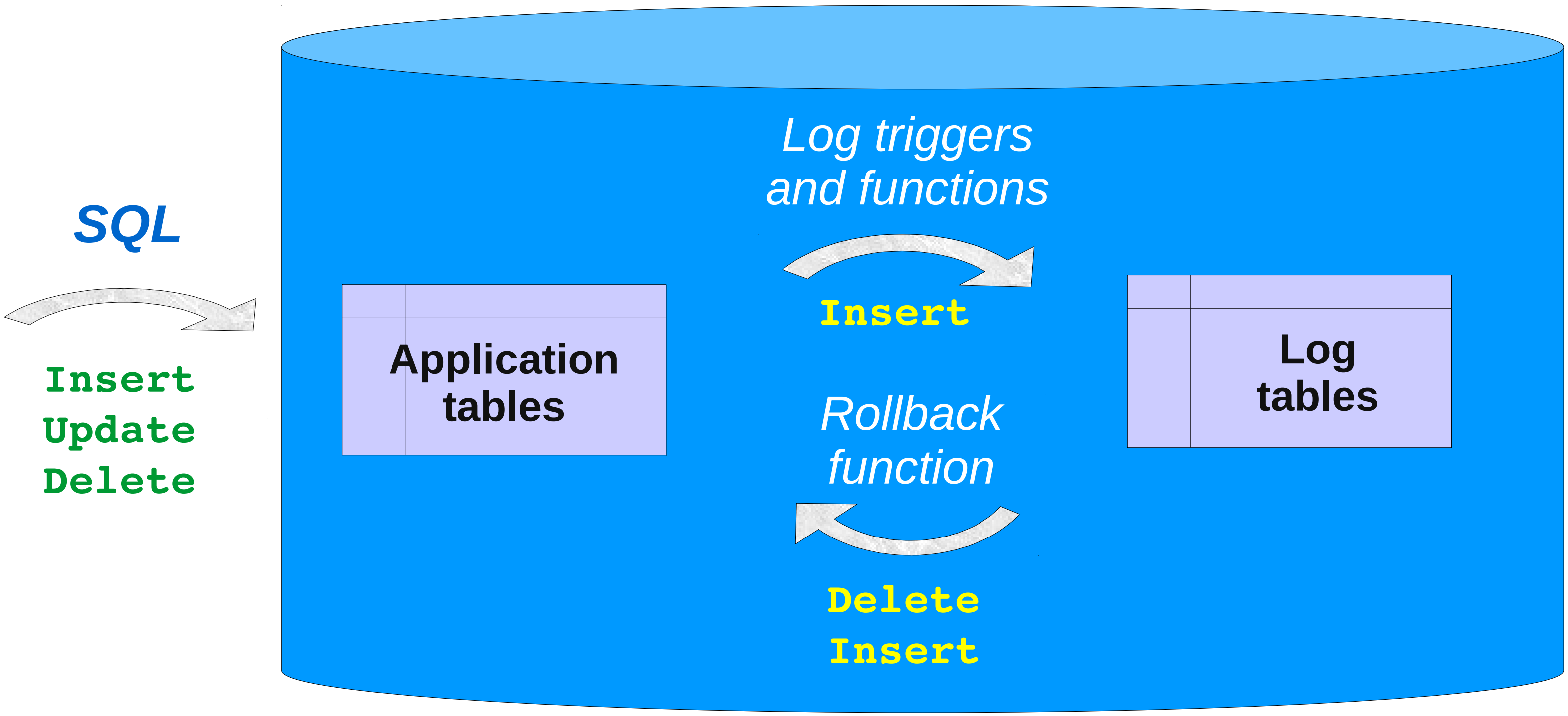
Concepts

- **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

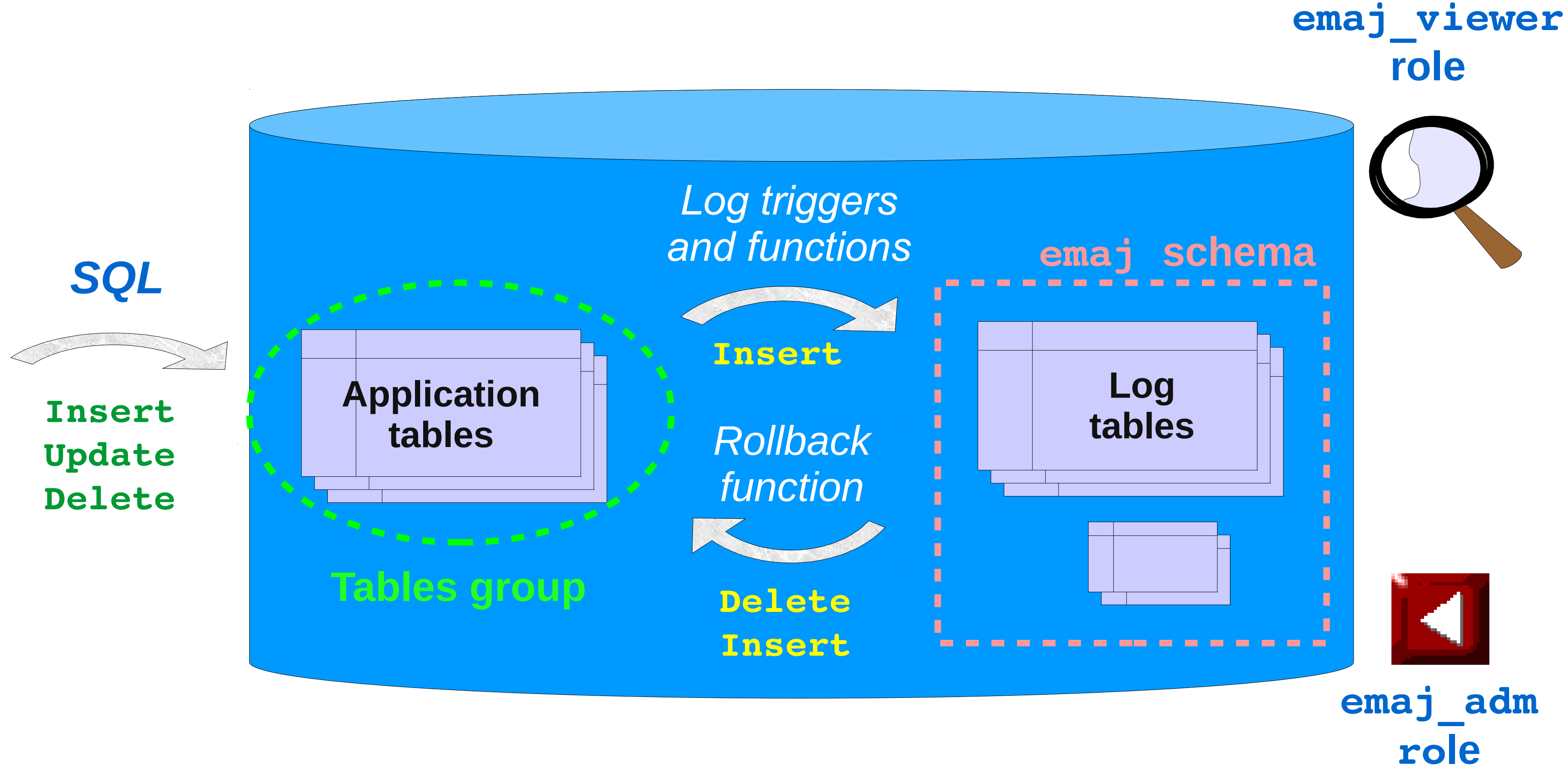
Concepts (addon)

- 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
    - TRUNCATE are recorded and not blocked
    - A table may have no declared PRIMARY KEY

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
- Install : `sudo make install`
- Log on the target database as super-user and execute
  - `CREATE EXTENSION IF NOT EXISTS dblink;`
  - `CREATE EXTENSION IF NOT EXISTS btree_gist;`
  - `CREATE EXTENSION emaj;`
- The installation adds to the database
  - 1 schema, named 'emaj', with about 110 functions, 15 technical tables, 8 types, 1 view, 1 sequence, 2 event triggers
  - 2 roles

Initialization

- Populate the `emaj_group_def` table to define the tables groups content
  - 1 row per application table/sequence
  - At least `grpdef_group`, `grpdef_schema` and `grpdef_tblseq` columns
- For each group:
  - `SELECT emaj_create_group (`*`group`*`, `*`is_rollbackable`*`);`
  - Creates for each application table:
    - 1 log table + 1 sequence
    - 1 trigger + 1 log function
  - NB: `SELECT emaj_drop_group (`*`group`*`)`
    - … drops 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
  - by default `emaj.<schéma>_<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` (image of the old row)
  - 2 log rows for an `UPDATE` (image of the old and the new rows)
- A `TRUNCATE` generates a single log row

Log tables technical columns

- 8 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`
  - `emaj_user_ip` : client ip adress - `inet_client_addr()`
  - `emaj_user_port` : client ip port – `inet_client_port()`
- 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)
    - 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)`
- 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

