PERFORMANCE IMPROVEMENTS IN SQL SERVER 2019

Albuquerque SQL Server User Group (ABQSQL)

March 12, 2021

ABOUT ME

In IT for 21 years, 13 of it working with SQL Server

Senior Data Engineer at Concurrency, Inc.

Learning more about Azure every day

Lover of all things internal to SQL Server

When not working with the Microsoft Data Platform I love to read, volunteer at the Art Institute of Chicago, and hang out with my cat

Twitter - @skreebydba

Email - skreebydba@gmail.com

Blog - www.skreebydba.com

Slides and Scripts - https://github.com/skreebydba/MinnesotaPresentation

WHAT WE WILL COVER

Transaction log

Current crash recovery process

Accelerated Database Recovery (ADR)

ADR crash recovery process

In-memory tempdb metadata

Persistent Memory

TRANSACTIONS

Unit of work in the database

All transactions begin

Transactions can commit or rollback

Default behavior is auto-commit

TRANSACTION LOG

Records all changes to the database

Changes written to the log buffer in memory

SQL Server uses write-ahead logging (WAL)

Log buffer is flushed to disk on COMMIT or when it fills up

Data pages associated with transactions can remain in memory

TRANSACTION LOG ARCHITECTURE

Transaction log contains logical units called Virtual Log Files (VLF)

