Worldwide distribution of experimental physics data using Oracle Streams

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Outline

- CERN and LHC Overview
- Oracle Streams Replication
- Replication Performance
- Optimizations: Downstream Capture, Split and Merge, Network, Rules and Flow Control
- Periodic Maintenance
- Lessons Learned
- Tips and Tricks
- Streams Bugs and Patches
- Scalable Resynchronization
- 3D Streams Monitor
- New 11g Streams Features
- Streams Setups Examples
- Summary

CERN and LHC

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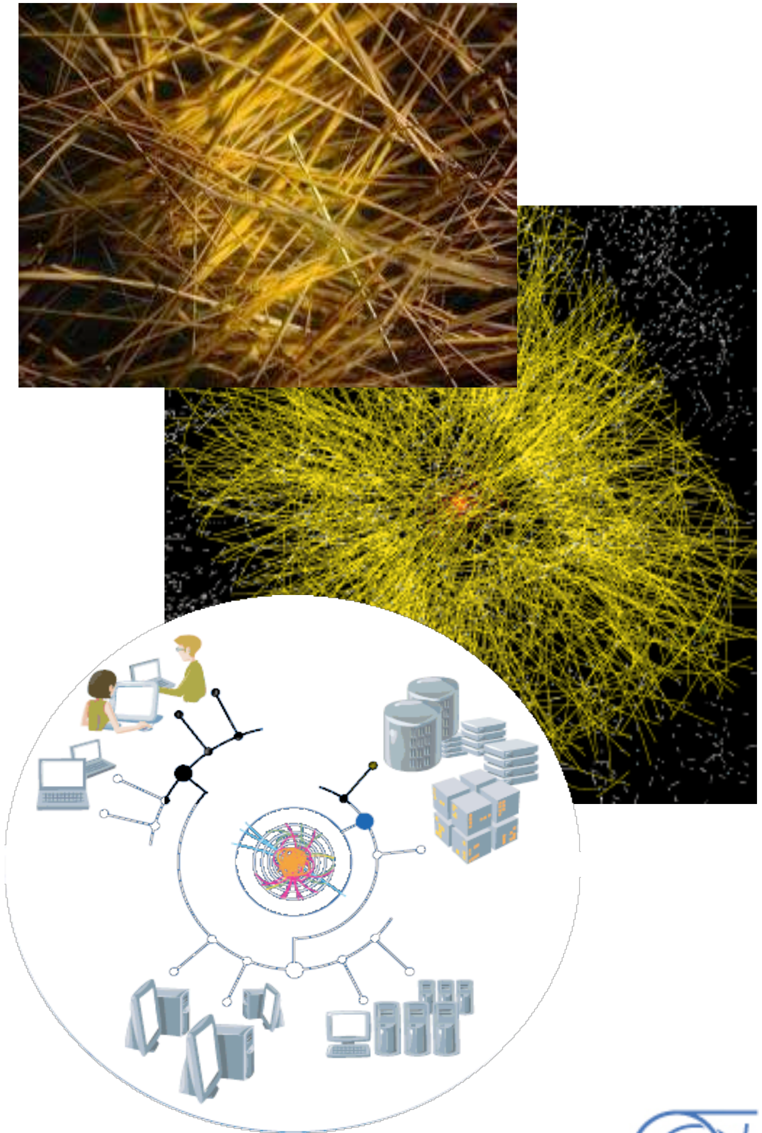
- European Organization for Nuclear Research
  - world's largest centre for scientific research
  - founded in 1954
  - mission: finding out what the Universe is made of and how it works
- LHC, Large Hadron Collider
  - particle accelerator used to study the smallest known particles
  - 27 km ring, spans the border between Switzerland and France about 100 m underground
  - will recreate the conditions just after the Big Bang

The LHC Computing Challenge

- Data volume
  - high rate x large number of channels x 4 experiments
  - **15 PetaBytes of new data each year stored**
  - **much more data discarded during multi-level filtering before storage**
- Compute power
  - event complexity x Nb. events x thousands users
  - **100 k of today's fastest CPUs**
- Worldwide analysis & funding
  - computing funding locally in major regions & countries
  - efficient analysis everywhere
  - **GRID technology**



Distributed Service Architecture

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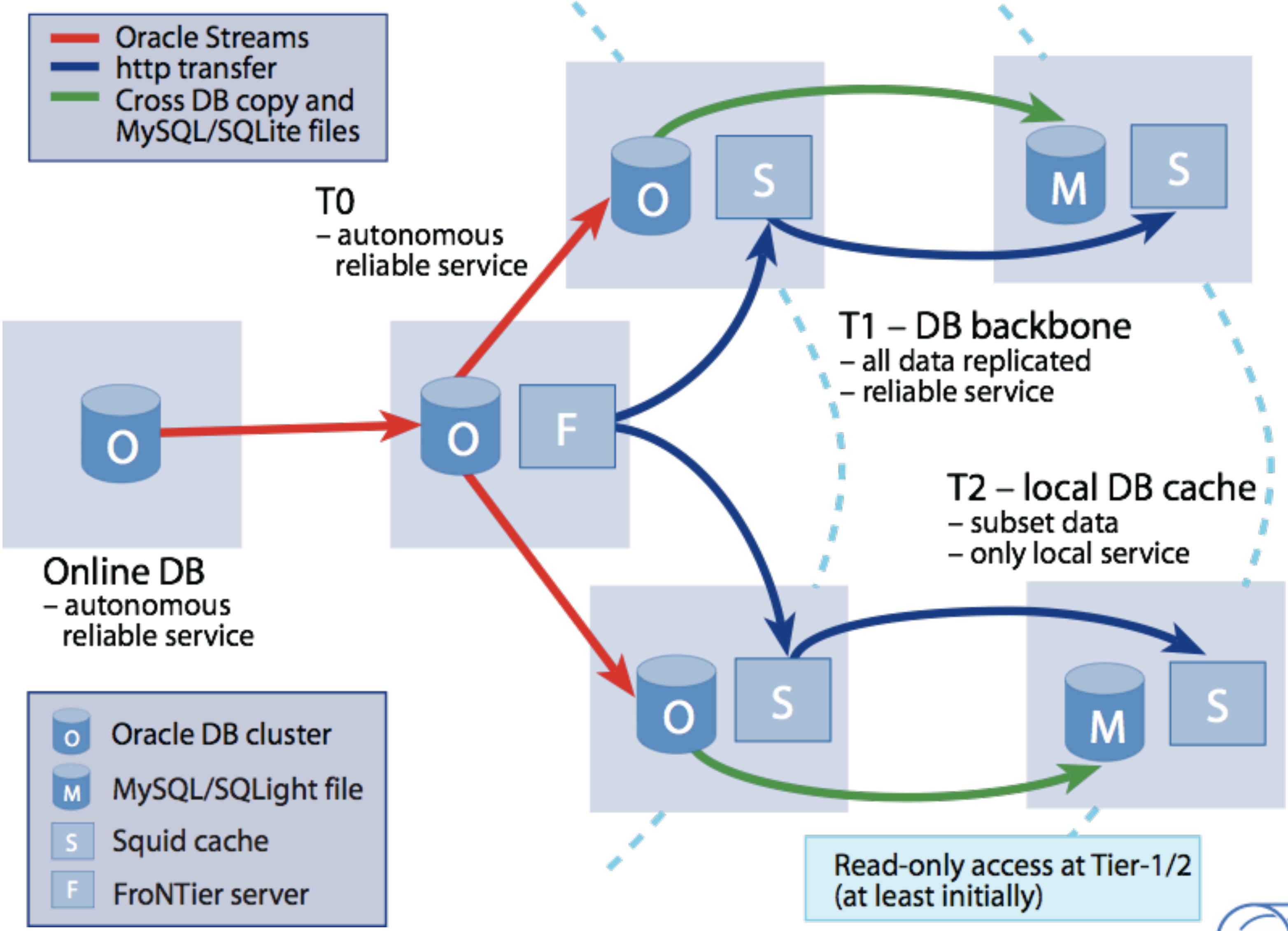

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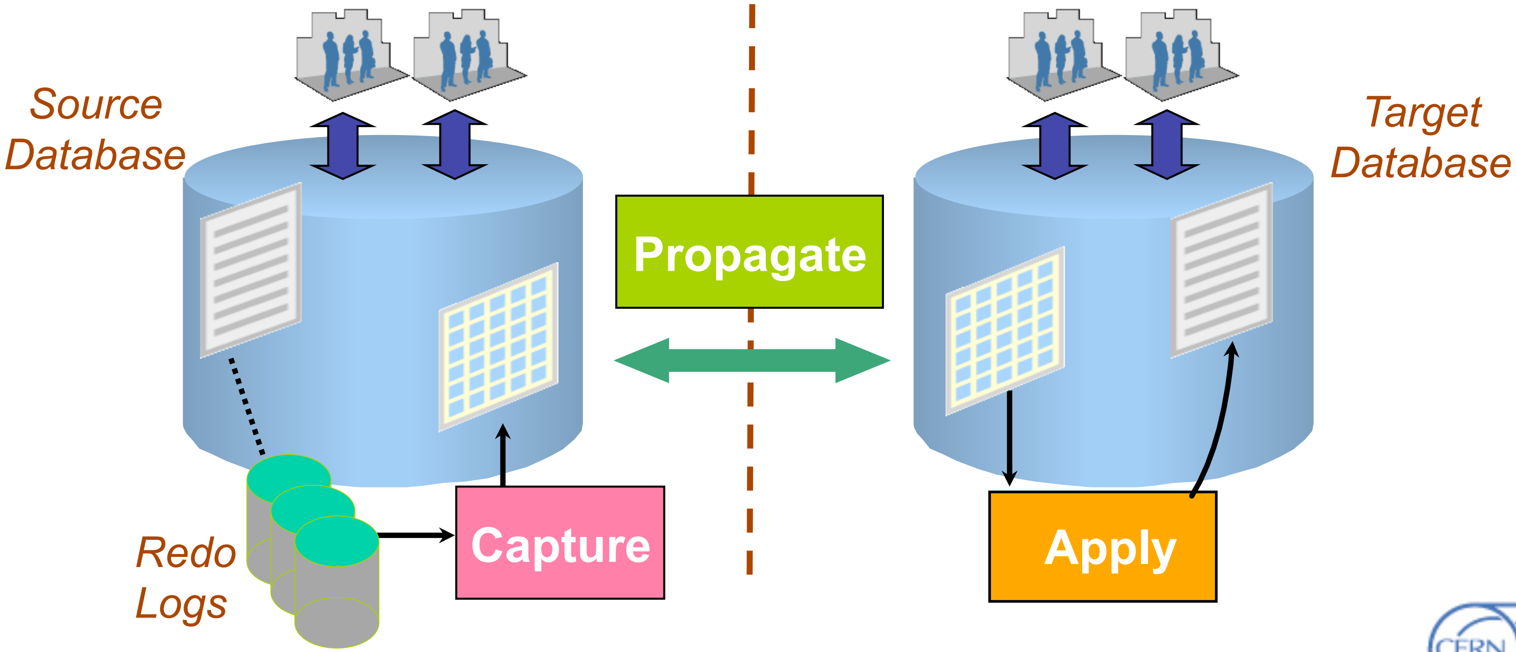
Oracle Streams Replication