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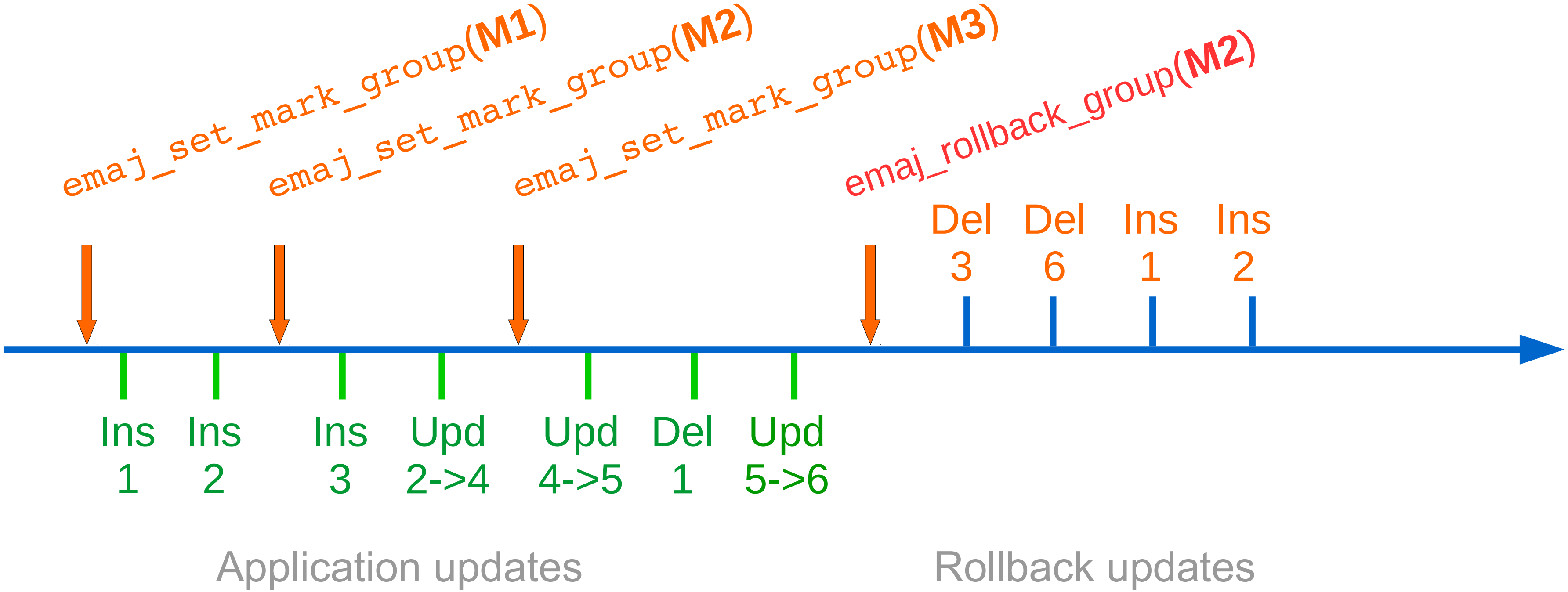
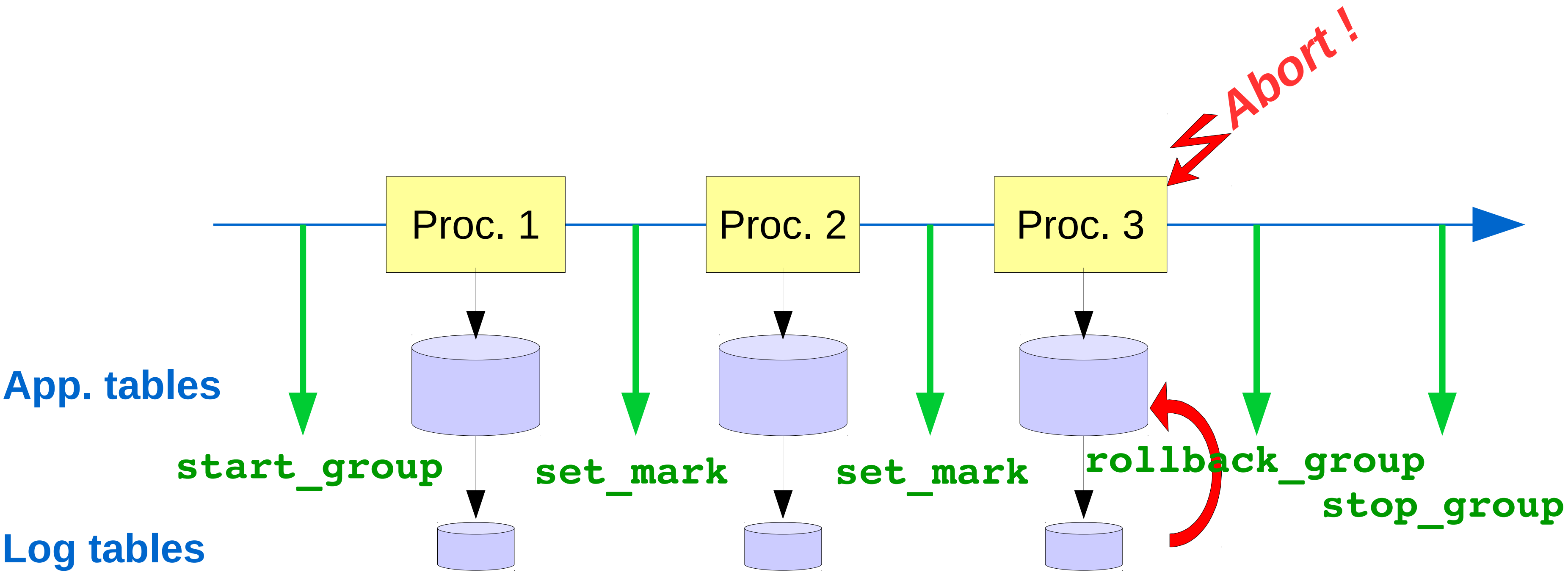
An optimised rollback algorithm