VLFs can be active or free

VLFs containing log records that may be needed must be active

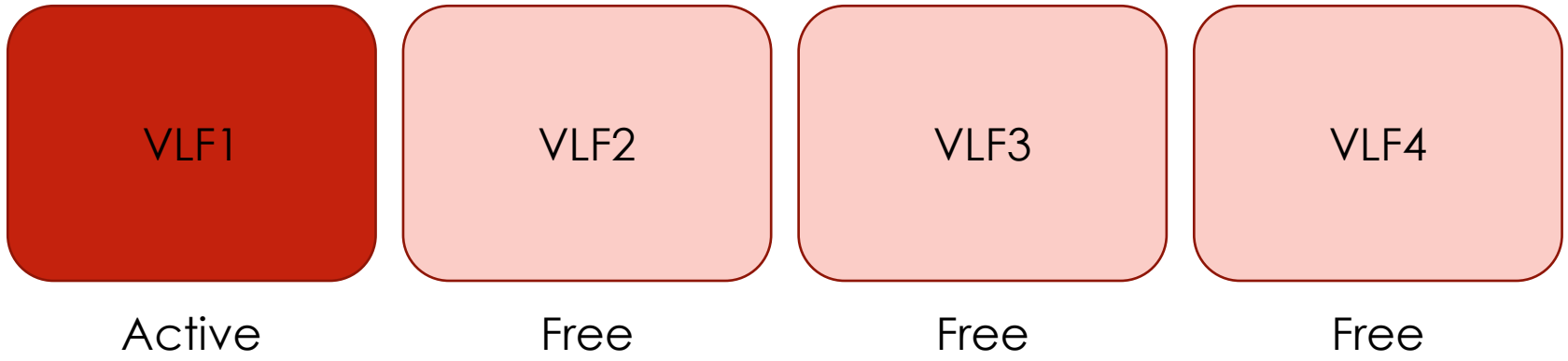
Always one active VLF

In SIMPLE recovery, VLFs freed by CHECKPOINT operation

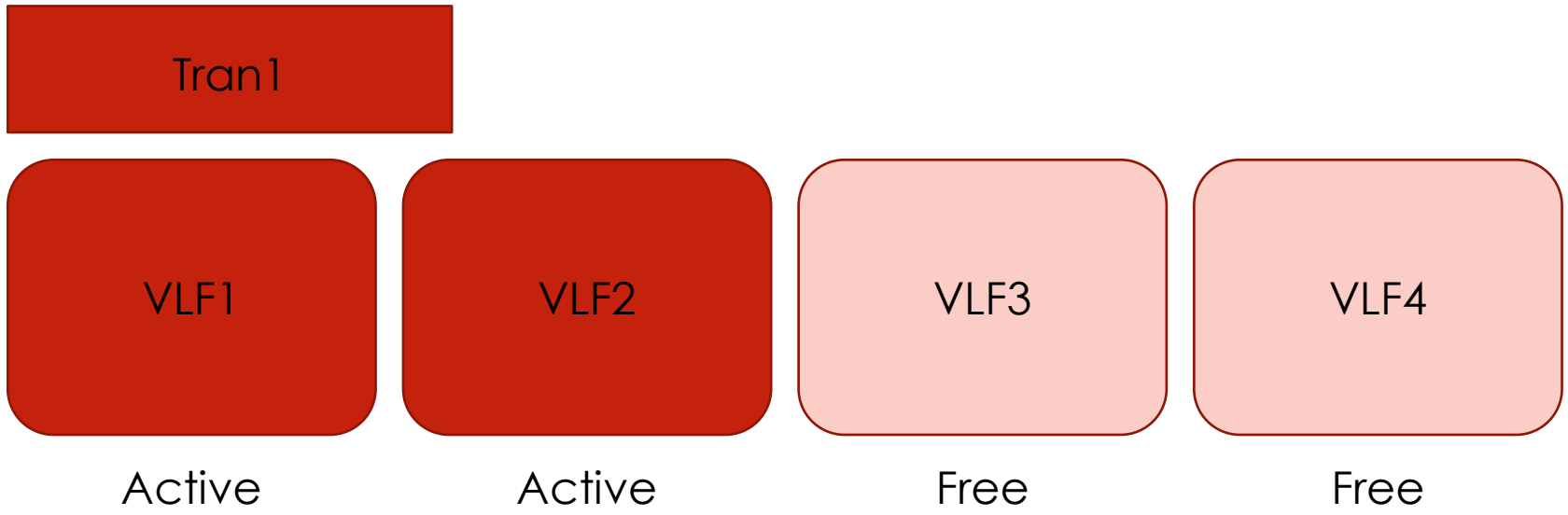
In FULL recovery, VLFs freed by LOG backup