- Technology for sharing information between databases
- Database changes captured from the redo-log and propagated asynchronously as Logical Change Records (LCRs)



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Replication Performance

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- The atomic unit is the change record: LCR
- LCRs can vary widely in size

  →Throughput is not a fixed measure

- Capture performance:
  – Read changes from the redo
    - from redo log buffer (memory - much faster)
    - from archive log files (disk)
  – Convert changes into LCRs
    - depends on the LCR size and number of columns
  – Enqueue the LCRs
    - concurrent access to the data structure can be costly

Replication Performance

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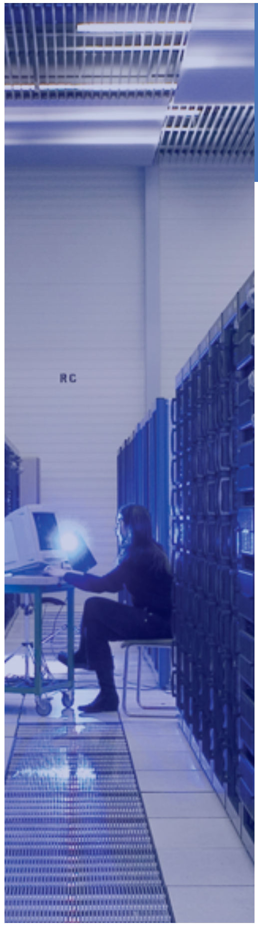
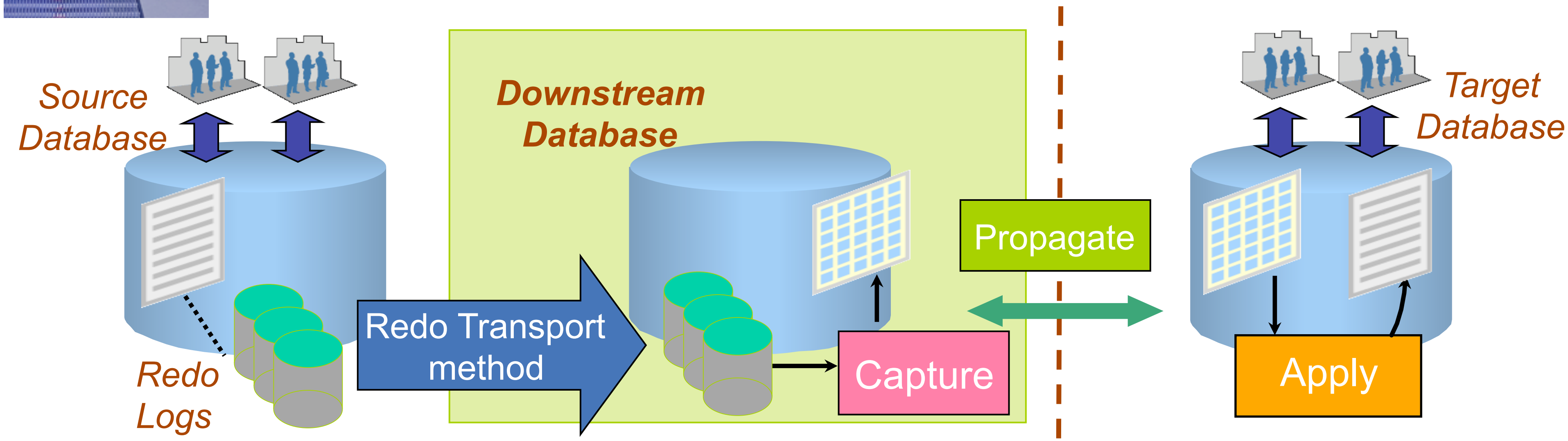
- Propagation performance:
  - Browse LCRs
  - Transmit LCRs over the network
  - Remove LCRs from the queue
    - Done in separate process to avoid any impact

- Apply performance:
  - Browse LCRs
  - Execute LCRs
    - Manipulate the database is slower than the redo generation
    - Execute LCRs serially => apply cannot keep up with the redo generation rate
  - Remove LCRs from the queue



Downstream Capture

- Downstream capture to de-couple Tier 0 production databases from destination or network problems
  - source database availability is highest priority
- Optimizing redo log retention on downstream database to allow for sufficient re-synchronisation window
  - we use 5 days retention to avoid tape access
- Dump fresh copy of dictionary to redo periodically
- 10.2 Streams recommendations (metalink note 418755)