- It processes each primary key value only once



A typical E-Maj usage (production batch processing)

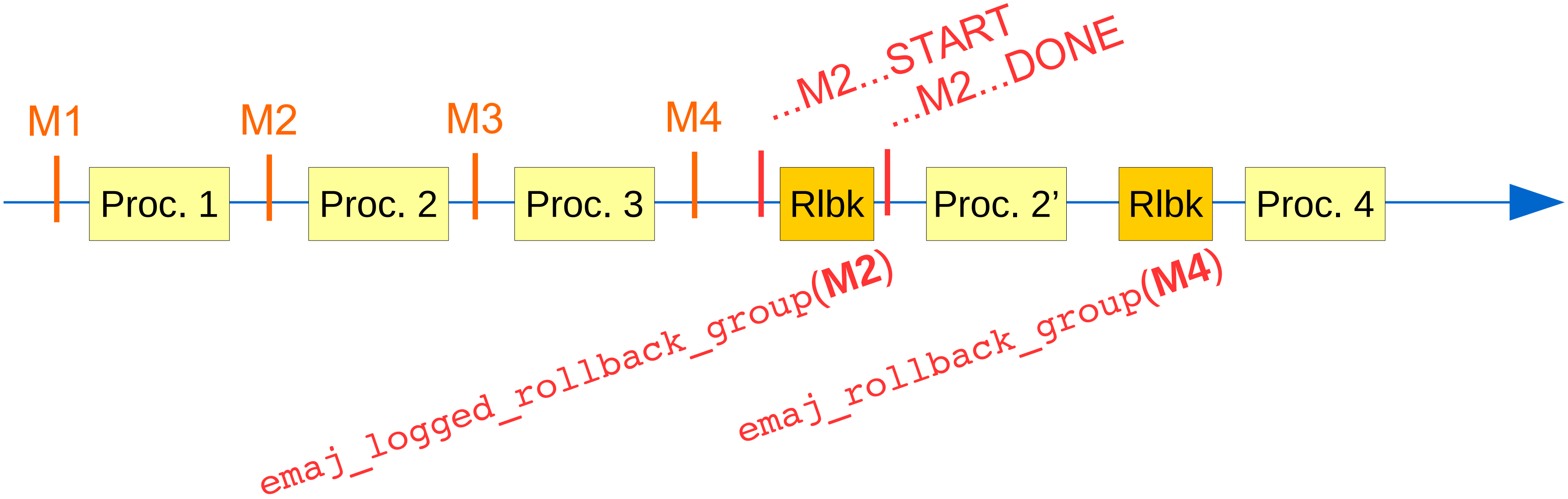


Cancelling updates : the “logged” rollback

- 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 automaticaly 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 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]
    ```
- Automatically spreads the tables to process into a given number of parallel sessions
- All sessions belong to a single transaction (2PC)

  => max_prepared_transaction >= nb sessions
- Needs php 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 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>`

