Multi-thread sweep, backup and restore

Firebird Conference 2019

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Introduction

- Big demand from users to speed up most time consuming regular maintenance operations:
  - Backup
  - Restore
  - Sweep
- Initial implementation based on Firebird 2.5 Classic
  - Firebird 2.5 Super Server is not suitable
- Front ported to the v3 codebase
  - Including Super Server, of course
- Available in HQbird 2020 (for Firebird 2.5 and 3.0)
- Will be included into Firebird 4+

Introduction

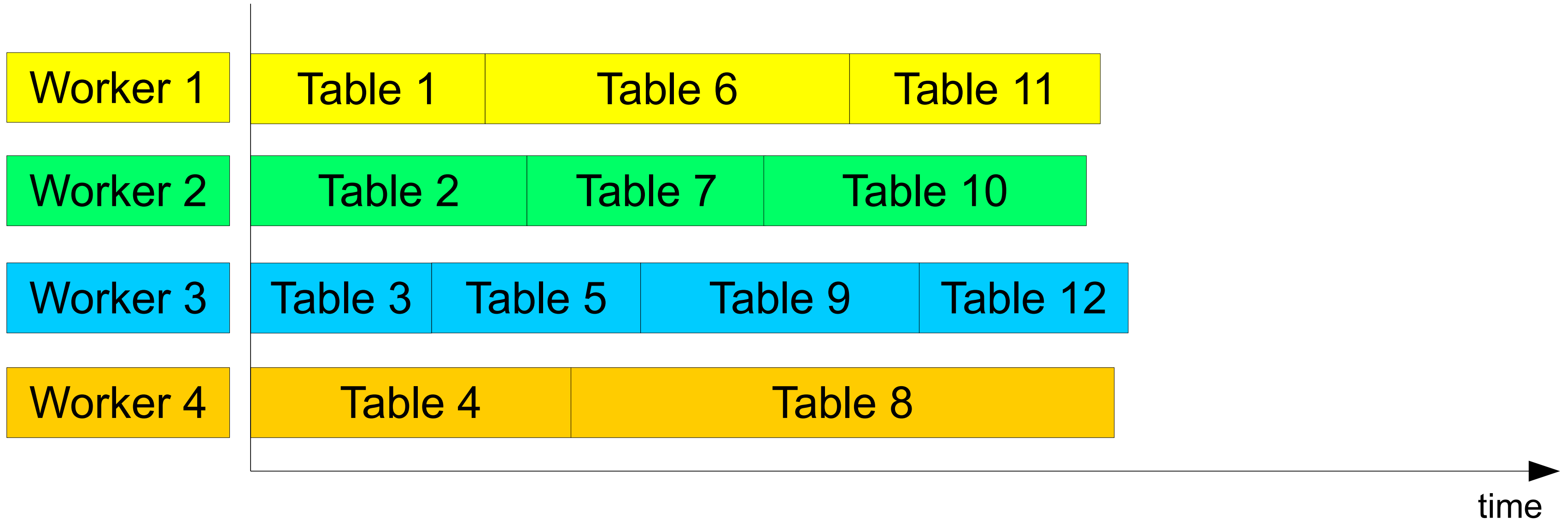
- The good parallel implementation should, at least
  - Evenly distribute workload between workers
  - Avoid or minimize possible contentions for shared resources (disk, memory, internal locking)
  - Minimize necessary coordination between workers and task manager

Sweep

- How sweep works
  - Read each table in database
  - Cleanup unneeded record versions
  - Move OIT marker on success

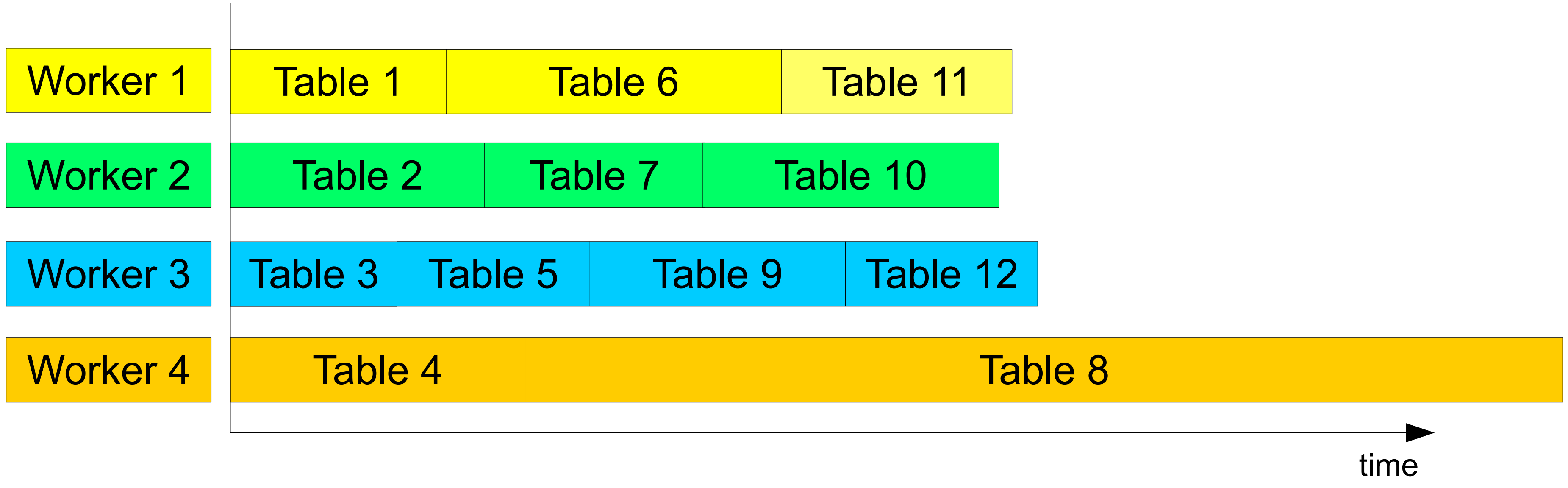
Sweep

- What can be run in parallel ?
  - Each parallel worker could handle (read and cleanup) separate table