Log records are also needed for rollback and high availability

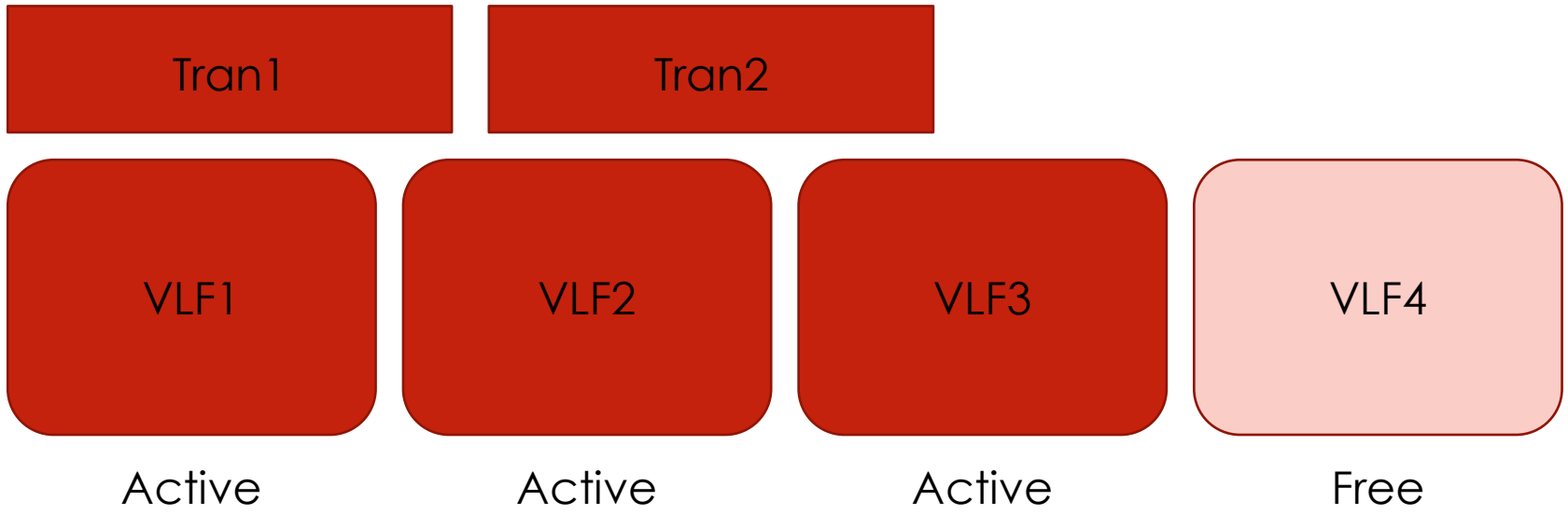
VIRTUAL LOG FILES