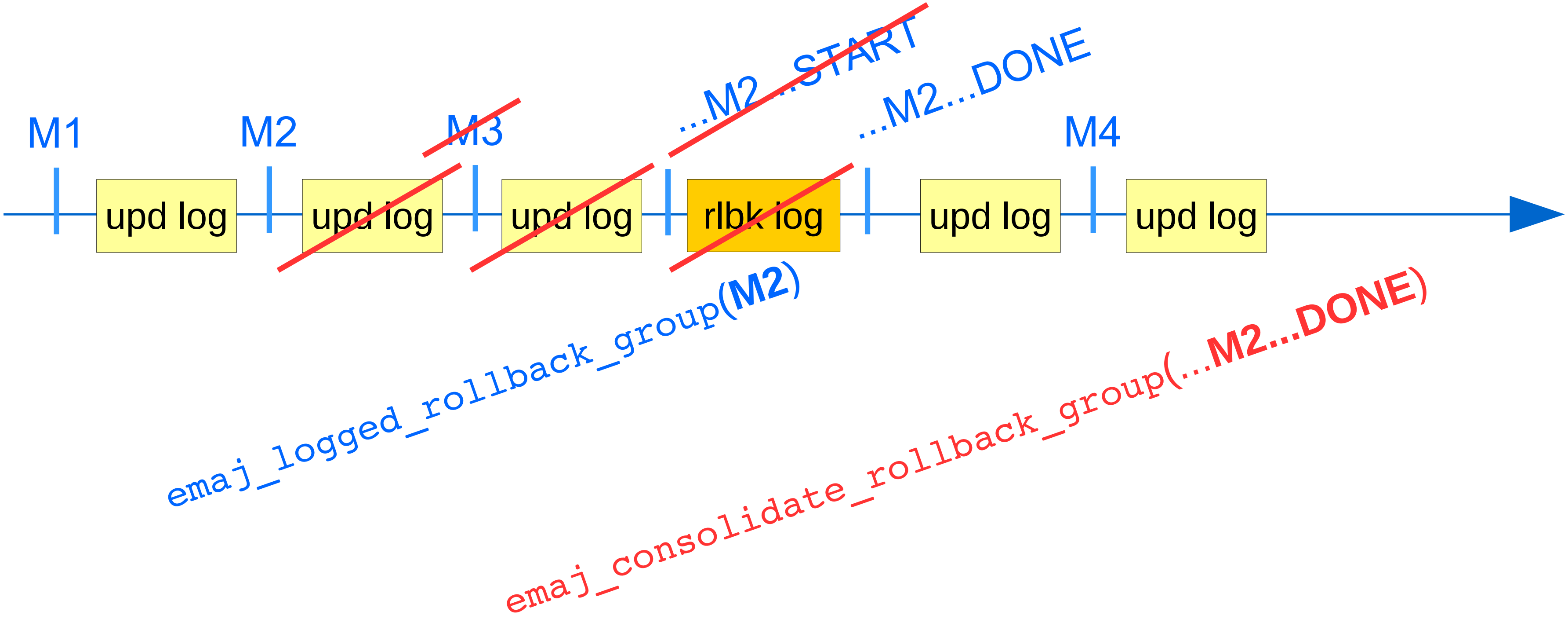
```
 E-Maj (version 2.2.0) - Monitoring rollbacks activity
---------------------------------------------------------------

04/09/2017 - 12:07:17
** rollback 35 started at 2017-09-04 12:06:21.474217+02 for groups {myGroup1}
   status: COMMITTED ; ended at 2017-09-04 12:06:21.787615+02
-> rollback 36 started at 2017-09-04 12:04:31.769992+02 for groups {group1232}
   status: EXECUTING ; completion 89 % ; 00:00:20 remaining
-> rollback 37 started at 2017-09-04 12:04:21.894546+02 for groups {group1233}
   status: LOCKING ; completion 0 % ; 00:22:20 remaining
```

Consolidate a “logged” rollback

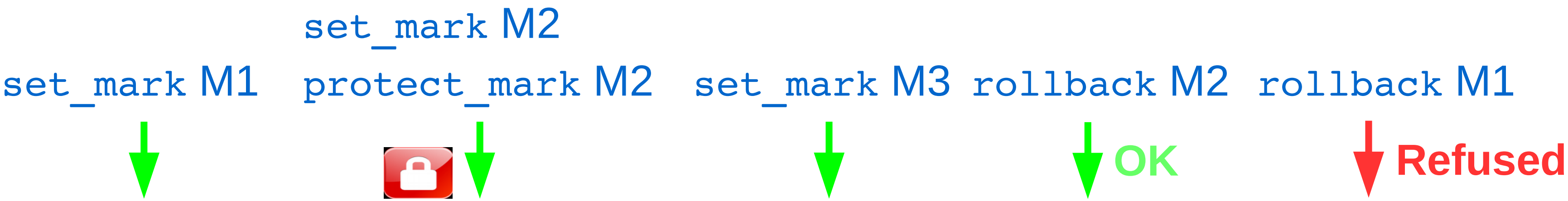
- “Consolidate” a rollback means transform a “logged rollback” into a “simple rollback”
- Intermediate logs and marks are deleted, recovering some place in the logs
  - `emaj_consolidate_rollback_group (`*`groups, end_rollback_mark`*`)`
- Tables can be updated during the consolidation
- A function returns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