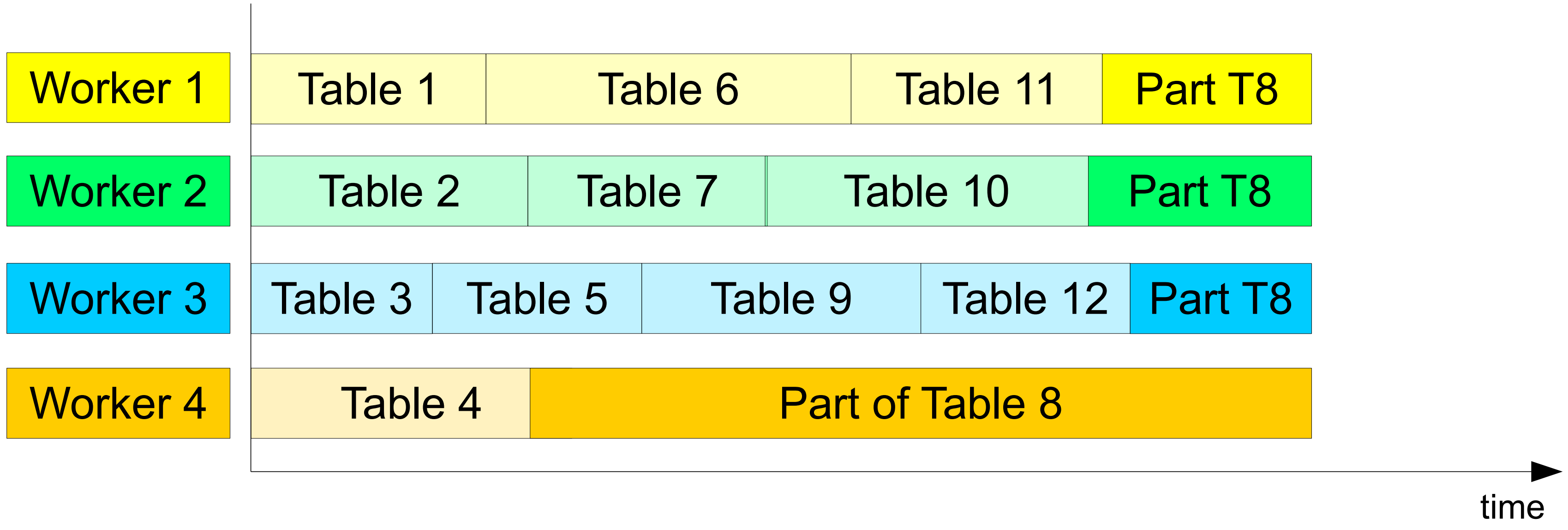
Sweep

- What if there is few big tables and many small tables ?



Sweep

- What if there is few big tables and many small tables ?
  - Big table could be handled by few parallel workers



Sweep

- How to divide big table between few workers to minimize contention and coordination ?
  - Every worker could handle one data page and then ask for a next (not handled) one
    - Almost fair distribution of workload
    - No contention for the same data pages
    - Some contention for the same pointer page
    - Coordinate with manager very often

Sweep

- How to divide big table between few workers to minimize contention and coordination ?
  - Every worker could handle few data pages and then ask for a next (not handled) few pages
    - How much ?

Sweep

- How to divide big table between few workers to minimize contention and coordination ?
  - Every worker handle data pages from the same pointer page and then ask for a next (not handled) pointer page
    - Workload distribution still fair enough
    - No contention for the same data pages
    - No contention for the same pointer page
    - Coordinate with manager not too often

Sweep

- Implementation details
  - Single attachment can’t be handled by concurrent threads simultaneously
  - Every worker have its own private attachment and transaction
  - Internal pool of worker attachments
    - Per database and per server process
    - Limited by value of new configuration setting

      MaxParallelWorkers
    - Created automatically when required
    - Works in the same server process
    - Closed automatically when last connection to the database is gone

Sweep

- Usage
  - gfix -sweep *-parallel 4* <database>
    - Run sweep using 4 parallel attachments
      - 1 user attachment and 3 additional worker attachments
  - New DPB tag

    `isc_dpb_parallel_workers`

Sweep

- Usage
  - Auto-sweep also could run in parallel mode
    - New configuration setting *ParallelWorkers*

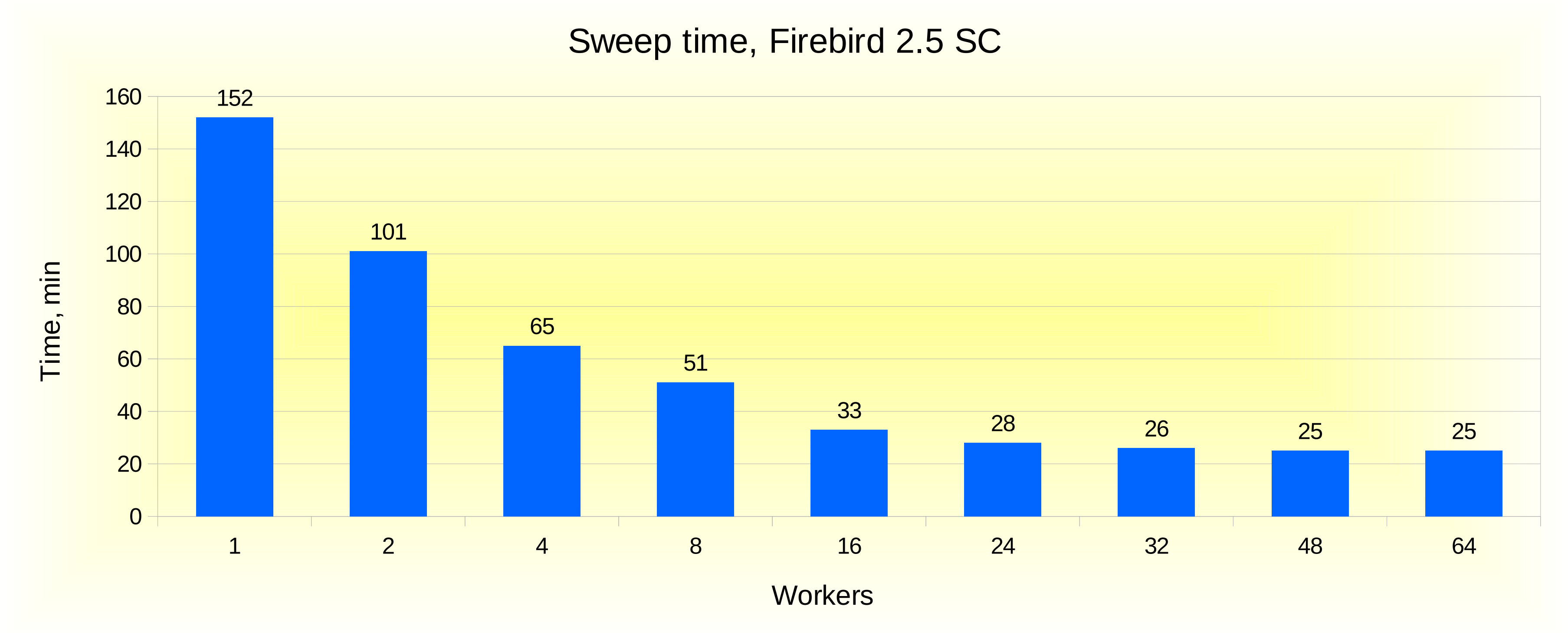
Sweep

- Test results
  - Big database

Test environment 1	
Firebird version	2.5.9 HQBird
OS	CentOS 6.7
Server	ProLiant DL380 Gen9
CPU	2 x Intel(R) Xeon(R) CPU E5-2667 v3 @ 3.20GHz
Cores per socket	8
Logical CPU's	32
RAM	96 GB
HDD	4xHDD SAS 15k RAID 10
Database	510 GB