Streams Setup Example: ATLAS

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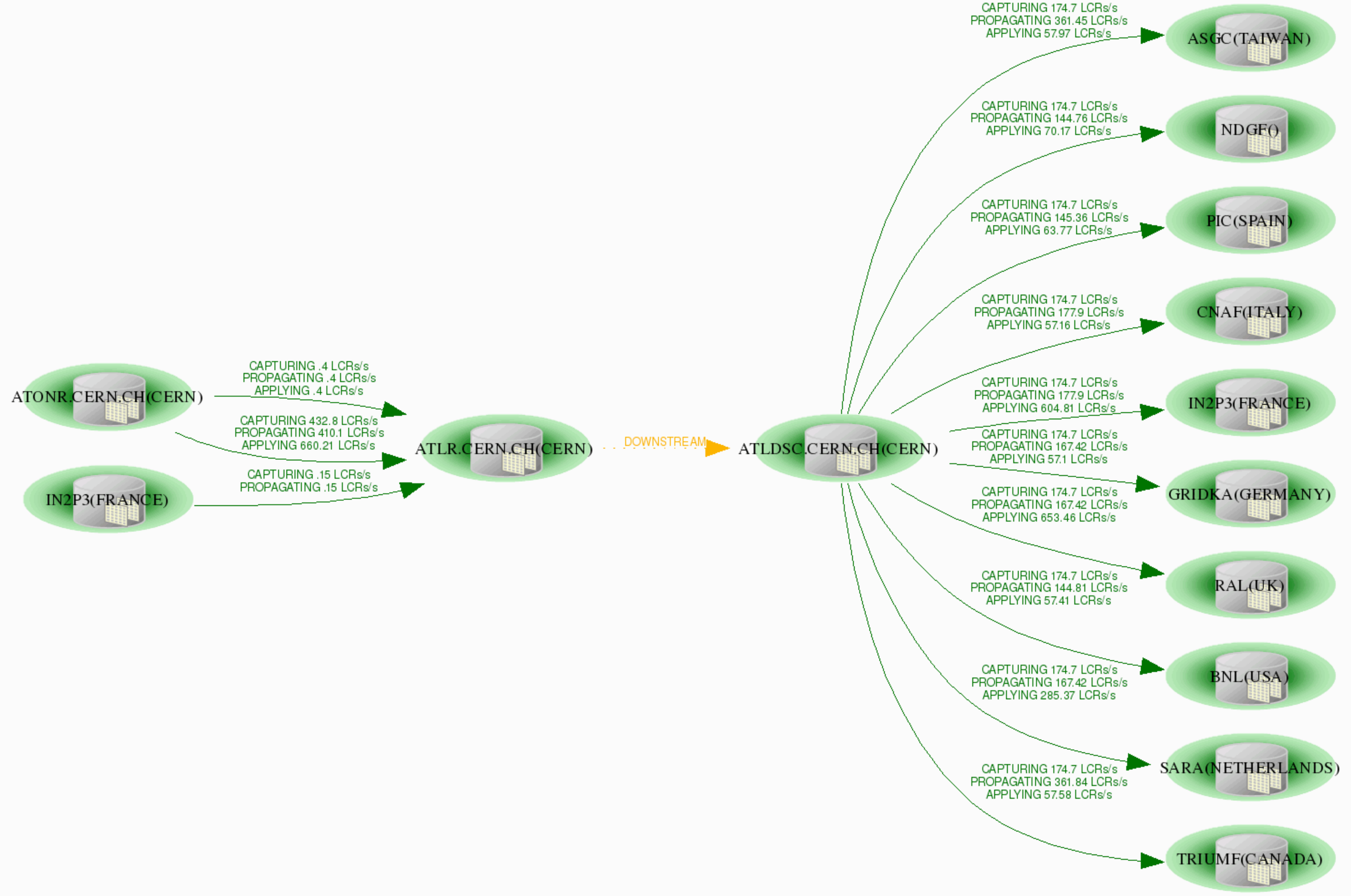
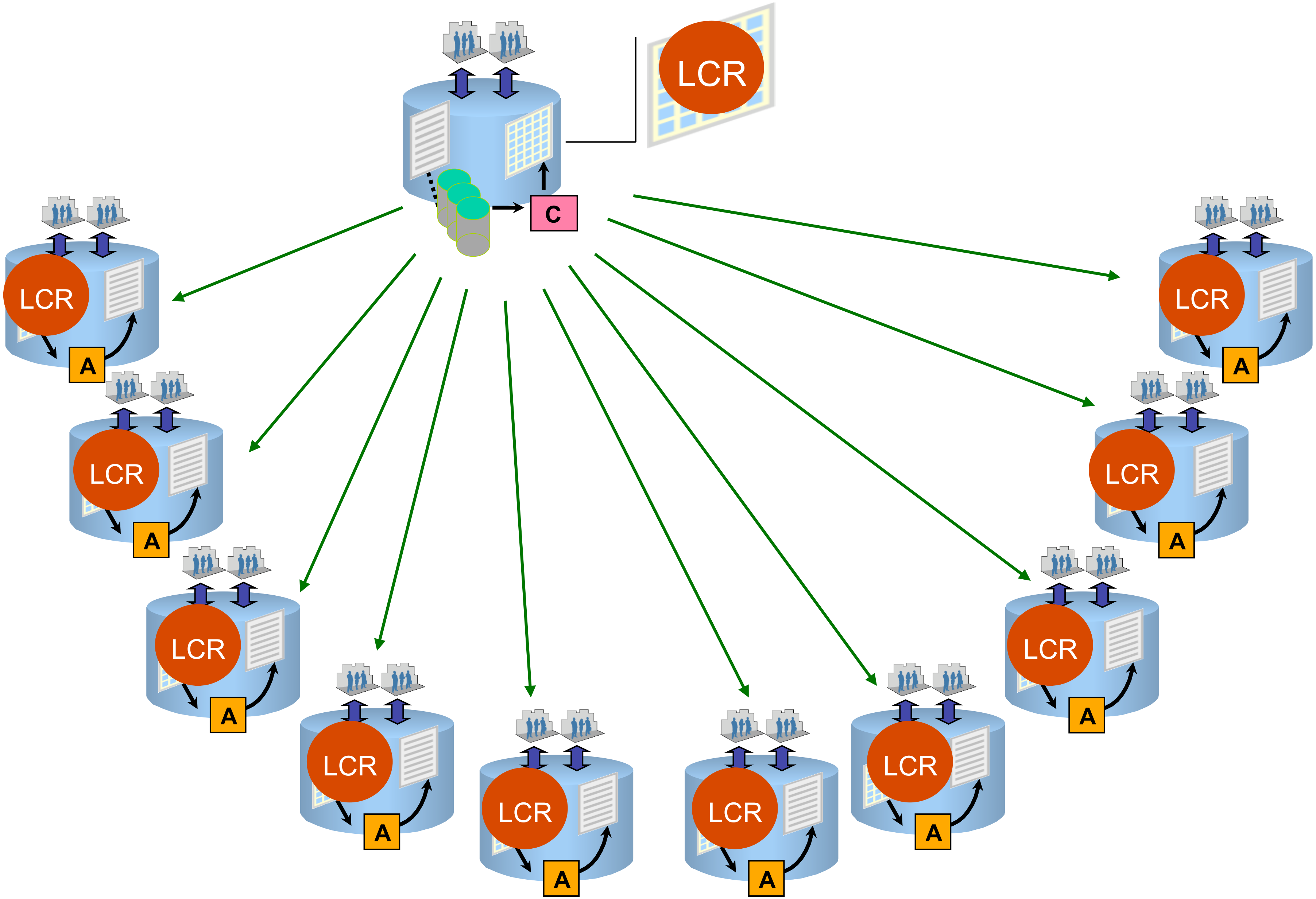
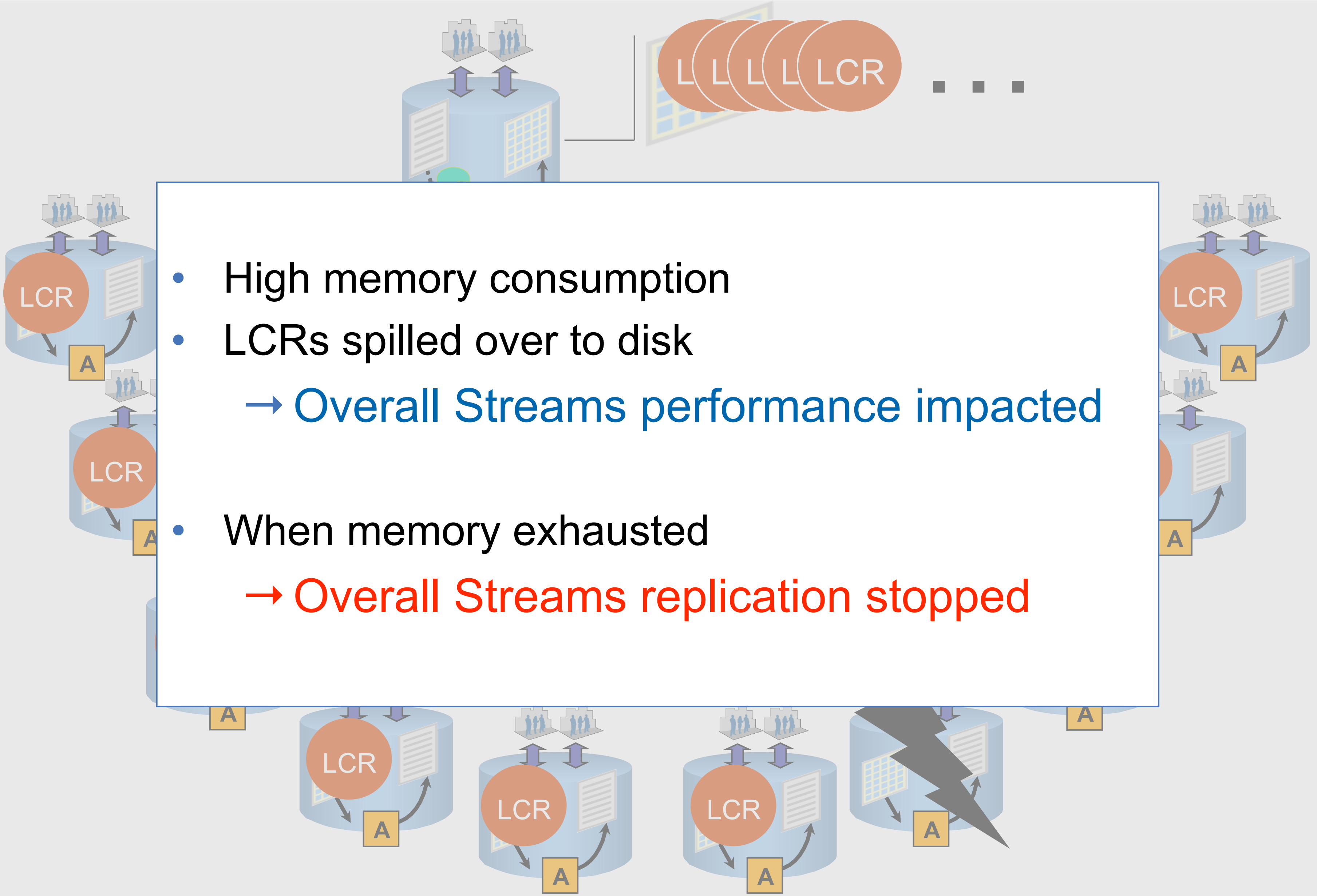


Split & Merge: Motivation



Split & Merge: Motivation



- High memory consumption
- LCRs spilled over to disk

  → Overall Streams performance impacted

- When memory exhausted

  → Overall Streams replication stopped

Split & Merge

in collaboration with Patricia McElroy
Principal Product Manager Distributed Systems/Replication - Oracle

- Objective: isolate replicas against each other
  - Split
    - (original) Streams setup for “good” sites
      - drop propagation job/s to “bad” site/s
      - →spilled LCRs are removed from the capture queue
    - (new) Streams setup for “bad” site/s
      - new capture queue
      - clone capture process and propagation job/s
    - does not require any change on the destination site/s
  - Merge
    - move back the propagation job/s to the original setup
    - clean up additional Streams processes and queue
    - does not require any change on the destination site/s

Split & Merge: Details

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- Split:

```
SQL> exec split ('STRM_PROP_A’,'STRM_CAP_CL’, 'STRMQ_CL', 'STRM_PROP_CL');
        exec resynchronize_site ('STRMTEST.CERN.CH’,'STRM_CAP_CL',
            'STRMQ_CL’,1,2,'STRM_PROP_CL’,'STRMQ_A_AP','RULESET$_18','');
```

  – gather cloning information:
    - **capture**:
      – rule set name
      – start_scn = last applied message scn @target
      – first_scn = previous dictionary build < start_scn
    - **propagation**:
      – rule set name
      – target queue name and db link
- Merge:

```
SQL> exec merge('STRM_CAP_SA','STRM_CAP_CL’,'STRM_PROP_A','STRM_PROP_CL');
```

  – select the minimum required checkpoint scn between the 2 capture processes
  – recover original propagation

TCP and Network Optimizations

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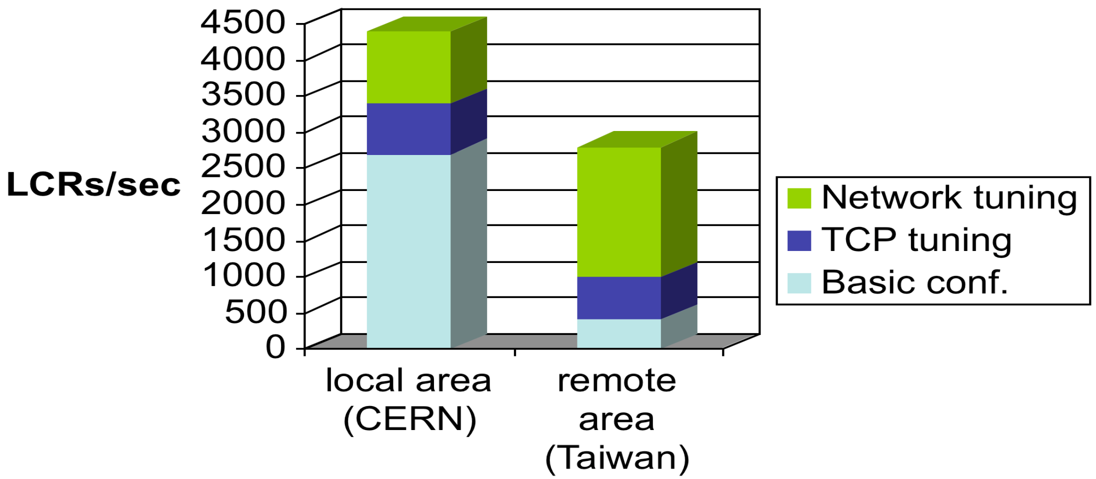
- TCP and Network tuning
  - adjust system max TCP buffer (/etc/sysctl.conf)
  - parameters to reinforce the TCP tuning
    - DEFAULT_SDU_SIZE=32767
    - RECV_BUF_SIZE and SEND_BUF_SIZE
      - Optimal: 3 * Bandwidth Delay Product
- Reduce the Oracle Streams acknowledgements
  - alter system set events '26749 trace name context forever, level 2';



Streams Rules

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- Used to control which information to share
- Rules on the capture side caused more overhead than on the propagation side
- Avoid Oracle Streams complex rules

Complex Rule

condition => '(**SUBSTR(:ddl.get_object_name(),1,7)** IN ("COMP200", "OFLP200", "CMCP200", "TMCP200", "TBDP200", "STRM200")
OR **SUBSTR (:ddl.get_base_table_name(),1,7)** IN ("COMP200", "OFLP200", "CMCP200", "TMCP200", "TBDP200", "STRM200")) '

Avoid complex rules:

- LIKE
- Functions
- NOT

Simple Rule

condition => '(((:ddl.get_object_name() **>=** "STRM200_A" and :ddl.get_object_name() **<=** "STRM200_Z") OR
(:ddl.get_base_table_name() **>=** "STRM200_A" and :ddl.get_base_table_name() **<=** "STRM200_Z"))
OR ((:ddl.get_object_name() **>=** "OFLP200_A" and :ddl.get_object_name() **<=** "OFLP200_Z") OR
(:ddl.get_base_table_name() **>=** "OFLP200_A" and :ddl.get_base_table_name() **<=** "OFLP200_Z"))