set_mark M1

set_mark M2
protect_mark M2

set_mark M3

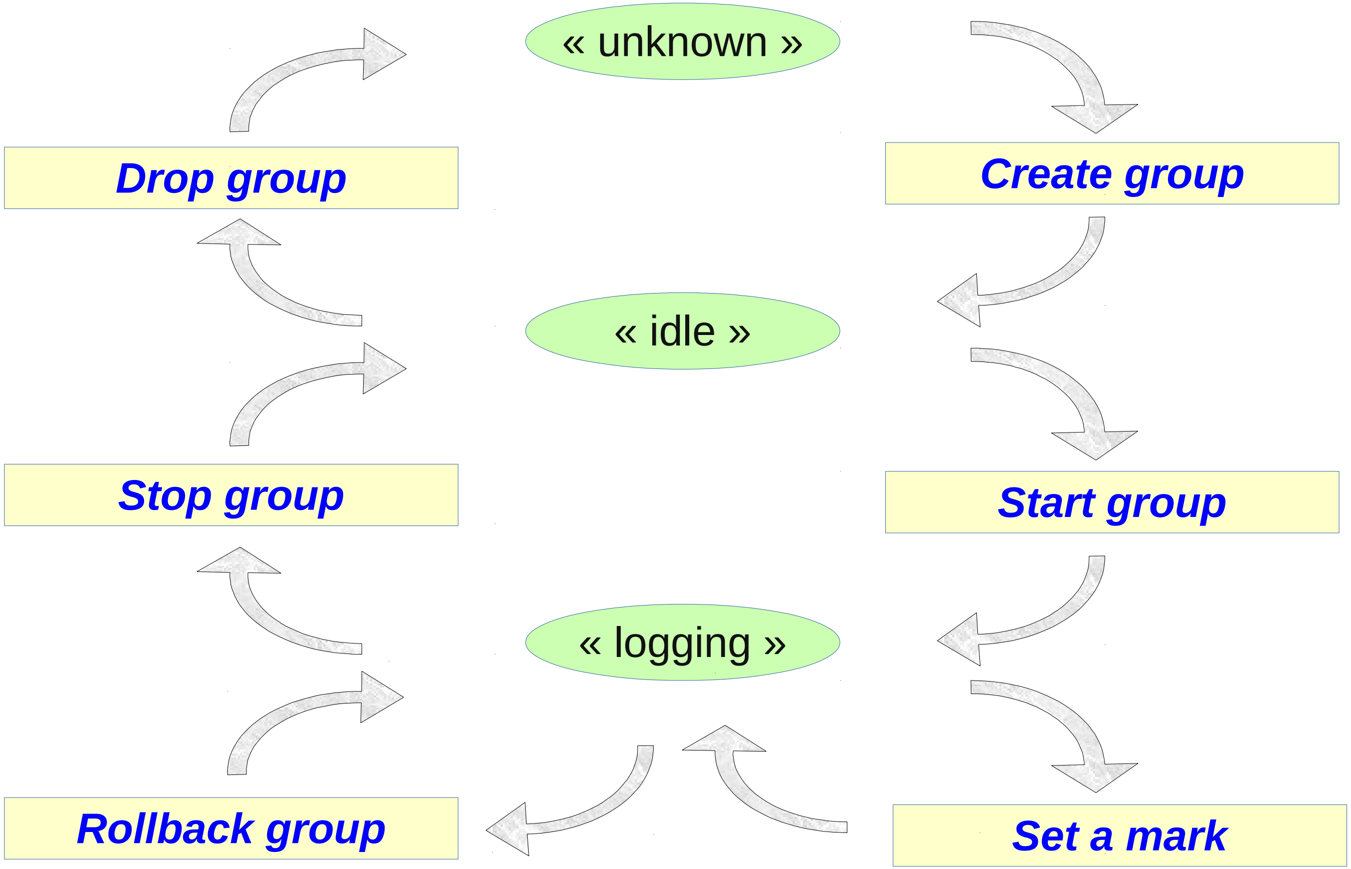
rollback M2
OK

rollback M1
Refused

Exporting from an E-Maj environment

- Generate a sql script replaying the recorded updates between 2 marks, for some or all tables and sequences of a group
  - `emaj_gen_sql_group (group, start_mark, end_mark, dest_file [,tables/seq_list])`
- Snap on files in a given directory, by `COPY`, all tables and sequences of a group
  - `emaj_snap_group (group, directory, copy_options)`
- Snap on files in a given directory, by `COPY`, a part of log tables and sequences of a group
  - `emaj_snap_log_group (group, start_mark, end_mark, directory, copy_options)`
- Useful in test to compare several executions of a processing or to “replicate” the updates produced by a processing

The tables group life cycle



Modifying the groups structure

- 2 steps
  - Modify the content of the `emaj_group_def` table (insert/delete rows, change attributs)
  - Call the function `emaj_alter_group (`*`group`*`)`
- The tables group must be stopped before calling the function, to
  - Add a table or a sequence
  - Modify the structure af an application table
- The tables group may remain in logging state, to
  - Modify attributes in `emaj_group_def`
  - Remove a table or a sequence from the group

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_gen_sql_groups (groups_array, … )`
  - `emaj_alter_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`*`)`
- 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`*`)`
- Force a group stop (in case of problem with the normal stop function)
  - `emaj_force_stop_group (`*`group`*`)`

Other actions

- Verify the good health of the E-Maj installation
  - `emaj_verify_all ()`

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**
  - Can be configured for each table in `emaj_group_def`
- Log objects can be located into dedicated **secondary schemas**
  - Can be configured for each table in `emaj_group_def`
  - These schemas are automatically created and dropped by E-Maj