Sweep

- Test results
  - Big database

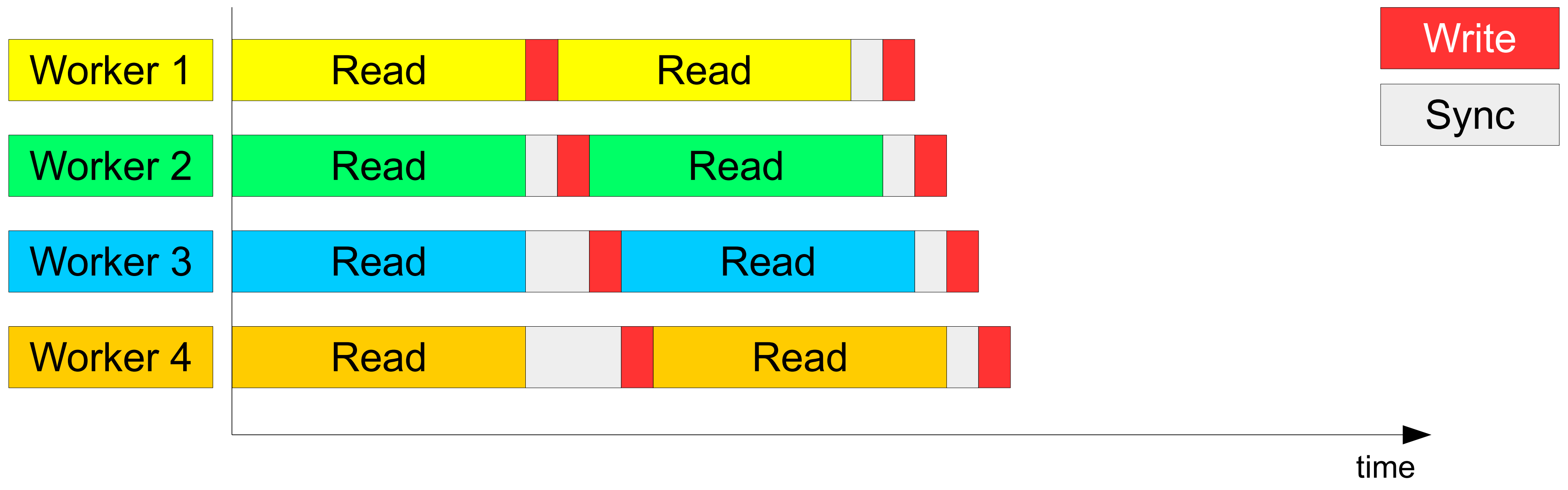


Backup

- How backup works
  - Read system tables and store user metadata in backup file
  - Read user tables and store records in backup file

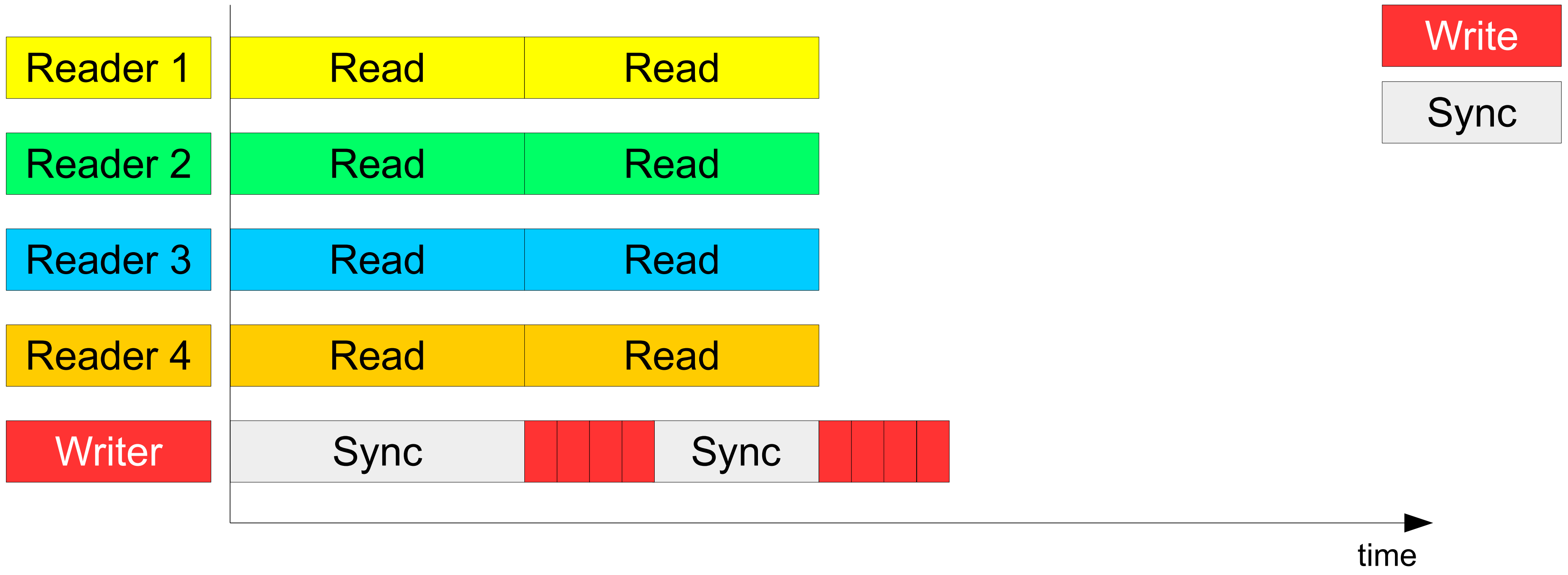
Backup

- What can be run in parallel ?
  - Parallel workers could read database independently, but backup file should be written in correct order
    - Serialize workers when backup file is written



Backup

- What can be run in parallel ?
  - Parallel workers could read database independently, but backup file should be written in correct order
    - Move all write activity into another dedicated thread



Backup

- What can be run in parallel ?
  - Read and store metadata
    - Could be done but
      - It will significantly complicate code
      - Amount of metadata usually much less than size of user data

Backup

- What can be run in parallel ?
  - Read and store user data
    - Handle different tables by parallel workers
      - Backup file will contain mix of records from different tables
      - Requires change in backup file structure to allow restore to handle such file
      - “Big table” problem as in sweep case

Backup

- What can be run in parallel ?
  - Read and store user data
    - Parallel workers should handle different parts of the same table
    - Requires a way to split table by parts
      - Ideally parts of the equal size

Backup

- How to split table for few parallel workers ?
  - Use ranges of primary\unique key values
    - Not every table could have primary\unique key
    - Unknown in advance whole range of key values
    - Uneven distribution of key values
    - How to make ranges for character keys ?
    - How to make ranges for composite (multi-segment) keys ?