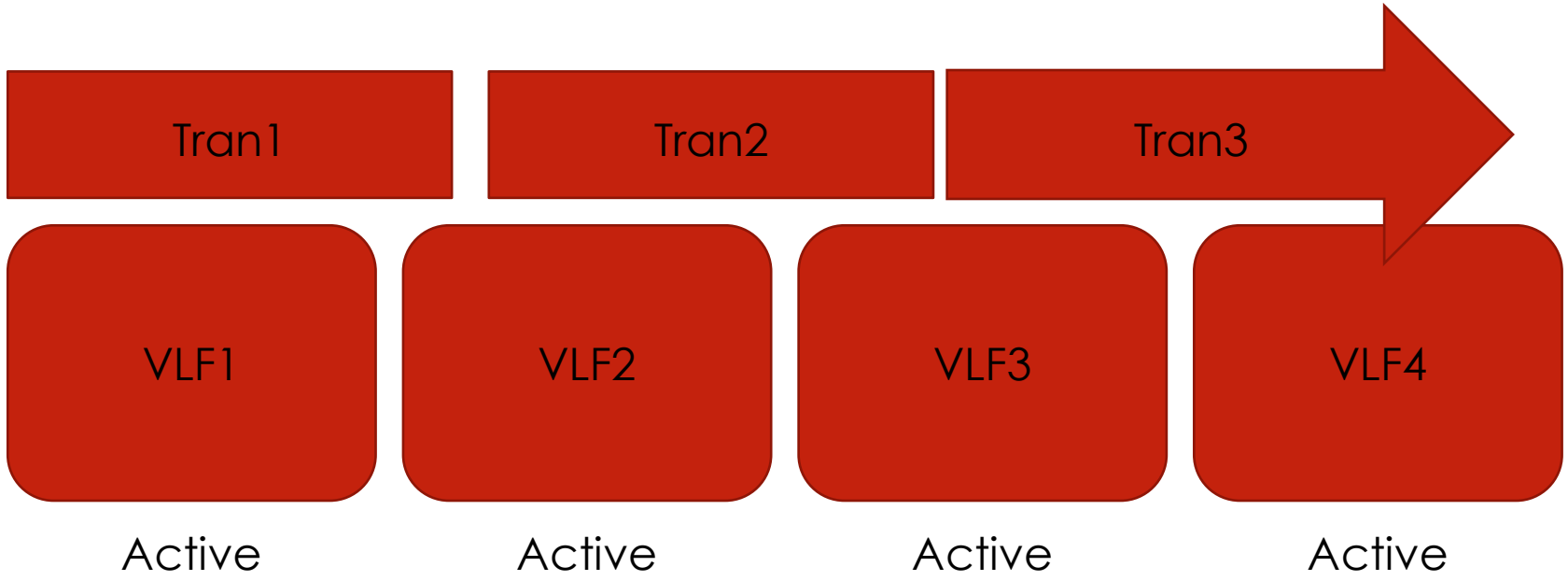
TRANSACTION 1 COMMITS



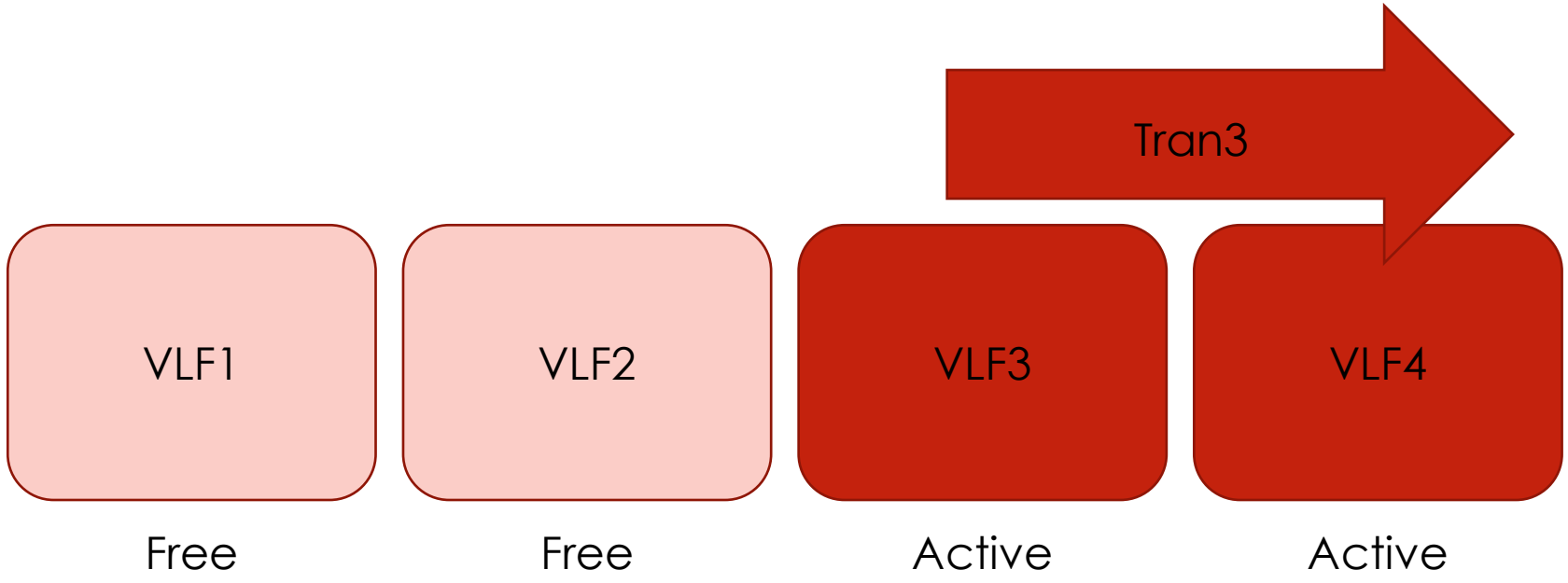
TRANSACTION 2 COMMITS