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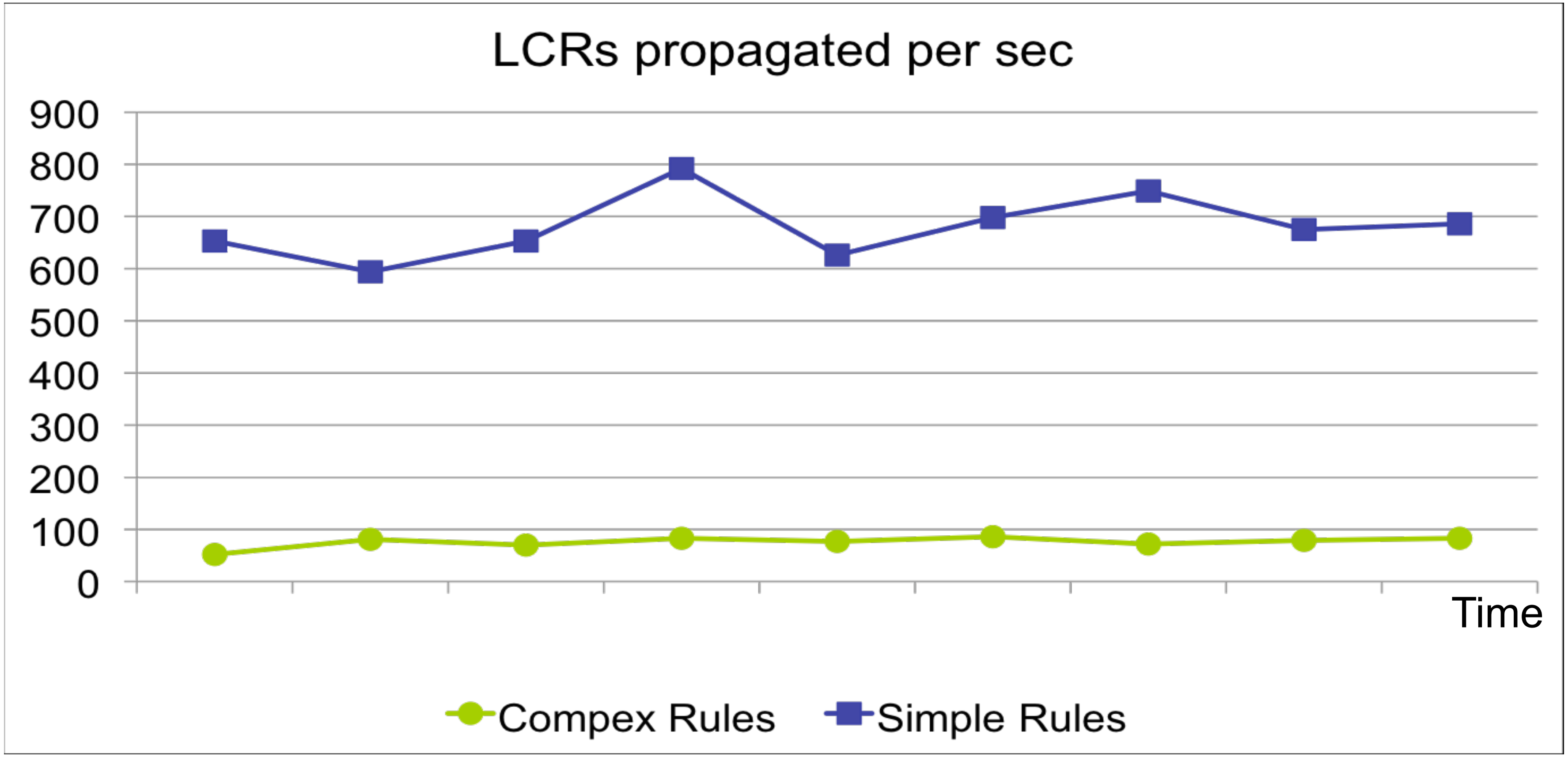
Streams Rules

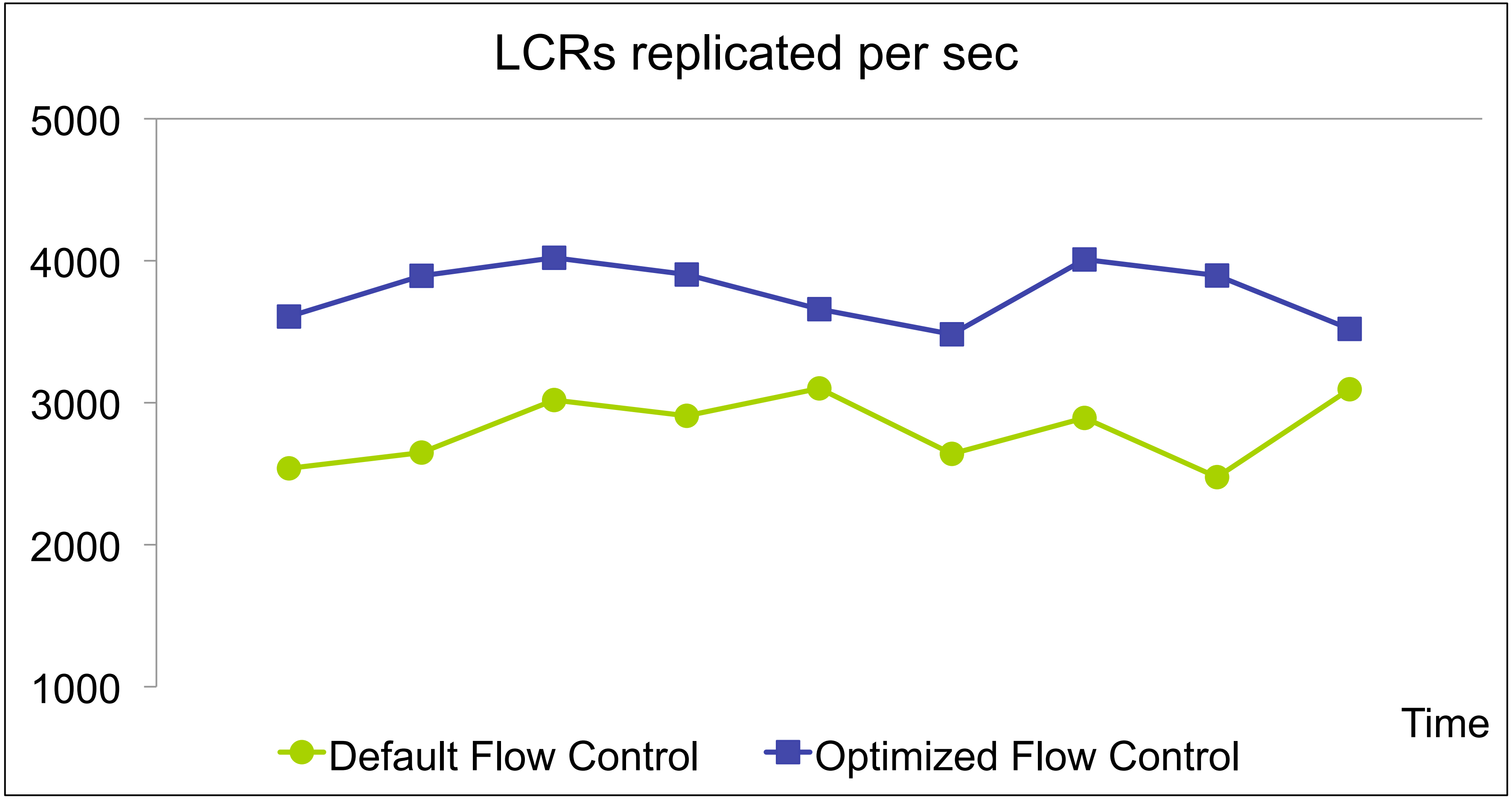
- Example: ATLAS Streams Replication
  - rules defined to filter tables by prefix



Flow Control

- By default, flow control kicks when the number of messages is larger than the threshold
  - Buffered publisher: 5000
  - Capture publisher: 15000
- Manipulate default behavior
- 10.2.0.3 + Patch 5093060 = 2 new events
  - 10867: controls threshold for any buffered message publisher
  - 10868: controls threshold for capture publisher
- 10.2.0.4 = 2 new hidden parameters
  - "_capture_publisher_flow_control_threshold"
  - "_buffered_publisher_flow_control_threshold"

- Example: ATLAS PVSS Streams Replication



Periodic Maintenance

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- Dump fresh copy of Dictionary redo
  - reduces the amount of logs to be processed in case of additional process creation
- Reduce high watermark of AQ objects
  - maintain enqueue/dequeue performance
  - reduce QMON CPU usage
  - metalink note 267137.1
- Shrink Logminer checkpoint table
  - improves capture performance
  - metalink note 429599.1
- Review the list of specific Streams patches
  - metalink note 437838.1

Lessons Learned

- SQL bulk operations (at the source db)
  - may map to many elementary operations at the destination side
  - need to control source rates to avoid overloading
- Batch processing
  - minimize the performance impact using Streams tags
  - avoid changes being captured, then run same batch load on all destination
- System generated names
  - do not allow system generated names for constraints and indexes
  - modifications will fail at the replicated site
  - storage clauses also may cause some issues if the target sites are not identical

Lessons Learned

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- Replication of “grant” operations
  - grants on views, PL/SQL procedures, functions and packages are NOT replicated
  - grantee must exist at all destinations
- Long transactions (non-frequent commits)
  - Total number of outstanding LCRs is too large
  - LCRs are in memory too long
    - → LCRs are spilled over to disk
    - → Apply performance is impacted
  - All LCRs in a single transaction must be applied by one apply server
    - →Parallel servers cannot be used efficiently
  - Too many unbrowsed messages enables flow control
    - →Streams processes are paused