Backup

- How to split table by few parallel workers ?
  - Use ranges of data pages
    - gbak works “outside” of the engine, it can’t address data pages directly
  - Use ranges of RDB$DB_KEY values
    - Engine supports equality comparison only for RDB$DB_KEY
    - Application (gbak) have no idea what data page is addressed by given RDB$DB_KEY value
    - <u>Need some support from the engine side</u>

Backup

- Use ranges of RDB$DB_KEY values
  - New built-in function MAKE_DBKEY
    - MAKE_DBKEY(relation_id, recnum)
      - Returns dbkey for record *recnum*
    - MAKE_DBKEY(relation_id, recnum, dpnum)
      - Returns dbkey for *recnum* at data page *dpnum*
    - MAKE_DBKEY(relation_id, recnum, dpnum, ppnum)
      - Returns dbkey for *recnum* at data page *dpnum* at pointer page *ppnum*
  - Engine now supports all kind of comparisons with RDB$DB_KEY (<, <=, >, >=, =, !=)

Backup

- How to split table for few parallel workers ?
  - Every worker handle records from the data pages from the same pointer page and then ask for a next (not handled) pointer page

```
SELECT * FROM TABLE
 WHERE RDB$DB_KEY >= MAKE_DBKEY(:relId, 0, 0, :ppNum)
   AND RDB$DB_KEY  < MAKE_DBKEY(:relId, 0, 0, :ppNum + 1)
```

Backup

- Backup consistency
  - gbak uses snapshot transaction to read user data in consistent way
  - Every worker uses own attachment and transaction
  - All worker attachments should read the same data despite of other activity in database
  - <u>Need shared database snapshot</u>

Backup

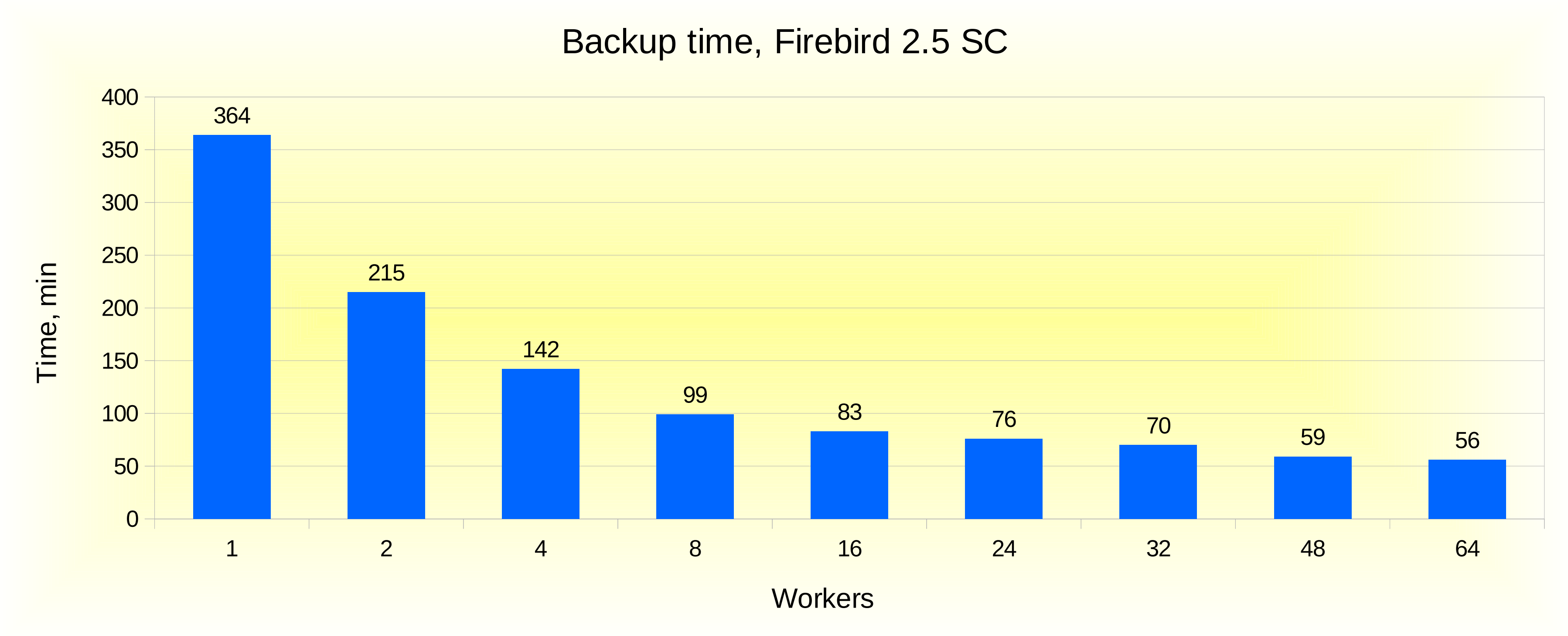
- Shared database snapshot
  - First introduced in Firebird 4 beta
    - Based on new database snapshots architecture using commits order
  - Re-implemented for Firebird 2.5 and Firebird 3 specially to support parallel backup
  - Follows the same interface as of Firebird 4