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
- Rollback all tables and sequences by a single **transaction**

To ensure the reliability (2)

- **`TRUNCATE`** statements are blocked for active “rollbackable” groups
- For PostgreSQL version ≥ 9.3, “**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 ()`

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

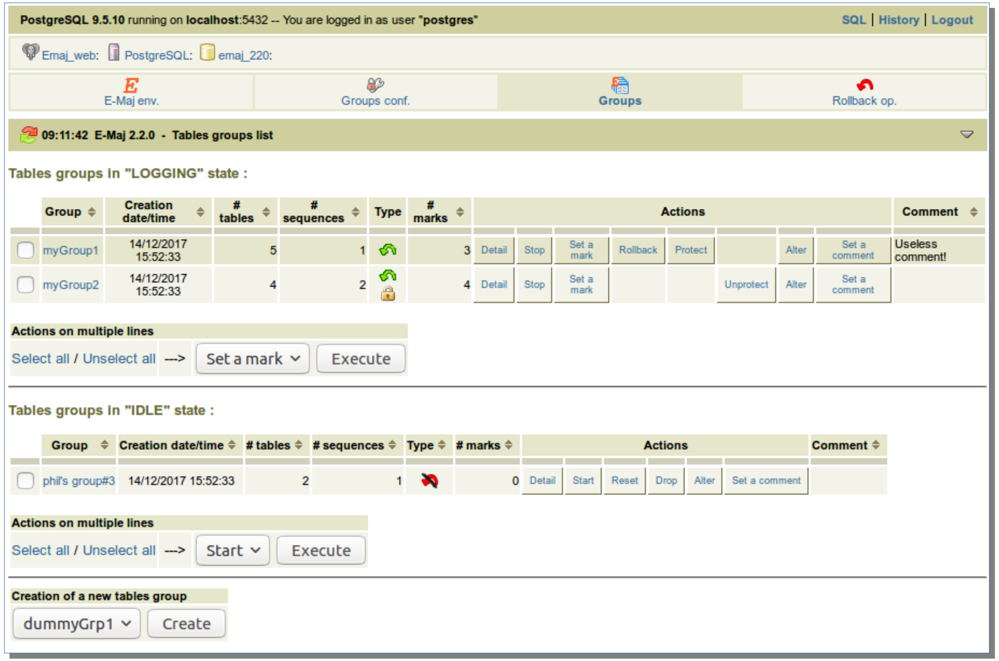
Performances

- 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

2 web clients

- 2 clients with same functionalities, to help administrators and users
  - Independant client **Emaj_web**
  - **Plug-in** totally integrated into **phpPgAdmin** (5.1+)

- Shows all E-Maj objects (groups, marks...) and their attributes
- Allows all possible actions on E-Maj objects



PostgreSQL 9.5.10 running on **localhost**:5432 -- You are logged in as user **"postgres"** SQL | History | Logout

Emaj_web: PostgreSQL: emaj_220:

09:11:42 E-Maj 2.2.0 - Tables groups list

Tables groups in "LOGGING" state :

	Group	Creation date/time	# tables	# sequences	Type	# marks	Actions								Comment
□	myGroup1	14/12/2017 15:52:33	5	1		3	Detail	Stop	Set a mark	Rollback	Protect		Alter	Set a comment	Useless comment!
□	myGroup2	14/12/2017 15:52:33	4	2		4	Detail	Stop	Set a mark			Unprotect	Alter	Set a comment	

Actions on multiple lines

Select all / Unselect all ---> Set a mark ⌄ Execute

Tables groups in "IDLE" state :

	Group	Creation date/time	# tables	# sequences	Type	# marks	Actions						Comment
□	phil's group#3	14/12/2017 15:52:33	2	1		0	Detail	Start	Reset	Drop	Alter	Set a comment	