Lessons Learned

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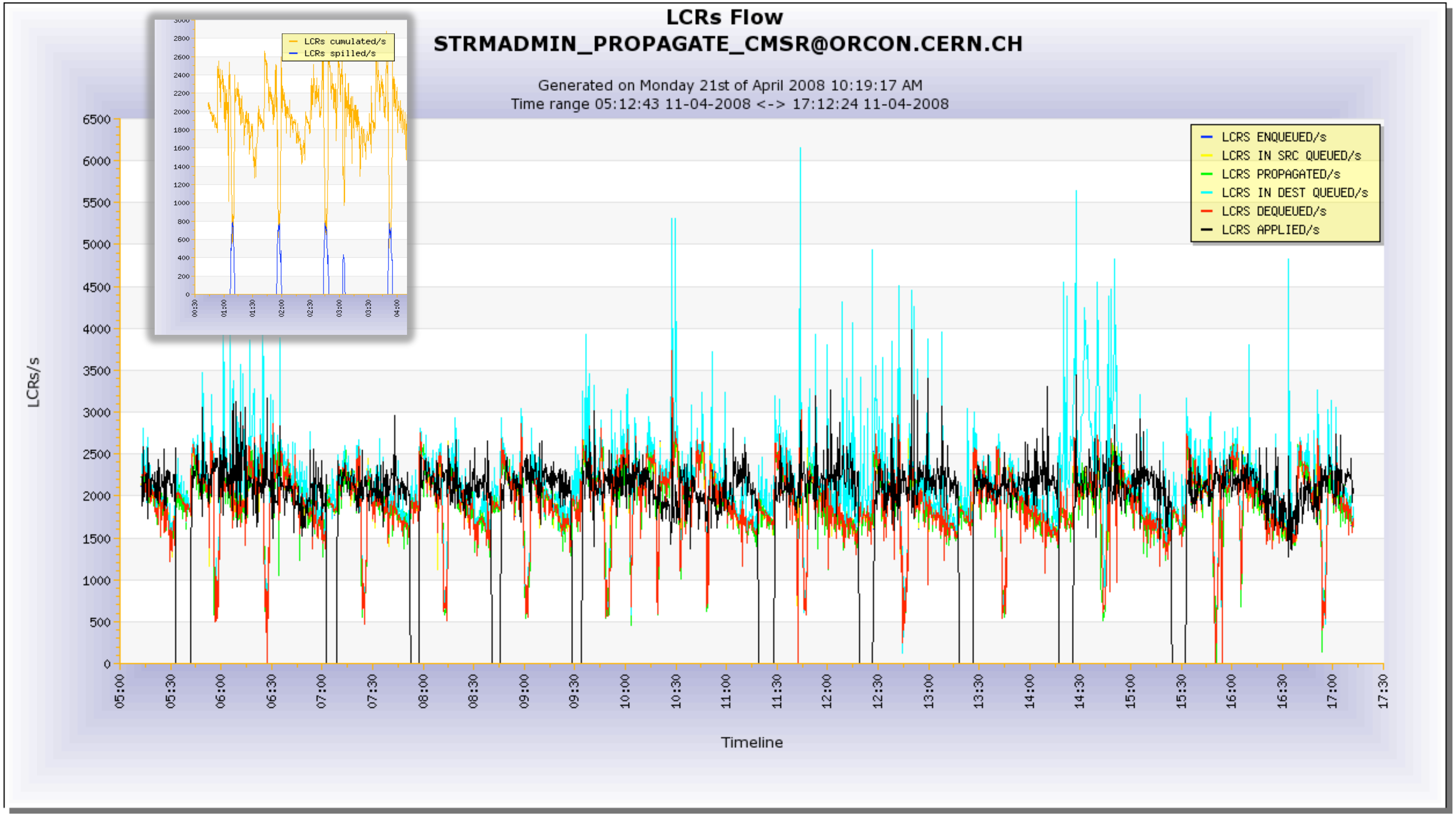
- Example: CMS replication - Online to Offline (CERN)
  - single transaction mapping 428400 LCRs



Lessons Learned

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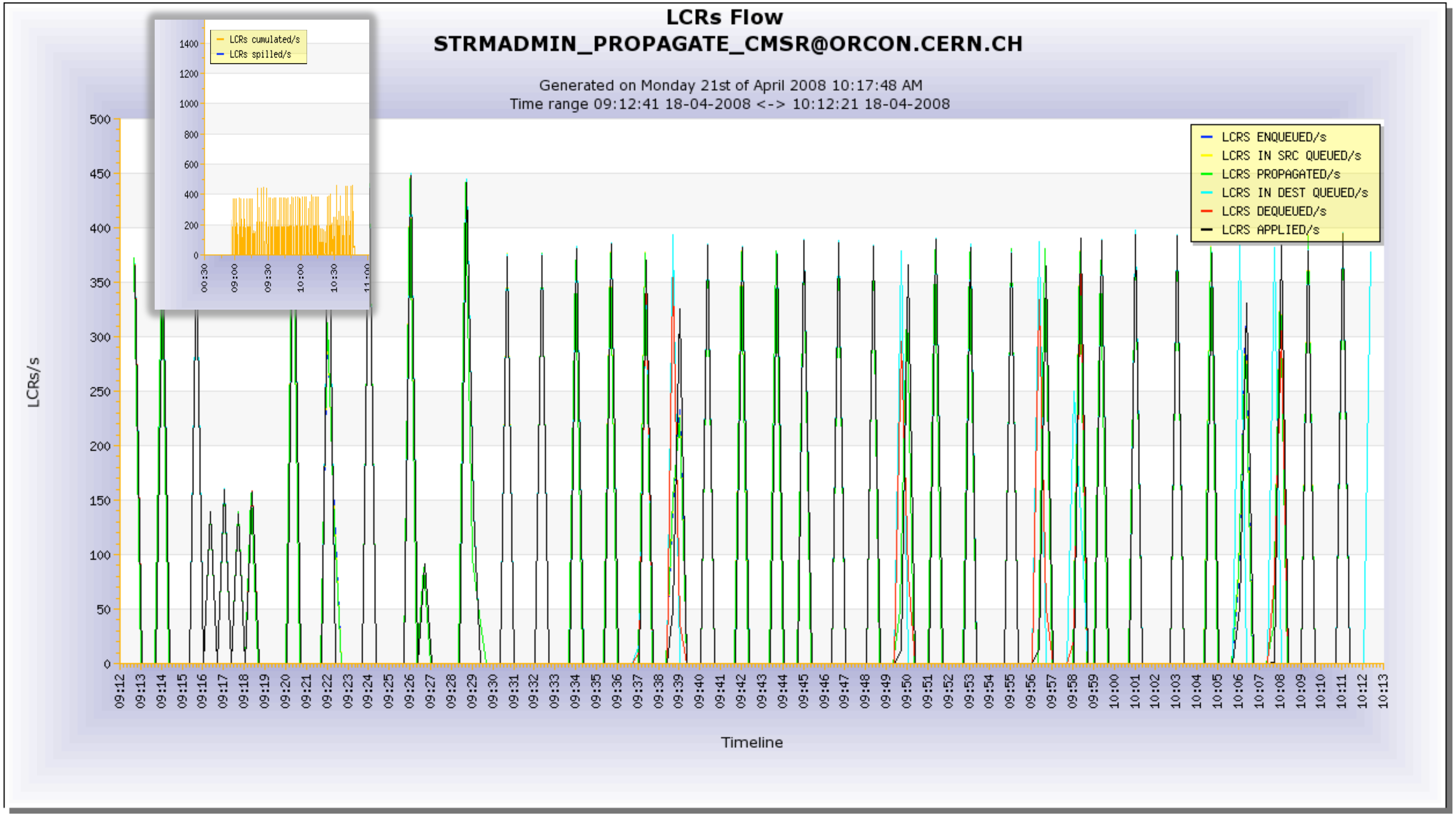
- Example: CMS replication - Online to Offline (CERN)
  - use BLOB objects: single transaction mapping 3600 LCRs



Lessons Learned

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- Apply oldest_message_number is not updated
  - caused by an old transaction not correctly removed from the apply spill table
  - dba_apply_spill_txn view in order to identify the transaction
  - set the apply parameter _IGNORE_TRANSACTION with the transaction id in the apply spill over queue
  - run purge_spill_txn procedure (metalink note 556183.1)

- Apply might degrade performance when applying transactions to tables > 10M rows

Tips and Tricks

- How to **recover** Streams if downstream database crashes
  - use source database as replacement
    - all archive logs are available
  - check the oldest message number applied at each of the destinations
  - select Streams dictionary SCN < min(oldest message numbers)
  - create the Streams queue and all the propagations
  - create capture process where
    - first_scn = dictionary SCN
    - start_scn = oldest_message_number

- Configure **back** the downstream database
  - build a new Streams dictionary
  - stop capture and wait until all LCRs are applied
  - repeat steps above
  - register the archive logs with the capture process

Tips and Tricks

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- Performing a **switchover** in a Streams environment
  - – database hw migration with minimal downtime
  - – completely transparent for destination databases
  - – source database:
    - before the switchover: move forward first_scn
    - after the switchover: check that the archivelog files are registered with the capture process
      - – otherwise, register them manually (from first_scn)

Streams Bugs and Patches

- Streams specific patches metalink note 437838.1
- Bug 6452375
  - ORA-26687 in Streams from “drop table”
  - when two streams setups between same source and destination databases to replicate different schemas
- Bug 6402302
  - inconsistent capture/propagation/apply of DDLs in Streams
  - for example: “drop synonym” DDL is not captured/ propagated or applied while create synonym is captured/ propagated and applied

Streams Bugs and Patches

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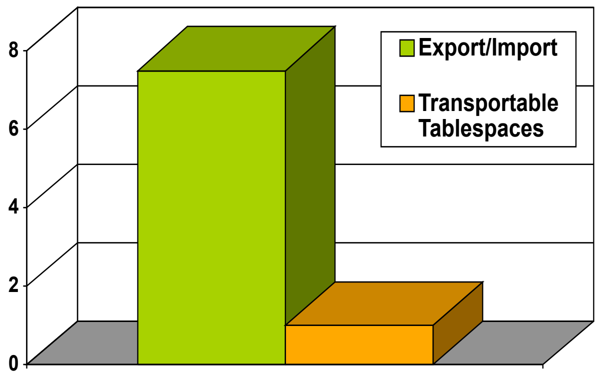
- ORA-00600: [KRVRDCBMDDLSQL1]
  - caused by rebuild index operation using parallel option
  - logminer corruption?
  - capture process could not be restarted at the current SCN
  - workaround proposed by Oracle: recreate capture using new dictionary after the index rebuild operation → data loss!!
  - complete re-instantiation of the Streams environment
- ORA-07445: exception encountered: core dump [kghufree()+485]
  - Oracle Database Change Notification cannot be used in a Streams environment

Scalable Resynchronization

- Target site out of the Streams recovery window
- Complete transfer of data (schemas and tables) using Oracle Data Pump might take too long
  - Example ATLAS Conditions data
- Transportable Tablespaces: move a set of tablespaces from one Oracle database to another
  - Export metadata of tablespace instead of data in tablespace

– But tablespaces must be in read-only while the data is copied

Example: ATLAS COOL test data - 67 GB



Moving data using transportable tablespaces is much faster than Data Pump export/import