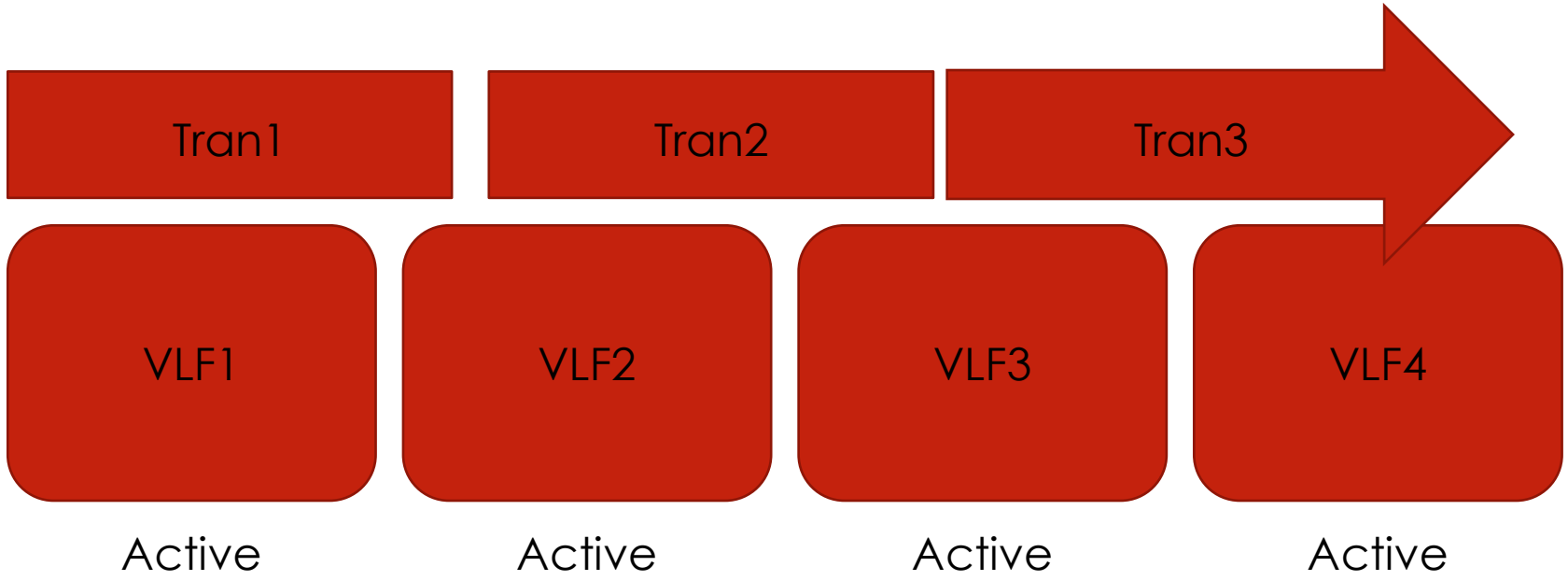
TRANSACTION 3 BEGINS



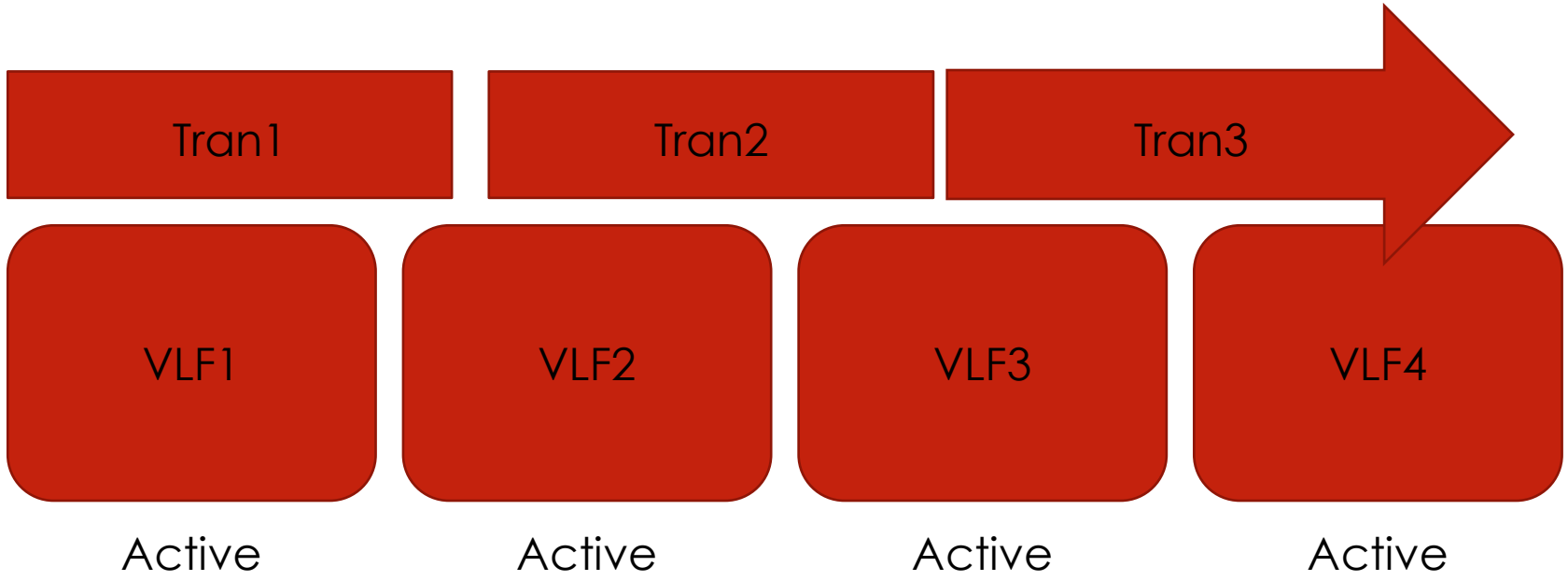
LOG BACKUP OR CHECKPOINT