Backup

- Usage
  - gbak -b -parallel 4 <database> <backup>

Backup

- Test results
  - Big database



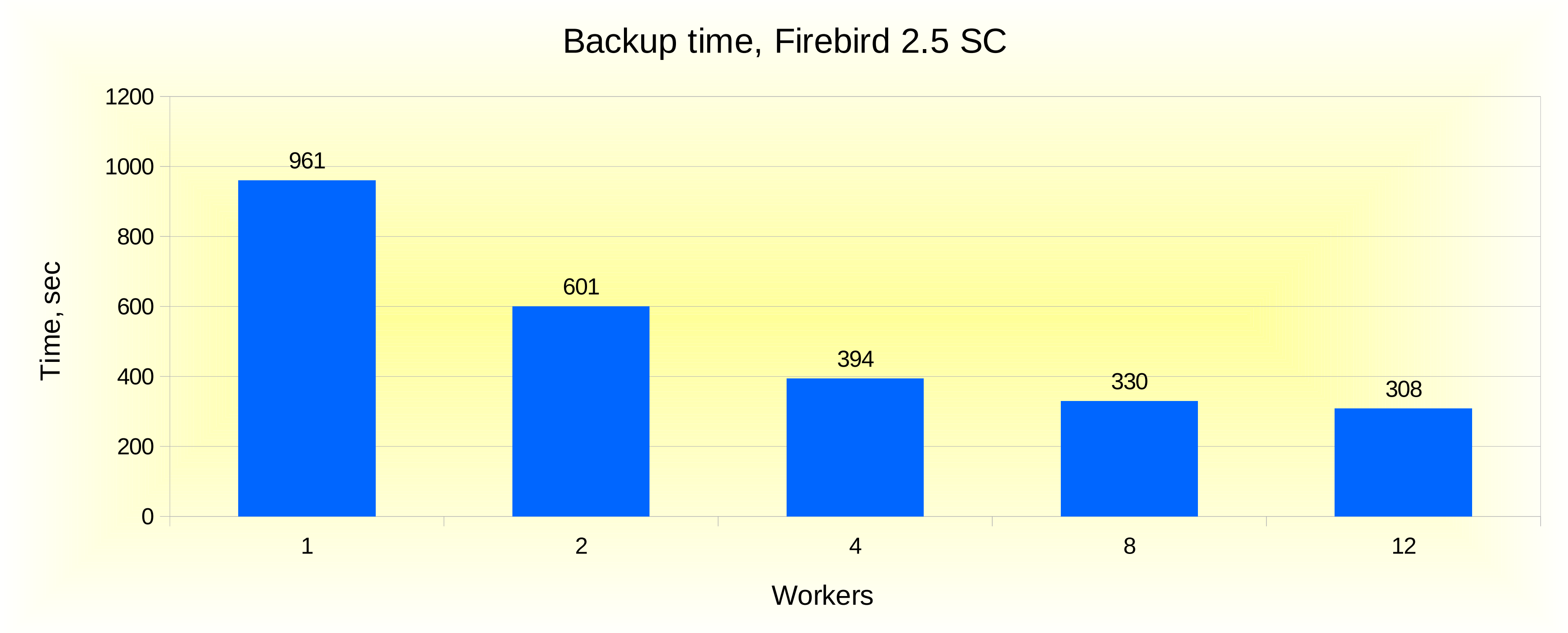
Backup

- Test results
  - Medium database

Test environment 2	
Firebird version	2.5.9 HQBird, 3.0.5 HQBird
OS	CentOS 6.7
Server	ProLiant DL380 Gen9
CPU	2 x Intel(R) Xeon(R) CPU E5-2620 v3 @ 2.40GHz
Cores per socket	6
Logical CPU’s	24
RAM	32 GB
HDD	4xHDD SAS 10k RAID 10
Database	42 GB

Backup

- Test results
  - Medium database



Restore

- How restore works
  - Create new database
  - Read metadata and populate system tables
  - Read data and populate user tables
  - Activate (build) indices

Restore

- What can be run in parallel ?
  - Create new database
    - no
  - Read metadata and populate system tables
    - not practical
  - Read data and populate user tables
    - yes
    - probably, requires changes in backup format
    - not now, sorry
  - Activate (build) indices
    - yes, exactly

Restore

- How indices are build at restore
  - Index metadata is created with table metadata
    - Indices are created with *DEFERRED_ACTIVE* flag
  - Indices are activated (build) after all user data is committed
  - Index is actually build at transaction commit
  - Every index is activated in separate transaction

Index build

- Index build steps
  - Read table data
    - Remove unneeded record versions (garbage collect)
    - Put index keys into the sorter
  - Build index b-tree using already sorted data

Index build

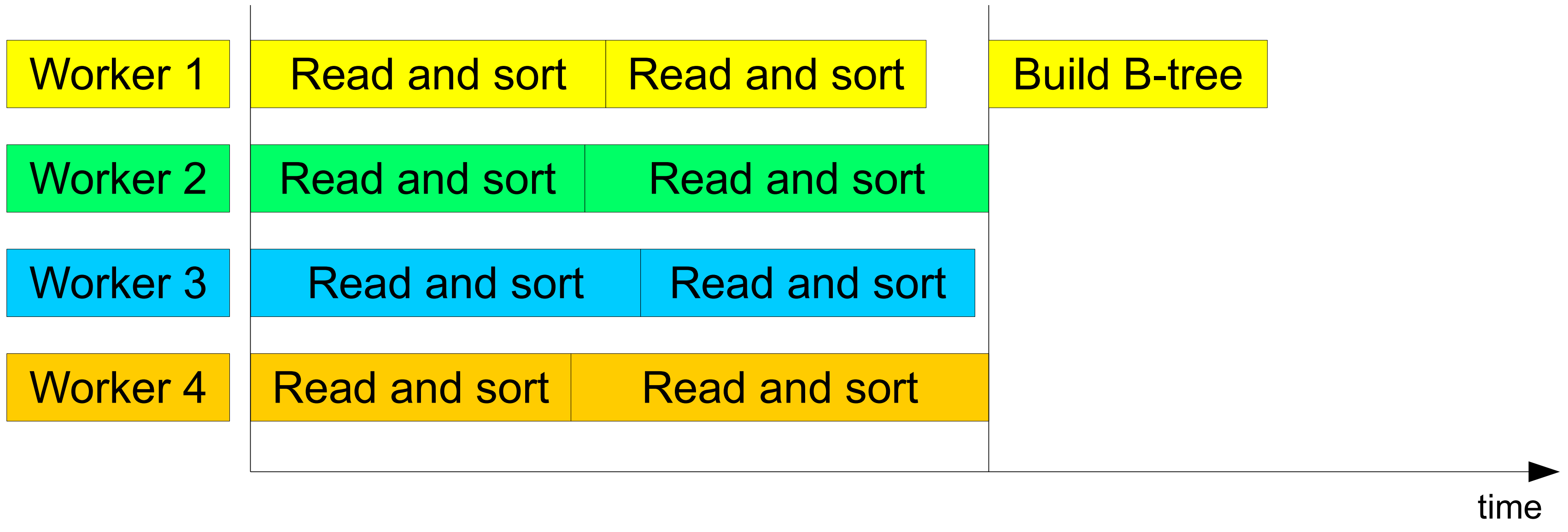
- What can be run in parallel ?
  - Read table and sort index keys
    - Yes
  - Build index B-tree
    - Non-trivial task: prefix compression of index keys
    - Not now, maybe later

Index build

- What can be run in parallel ?
  - Read table and sort data
  - Every worker handle records of data pages from the same pointer page and then ask for a next (not handled) pointer page
  - Every worker have its own attachment, transaction and sorter
- On the “B-tree build” step data from all sorters are merged into common sorted stream
  - By single thread