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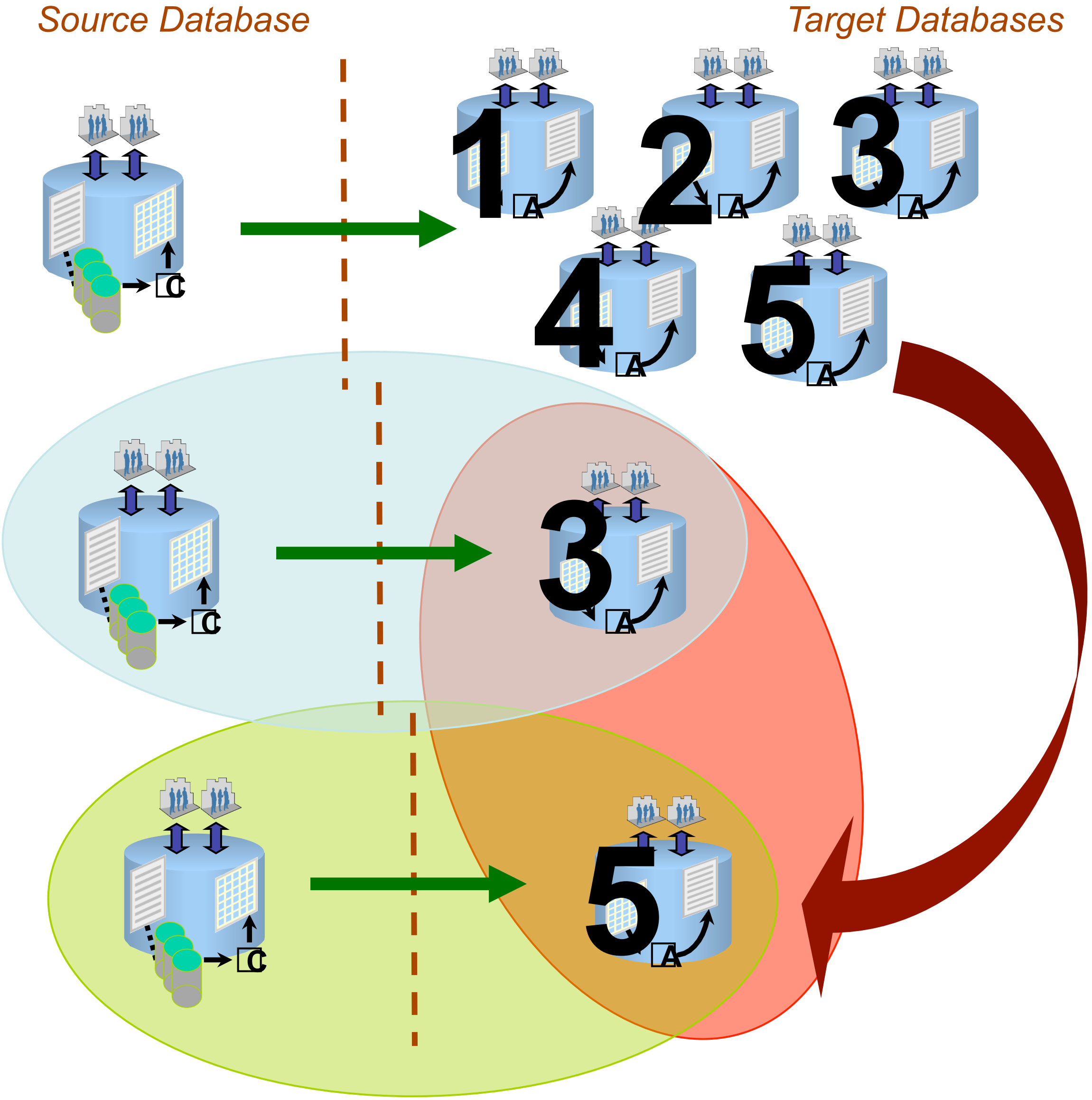
Scalable Resynchronization



1. Create database links between databases
2. Create directories pointing to datafiles
3. Stop replication to site 5
4. Ensure tablespaces are read-only
5. Transfer the data files of each tablespace to the remote system
6. Import tablespaces metadata in the target
7. Make tablespaces read-write
8. Reconfigure Streams

Streams Monitoring

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- Oracle Enterprise Manager
  - Streams monitoring enhancements on 10.2.0.5
- Oracle Streams STRMMON monitoring utility
- Streams configuration report and health check script

- Extended tool for Streams monitoring: 3D Streams Monitor tool @CERN

3D Streams Monitor

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- Features:
  - Streams topology
  - Status of streams connections
  - Error notifications
  - Streams performance (latency, throughput, etc.)
  - Other resources related to the streams performance (streams pool memory, redo generation)
- Architecture:
  - "strmmon" daemon written in Python
  - End-user web application http://oms3d.cern.ch:4889/streams/main
- 3D monitoring and alerting integrated with WLCG procedures and tools

3D Streams Monitor

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3D Streams Monitor

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Monitor | Maps | DBs | **Streams** | Graphs | Errors | Availability | History | Reports

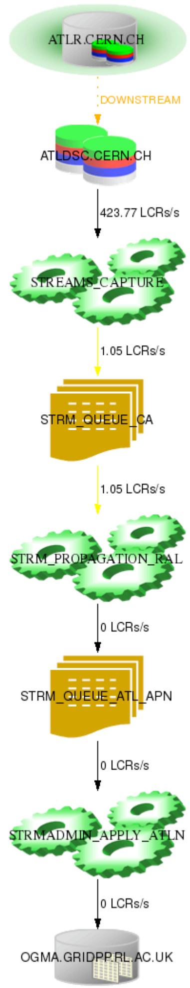
All | ALICE | **ATLAS** | CMS | LHCb | NEW | TEST | TEST11G2 | TEST_ATLAS

ACTIVE STREAMS

Stream	LCRs Cap	LCRs Enq	LCRs Prop	LCRs Deq	LCRs App	Cap Latency	Latency	Capture State	Propagation State	Apply State	State
ATLDSC.CERN.CH=>ASGC3D.GRID.SINICA.EDU.TW	951.34 /s	1.05 /s	1.05 /s	0 /s	0 /s	23 sec	--	CAPTURING CHANGES	ENABLED	IDLE	

SOURCE	ATLDSC.CERN.CH
CAPTURE	
Name	STREAMS_CAPTURE
SCN read	6083362640734
LCRs captured	10491139 (542.77 /s)
SCN captured	6083362640734
LCRs enqueued	613528 (.25 /s)
SCN enqueued	6083362621274
Capture Latency	29 sec
Info	ATLDSC.CERN.CH
State	CAPTURING CHANGES
Error Time	
Error Msg	
QUEUE	
Name	STRM_QUEUE_CA
Id	42947
Outstanding Msg	678227
Cumulative Msg	4538140 (.25 /s)
Cumulative Msg Spilled	711286 (0 /s)
PROPAGATION	
Name	STRM_PROPAGATION_RAL
LCRs Propagated	4532803 (.25 /s)
Bytes Propagated	15453 (0 /s)
State	ENABLED
Error Time	
Error Msg	

DESTINATION	OGMA.GRIDPP.RL.AC.UK
QUEUE	
Name	STRM_QUEUE_ATL_APN
Id	179048
Outstanding Msg	0
Cumulative Msg	94638683 (.05 /s)
Cumulative Msg Spilled	158012 (0 /s)
APPLY	
Name	STRMADMIN_APPLY_ATLN
LCRs Dequeued	49704552 (.05 /s)
Total LCRs Applied	48954298 (0 /s)
SCN Dequeued	6083362647224
Dequeue Latency	0 sec
Transaction Received	528045
Transaction Assigned	528045
Transaction Apllied	528045
State	IDLE
HWM SCN	6083362621274
HWM Apply Latency	29 sec
Error Time	
Error Msg	



3D Streams Monitor

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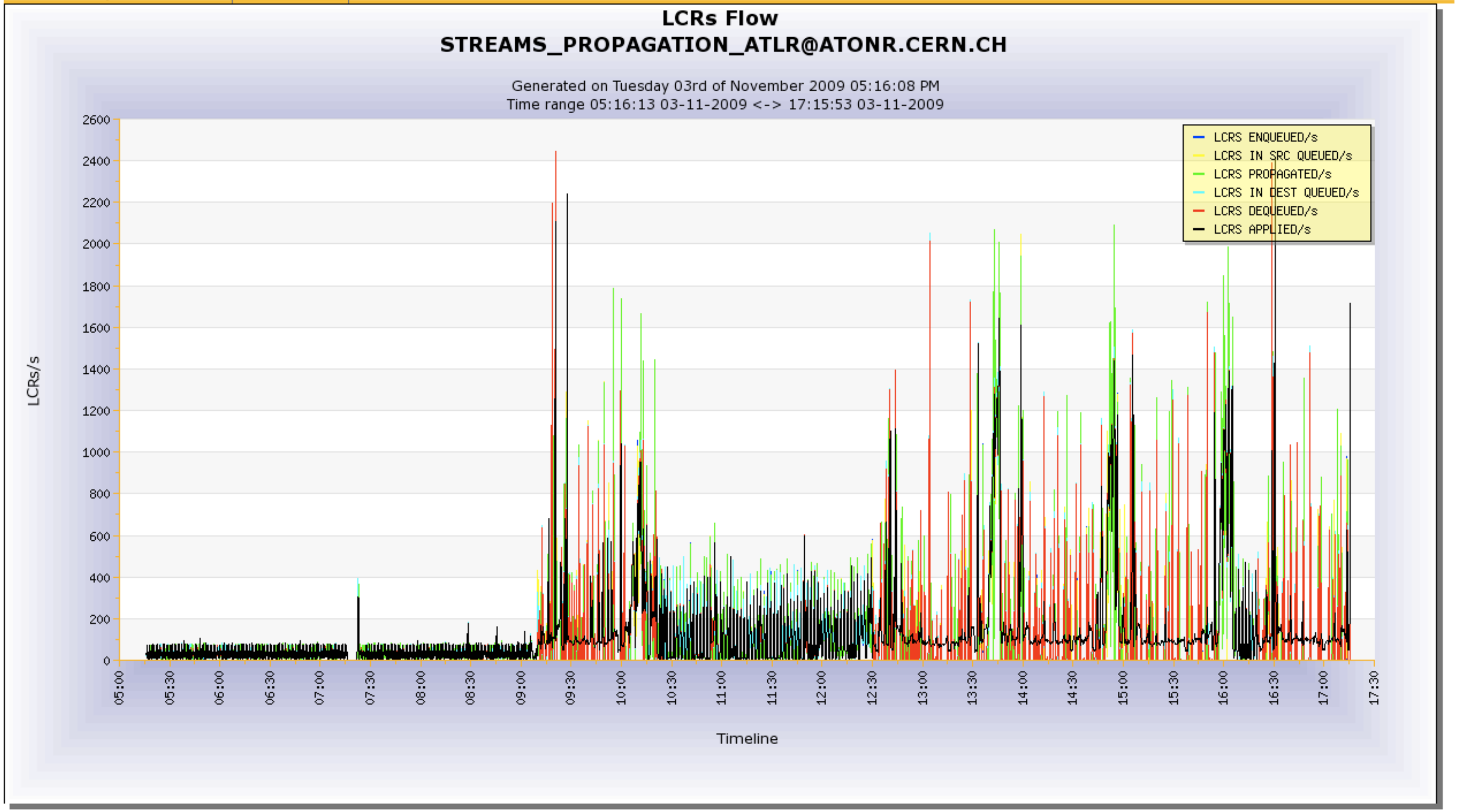
Monitor | Maps | DBs | Streams | **Graphs** | Errors | Availability | History | Reports