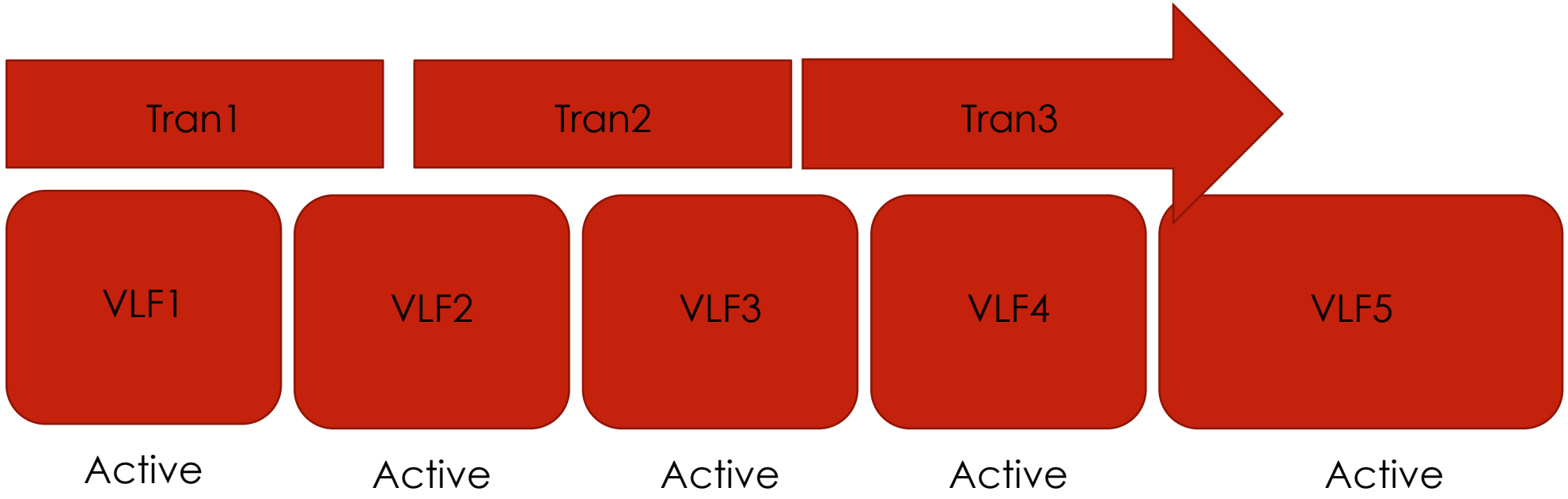
NO LOG BACKUP OR CHECKPOINT



WITH AUTOGROW



AUTOGROW ADDS VLF(S)