Actions on multiple lines

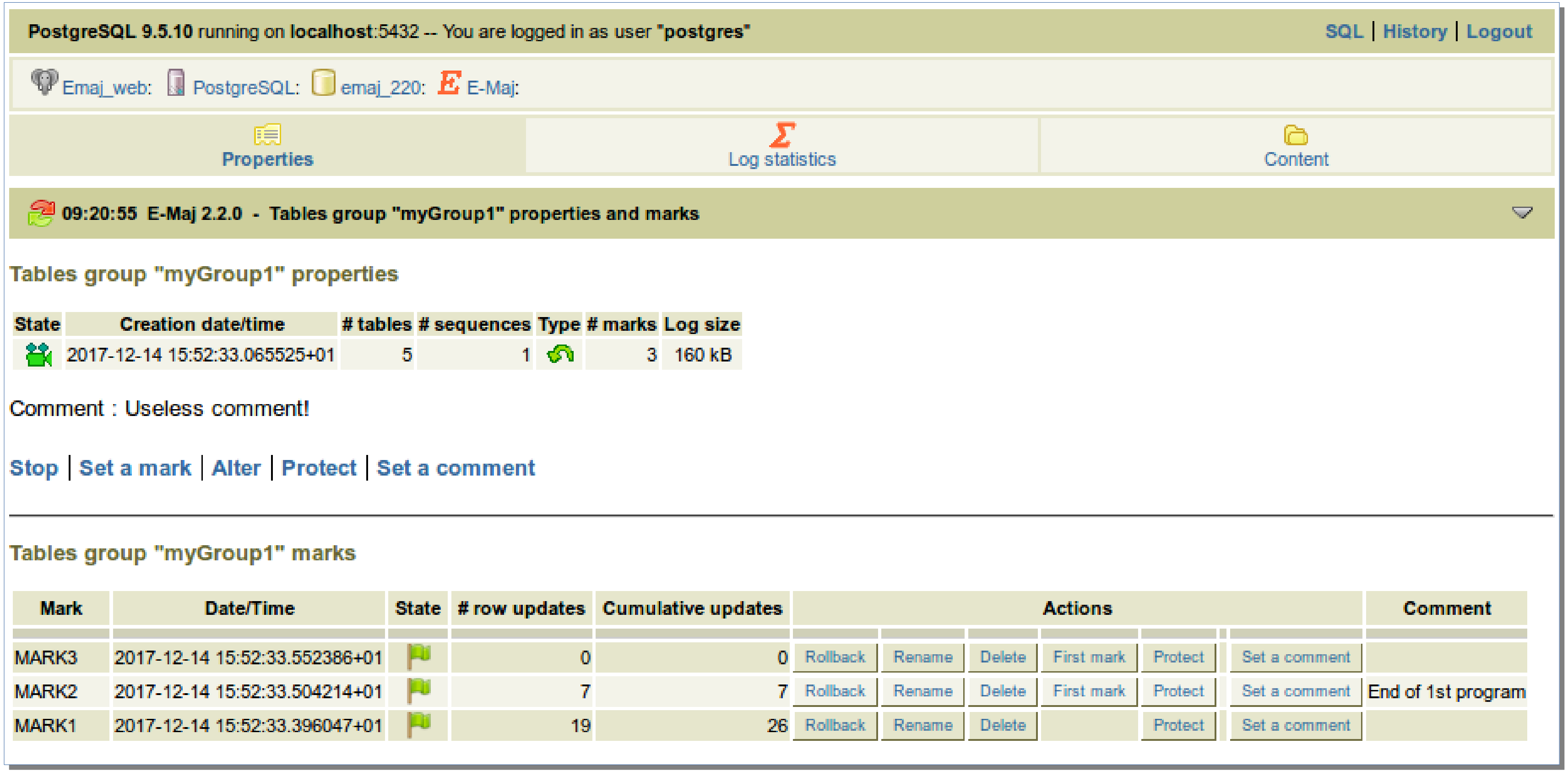
Select all / Unselect all ---> Start ⌄ Execute

Creation of a new tables group

dummyGrp1 ⌄ Create

Tables groups list

Emaj_web : tables group details



PostgreSQL 9.5.10 running on **localhost**:5432 -- You are logged in as user **"postgres"**

SQL | History | Logout
Emaj_web: PostgreSQL: emaj_220: E-Maj:
Properties
Log statistics
Content

09:20:55 E-Maj 2.2.0 - Tables group "myGroup1" properties and marks

Tables group "myGroup1" properties

State	Creation date/time	# tables	# sequences	Type	# marks	Log size
	2017-12-14 15:52:33.065525+01	5	1		3	160 kB

Comment : Useless comment!

Stop | Set a mark | Alter | Protect | Set a comment

Tables group "myGroup1" marks

Mark	Date/Time	State	# row updates	Cumulative updates	Actions						Comment
MARK3	2017-12-14 15:52:33.552386+01		0	0	Rollback	Rename	Delete	First mark	Protect	Set a comment	
MARK2	2017-12-14 15:52:33.504214+01		7	7	Rollback	Rename	Delete	First mark	Protect	Set a comment	End of 1st program
MARK1	2017-12-14 15:52:33.396047+01		19	26	Rollback	Rename	Delete		Protect	Set a comment	

Tables group properties and marks list

Current limitations

- Since E-Maj 2.2, the minimum required PostgreSQL version is **9.2**
- Every application table belonging to a rollbackable group needs a **`PRIMARY KEY`**
- Table **`TRUNCATE`** statements cannot be canceled
- **DDL** statement cannot be managed by E-Maj

To conclude...

- Many more **informations** in the documentation and in the `README` et `CHANGES` files
- Many thanks for their help to :
  - Andreas Scherbaum, Jean-Paul Argudo and the Dalibo team, CNAF DBA, Don Levine (for the english translation)
  - People who already contacted me for comments, requests...
- Feel free to give any **feedback** through github or email (phb.emaj@free.fr)