Database | Experiments | **Streams**



3D Streams Monitor

Streams report

Options

ALICE streams activities between 27.10.2009 and 03.11.2009

| availability | instances | captures | propagations | applys | queues | undefined primary keys |

Capture processes stats

2009-10-27 <-> 2009-11-02

Legend:

LCRS_CAP - LCRs captured
LCRS_ENQ - LCRs enqueued
CAP_LAT - capture latency - average time taken to capture single LCRs from log
ENQ_LAT - enqueue latency - average time taken to enque single LCRs (capture time included)

max min

DB_NAME	PROCESS_NAME	2009-10-27 LCRS_CAP	2009-10-27 LCRS_ENQ	2009-10-27 CAP_LAT	2009-10-27 ENQ_LAT	2009-10-28 LCRS_CAP	2009-10-28 LCRS_ENQ	2009-10-28 CAP_LAT	2009-10-28 ENQ_LAT	2009-10-29 LCRS_CAP	2009-10-29 LCRS_ENQ	2009-10-29 CAP_LAT	2009-10-29 ENQ_LAT
ALIONR.CERN.CH	STREAMS_PVSS_CAPTURE	8766353	291876	5.5 sec	3.6 sec	7418204	241186	5.4 sec	3.7 sec	6742596	169314	5.2 sec	3.5 sec

DB_NAME	PROCESS_NAME	2009-10-30 LCRS_CAP	2009-10-30 LCRS_ENQ	2009-10-30 CAP_LAT	2009-10-30 ENQ_LAT	2009-10-31 LCRS_CAP	2009-10-31 LCRS_ENQ	2009-10-31 CAP_LAT	2009-10-31 ENQ_LAT
ALIONR.CERN.CH	STREAMS_PVSS_CAPTURE	6795907	186108	5.3 sec	3.7 sec	6317804	193119	5.3 sec	3.7 sec

DB_NAME	PROCESS_NAME	2009-11-01 LCRS_CAP	2009-11-01 LCRS_ENQ	2009-11-01 CAP_LAT	2009-11-01 ENQ_LAT	2009-11-02 LCRS_CAP	2009-11-02 LCRS_ENQ	2009-11-02 CAP_LAT	2009-11-02 ENQ_LAT
ALIONR.CERN.CH	STREAMS_PVSS_CAPTURE	6583790	201615	5.2 sec	3.7 sec	7591331	204735	5.4 sec	3.6 sec

Total

DB_NAME	PROCESS_NAME	TOTAL LCRS_CAP	LCRS_ENQ	CAP_LAT	ENQ_LAT
ALIONR.CERN.CH	STREAMS_PVSS_CAPTURE	50215988	29759103	5.3 sec	2d 11h 2m 45s

Propagation processes stats

2009-10-27 <-> 2009-11-02

Legend:

LCRS_PROP - number of propagated LCRs
BYTES_PROP - number of propagated bytes

max min

DB_NAME	PROCESS_NAME	2009-10-27 LCR_PROP	2009-10-27 BYTES_PROP	2009-10-28 LCR_PROP	2009-10-28 BYTES_PROP	2009-10-29 LCR_PROP	2009-10-29 BYTES_PROP	2009-10-30 LCR_PROP	2009-10-30 BYTES_PROP	2009-10-31 LCR_PROP	2009-10-31 BYTES_PROP	2009-11-01 LCR_PROP	2009-11-01 BYTES_PROP	2009-11-02 LCR_PROP	2009-11-02 BYTES_PROP
ALIONR.CERN.CH	STREAMS_PROPAGATE_PDBR	5827071	130.3 kB	4814418	80.2 kB	3379169	79.7 kB	3714992	130.4 kB	3854643	105.3 kB	4024718	0 B	4086873	92.0 kB

Total

DB_NAME	PROCESS_NAME	TOTAL LCR_PROP	BYTES_PROP
ALIONR.CERN.CH	STREAMS_PROPAGATE_PDBR	29701885	617.9 kB

Queue stats

2009-10-27 <-> 2009-11-02

Legend:

LCRS_IN_Q - number of enqueued messages (LCRs)
LCRS_SPILLED - number of spilled LCRs to disk
SPILL_RATE - spilling percentage
LCRS_AVG - average number of messages in queue

max min

DB_NAME	QUEUE_NAME	2009-10-27 LCRS_IN_Q	2009-10-27 SPILLED	2009-10-27 SPILL_RATE	2009-10-27 LCRS_AVG	2009-10-28 LCRS_IN_Q	2009-10-28 SPILLED	2009-10-28 SPILL_RATE	2009-10-28 LCRS_AVG	2009-10-29 LCRS_IN_Q	2009-10-29 SPILLED	2009-10-29 SPILL_RATE	2009-10-29 LCRS_AVG
ALIONR.CERN.CH	STREAMS_PVSS_QUEUE_CA	5834670	0	0.0 %	660	4821164	0	0.0 %	560	3384564	0	0.0 %	397
PDBR.CERN.CH	STREAMS_PVSS_QUEUE_AP	5866178	0	0.0 %	135	4840116	0	0.0 %	144	3396840	0	0.0 %	96
PDBR.CERN.CH	KUPC$S_1_20091015143048	0	0	0.0 %	0	0	0	0.0 %	0	0	0	0.0 %	0

DB_NAME	QUEUE_NAME	2009-10-30 LCRS_IN_Q	2009-10-30 SPILLED	2009-10-30 SPILL_RATE	2009-10-30 LCRS_AVG	2009-10-31 LCRS_IN_Q	2009-10-31 SPILLED	2009-10-31 SPILL_RATE	2009-10-31 LCRS_AVG
ALIONR.CERN.CH	STREAMS_PVSS_QUEUE_CA	3720078	0	0.0 %	415	3860081	0	0.0 %	405
PDBR.CERN.CH	STREAMS_PVSS_QUEUE_AP	3737837	0	0.0 %	106	3876122	0	0.0 %	81
PDBR.CERN.CH	KUPC$S_1_20091015143048	0	0	0.0 %	0	0	0	0.0 %	0

DB_NAME	QUEUE_NAME	2009-11-01 LCRS_IN_Q	2009-11-01 SPILLED	2009-11-01 SPILL_RATE	2009-11-01 LCRS_AVG	2009-11-02 LCRS_IN_Q	2009-11-02 SPILLED	2009-11-02 SPILL_RATE	2009-11-02 LCRS_AVG
ALIONR.CERN.CH	STREAMS_PVSS_QUEUE_CA	4030247	0	0.0 %	450	4092501	0	0.0 %	471
PDBR.CERN.CH	STREAMS_PVSS_QUEUE_AP	4046299	0	0.0 %	100	4110115	0	0.0 %	111
PDBR.CERN.CH	KUPC$S_1_20091015143048	0	0	0.0 %	0	0	0	0.0 %	0

Total

DB_NAME	QUEUE_NAME	TOTAL LCRS_IN_Q	SPILLED	SPILL_RATE	LCRS_AVG
ALIONR.CERN.CH	STREAMS_PVSS_QUEUE_CA	29743307	0	0.0 %	480.2
PDBR.CERN.CH	STREAMS_PVSS_QUEUE_AP	29873509	0	0.0 %	110.8
PDBR.CERN.CH	KUPC$S_1_20091015143048	0	0	0.0 %	0.0

Generated in 39 min 57 sec

New Streams 11g Features

- Performance improvements:
  - reader process mines from the in-memory redo log buffers
    - minimizes disk I/O
    - reduces capture latency
  - direct communication between capture and apply processes: Combined Capture and Apply
    - improves LCR transmission throughput
    - reduces end-to-end replication latency
  - internal mechanism to execute change records and extensive caching
    - reduces CPU consumption
    - minimizes latch contention and other wait events