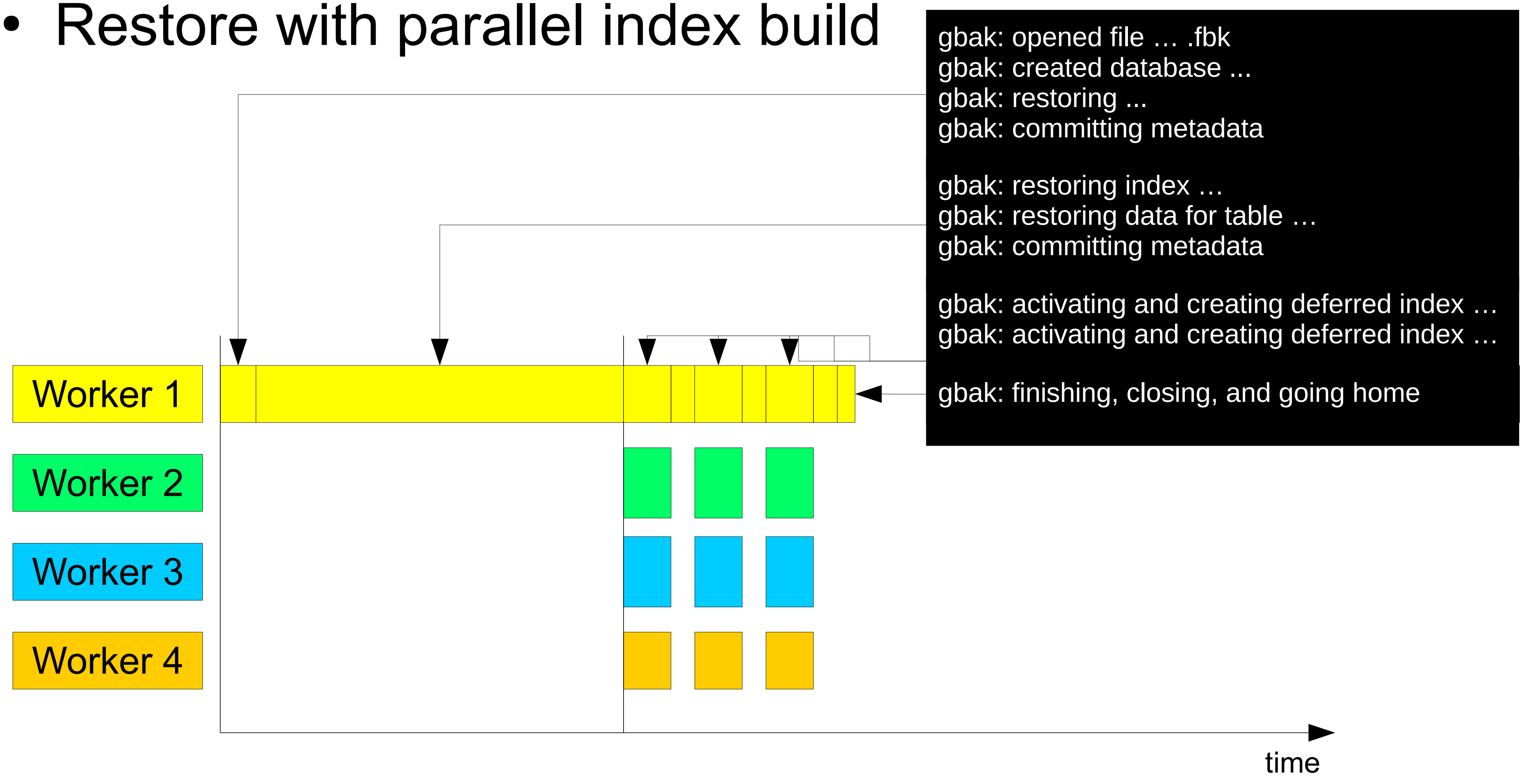
Index build

- What can be run in parallel ?



Restore

- Restore with parallel index build



```
gbak: opened file … .fbk
gbak: created database ...
gbak: restoring ...
gbak: committing metadata

gbak: restoring index …
gbak: restoring data for table …
gbak: committing metadata

gbak: activating and creating deferred index …
gbak: activating and creating deferred index …

gbak: finishing, closing, and going home
```

Restore

- What can be improved next ?
  - Parallel load of user data into database
    - Backup file format could be changed
  - Create few indices simultaneously at one table scan
    - Temporary space usage could be significantly increased

Restore

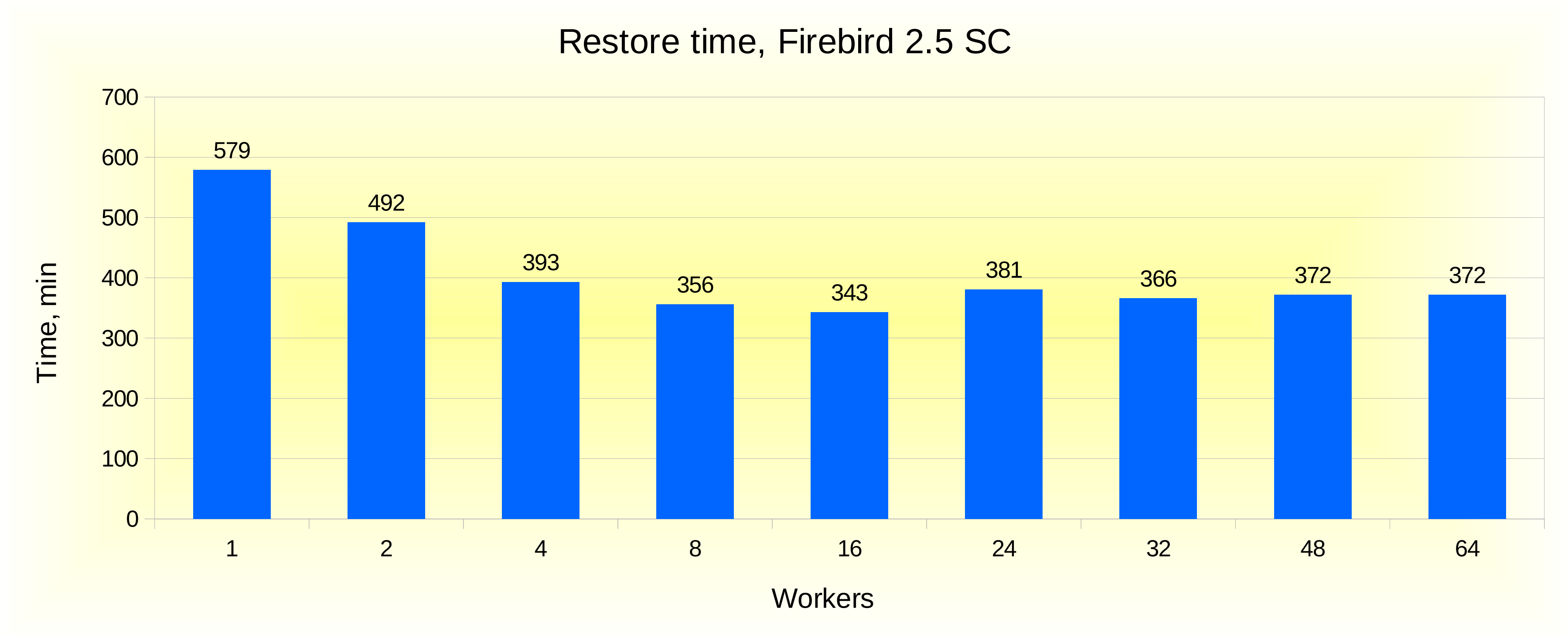
- Usage
  - gbak -c -parallel 4 <backup> <database>
  - Any application
    - DPB tag `isc_dpb_parallel_workers`
      - instruct engine how many parallel workers could be used for some tasks
      - currently index creation and auto-sweep supports such parallel handling

Index build

- Usage
  - Regular *CREATE INDEX* and *ALTER INDEX ACTIVE* statements also could build index with parallel workers
    - Configuration setting *ParallelWorkers*
    - DPB tag **`isc_dpb_parallel_workers`**

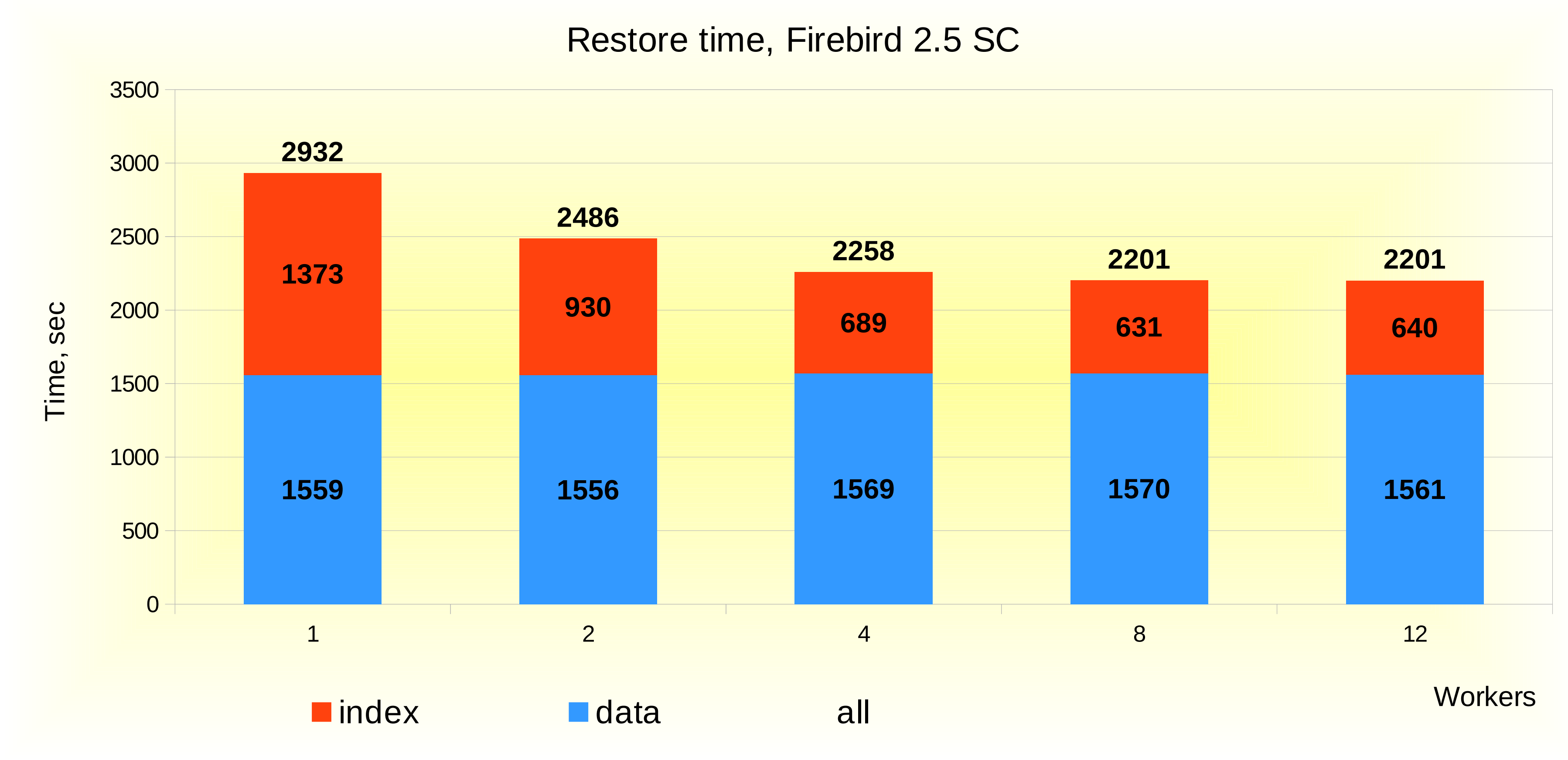
Restore

- Test results
  - Big database



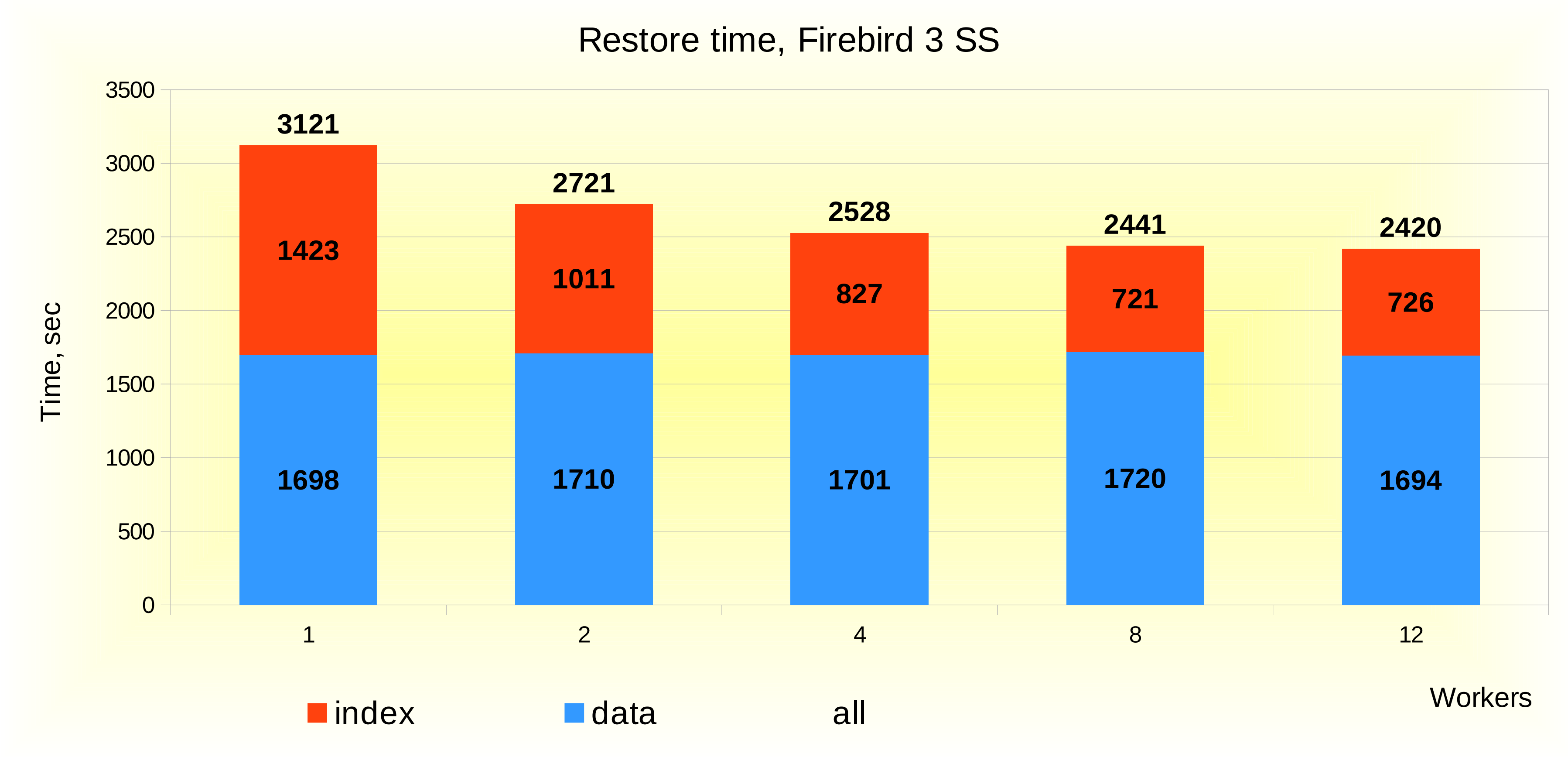
Restore

- Test results
  - Medium database



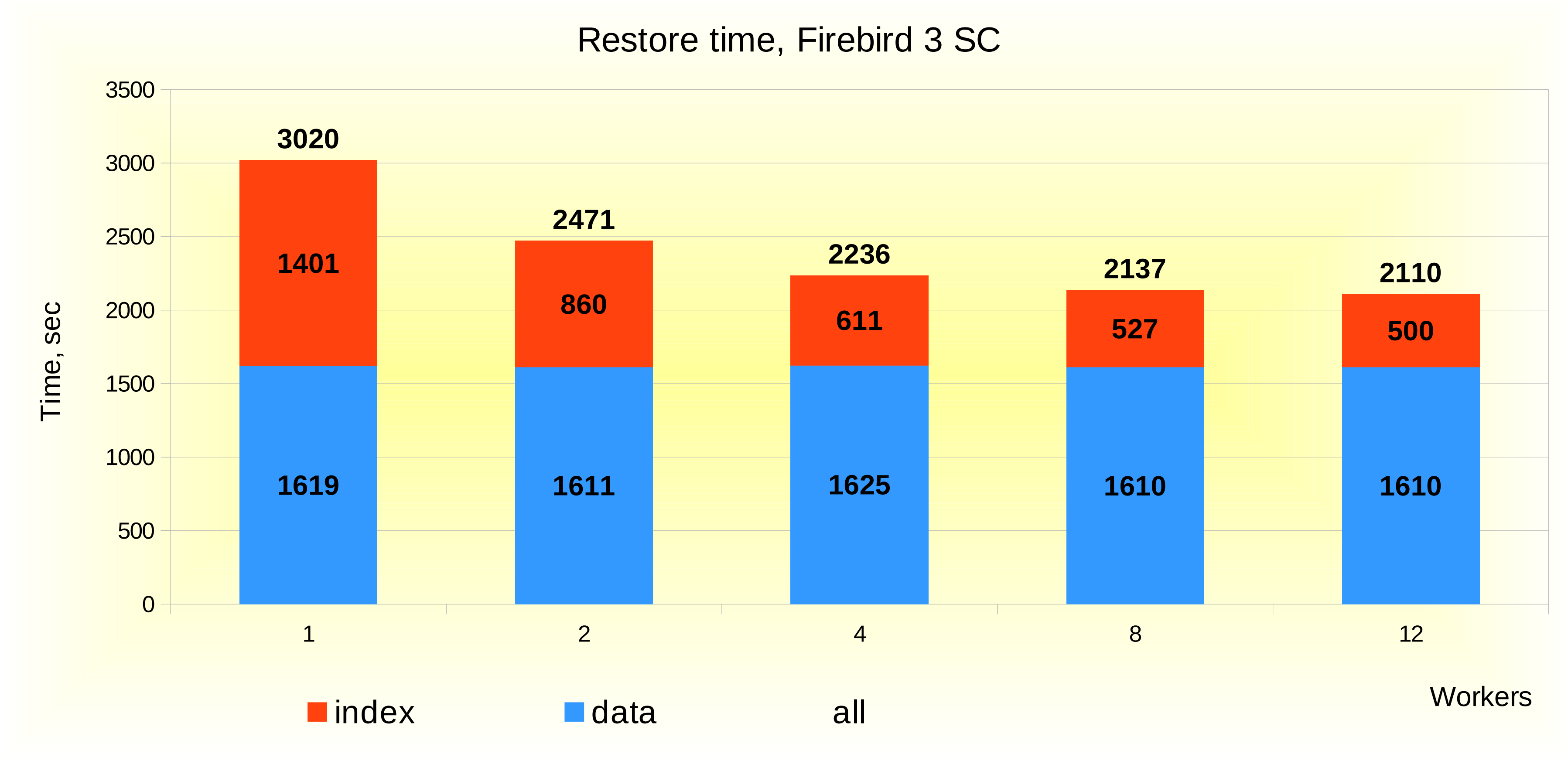
Restore

- Test results
  - Medium database



Restore

- Test results
  - Medium database



All together

- Firebird now could run tasks using multiply workers/threads
- Some tasks used parallelism built into engine
  - Sweep
  - Index build, gbak -restore
- Some tasks used parallelism “outside” of the engine
  - gbak -backup
- This list will be enhanced
  - Validation, Statistics
  - Query execution

All together

- firebird.conf, per database settings
  - *MaxParallelWorkers*
    - Set maximum number of parallel workers per Firebird process
  - *ParallelWorkers*
    - Set default number of parallel workers used to run some task
- DPB tag
  - **`isc_dpb_parallel_workers`**
    - Set number of parallel workers used to run some task by current attachment (overrides *ParallelWorkers* setting)

THANK YOU FOR ATTENTION

Questions ?

[Firebird official web site]

[Firebird tracker]

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