New Streams 11g Features

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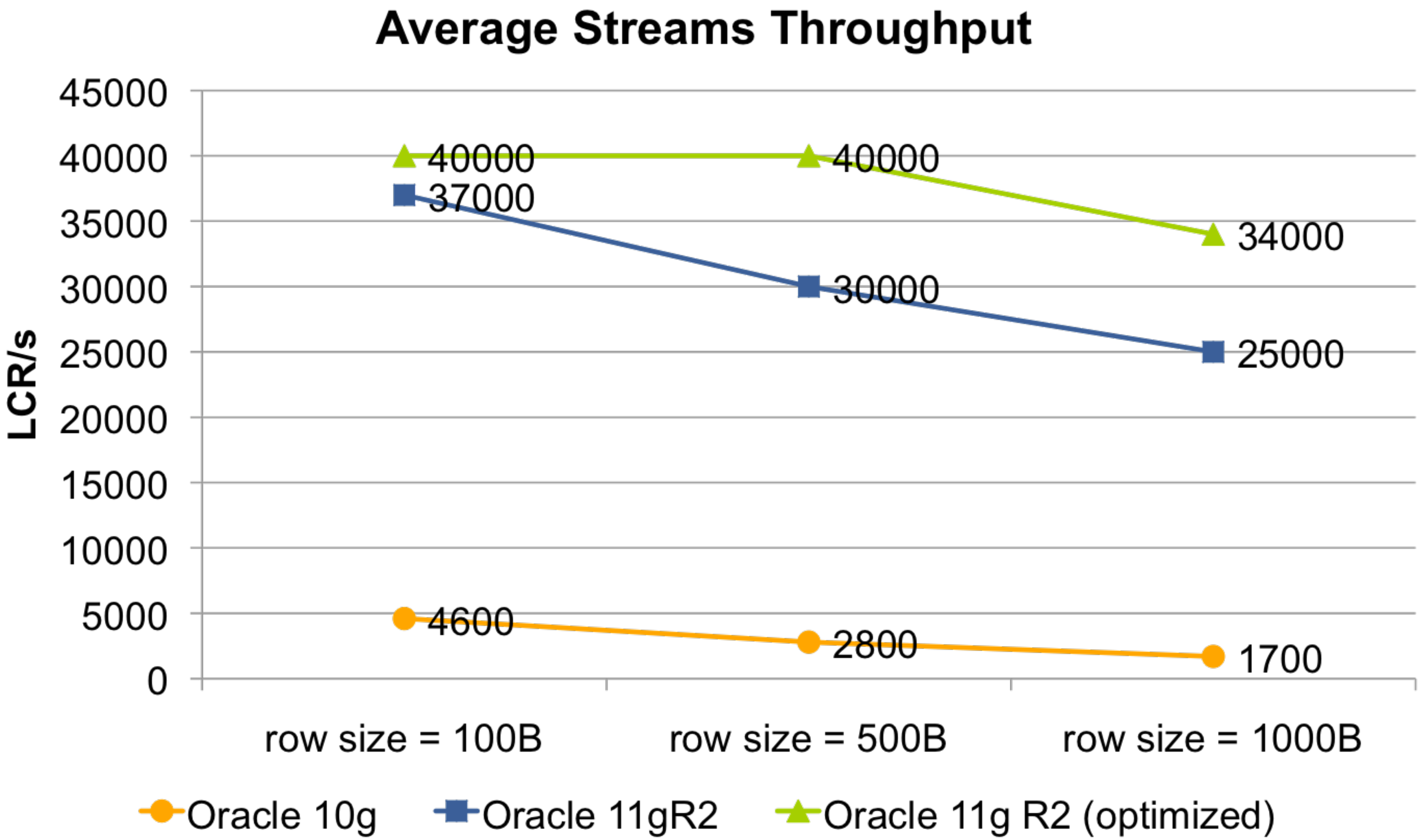

New 11g Streams Features

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- Automatic Split and Merge
  - split a stream in cases where a replica is unavailable
  - merge into a single stream when replica catches up
  - procedures and sql script generation
  - automatic replication management based on thresholds
- Compare and Converge
  - compare objects across databases for inconsistency
  - resynchronize objects if required
  - table or column level synchronization
  - additional scripting for schema comparison

New 11g Streams Features

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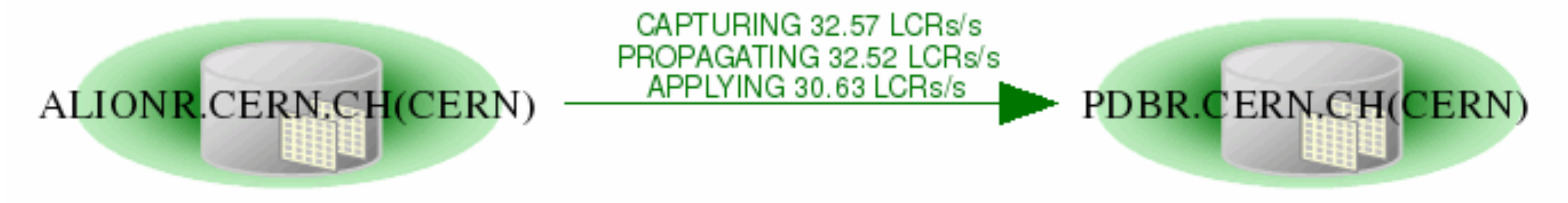
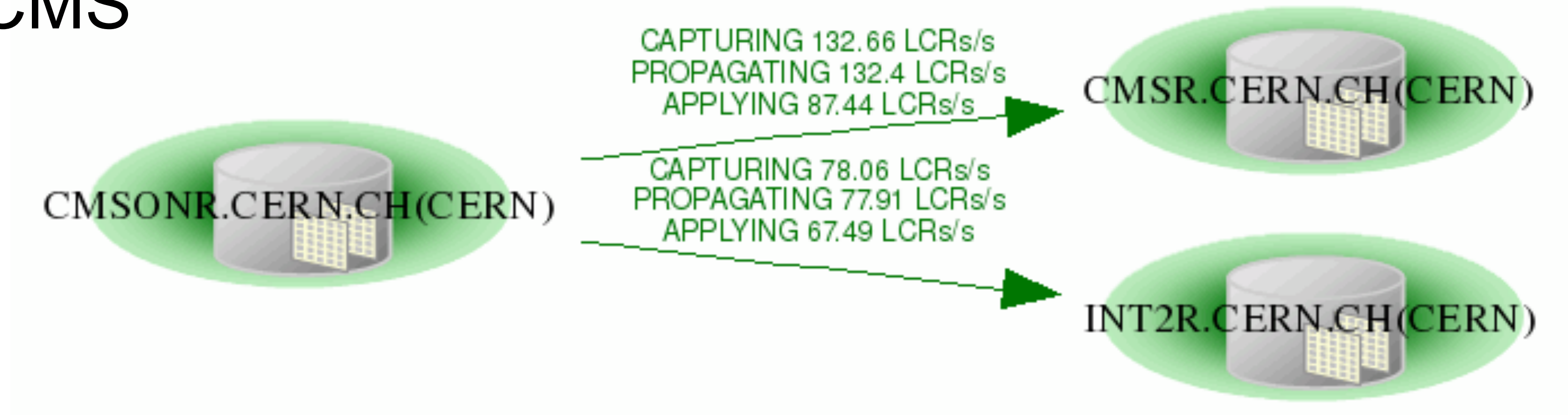
And more…

- Synchronous capture
- LCRs track through a Stream
- Topology and Performance Advisor
- New error messages for error handling

- ALICE

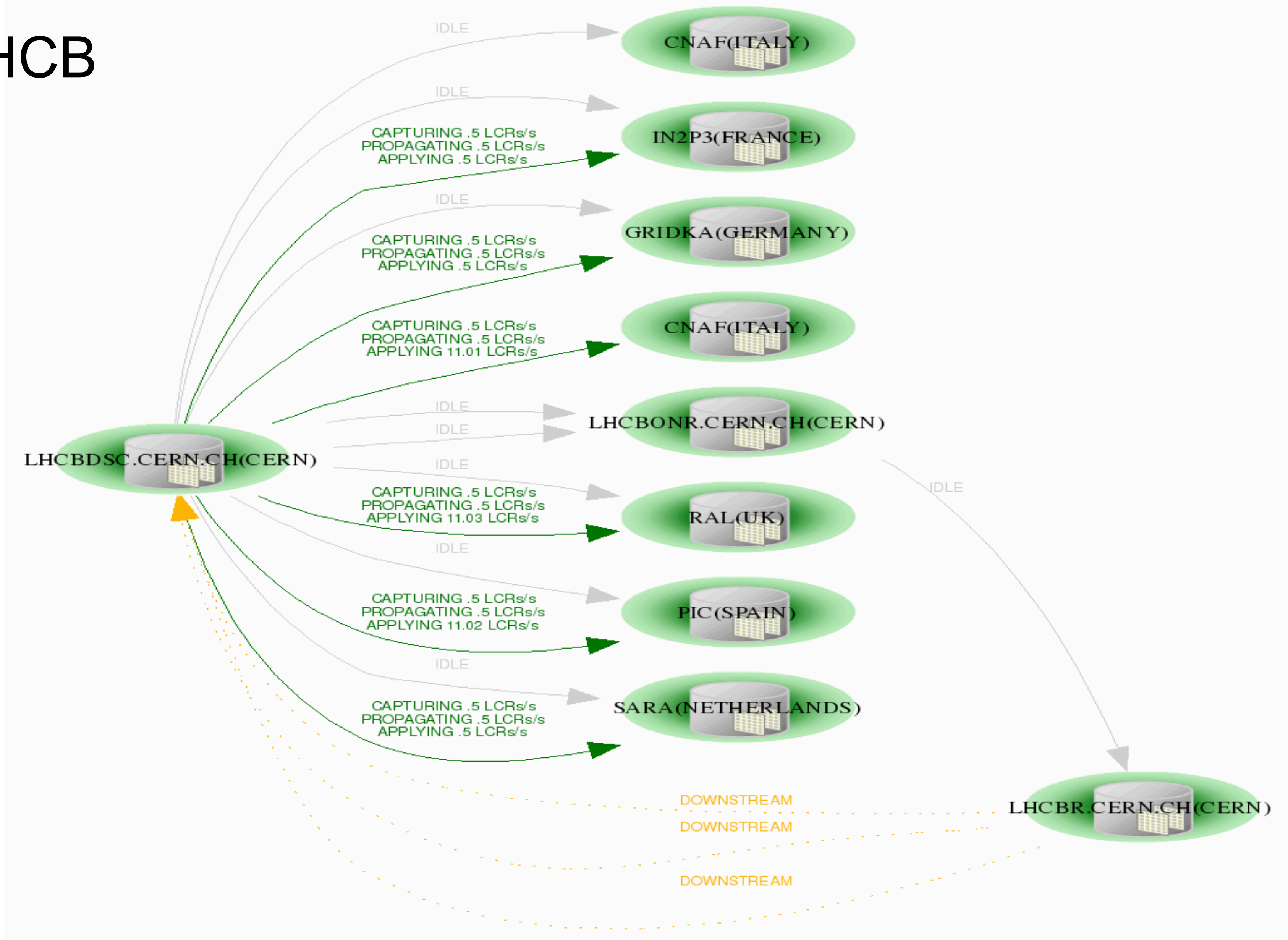

ALIONR.CERN.CH(CERN)
CAPTURING 32.57 LCRs/s
PROPAGATING 32.52 LCRs/s
APPLYING 30.63 LCRs/s
PDBR.CERN.CH(CERN)

- CMS


CMSONR.CERN.CH(CERN)
CAPTURING 132.66 LCRs/s
PROPAGATING 132.4 LCRs/s
APPLYING 87.44 LCRs/s
CMSR.CERN.CH(CERN)
CAPTURING 78.06 LCRs/s
PROPAGATING 77.91 LCRs/s
APPLYING 67.49 LCRs/s
INT2R.CERN.CH(CERN)

More Streams Setup Examples

- LHCB



Summary

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- The LCG Database Deployment Project (LCG 3D) has set up a world-wide distributed database infrastructure for LHC
  - some 33 RAC clusters = 636 CPU cores at CERN + several tens of nodes at 10 partner sites are in production now
- Large scale tests have validated that the experiment are implemented by the RAC & streams based set-up
  - backup & recovery tests have been performed to validate the operational procedures at all sites
- Monitoring of database & streams performance has been implemented building on grid control and strmmon tools
  - key to maintain and optimize any larger system

Q&A

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