WITHOUT AUTOGROW

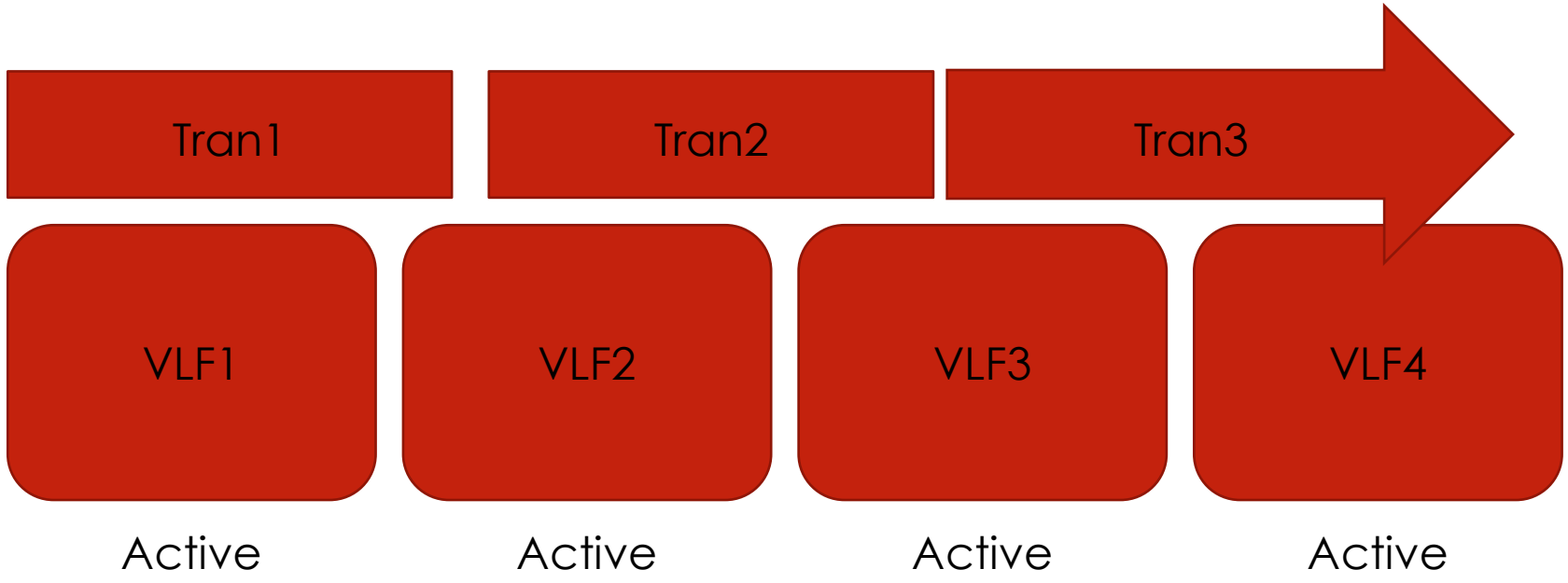


Image Source: https://tarnmoor.files.wordpress.com/2018/12/PICComputerMalfunction2.jpg

CRASH RECOVERY

SQL Server uses the transaction log to maintain consistency and durability

After the SQL Server service restarts, each database transaction log is scanned

CURRENT CRASH RECOVERY PROCESS

3 phases

Analysis – Scans log from last checkpoint searching for

- Transactions written to log file but not to data file
- Transactions not committed

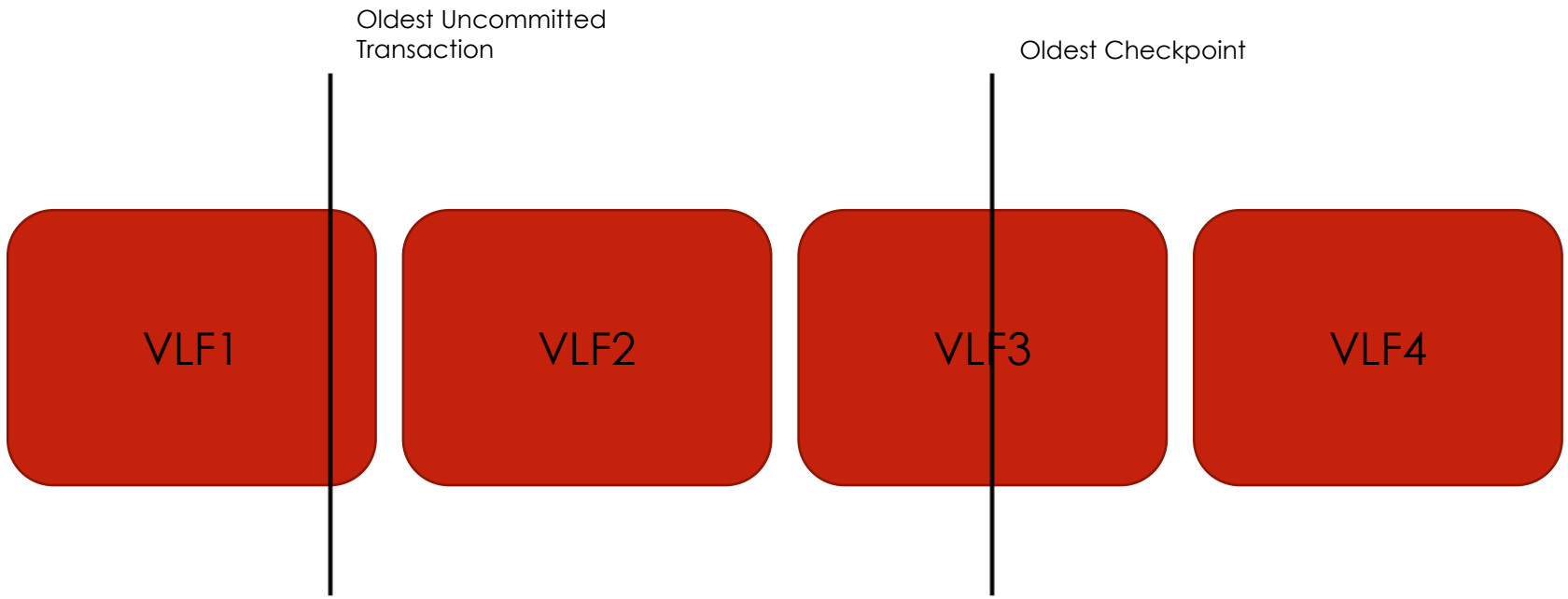
Redo

- Committed transactions hardened to disk in data file

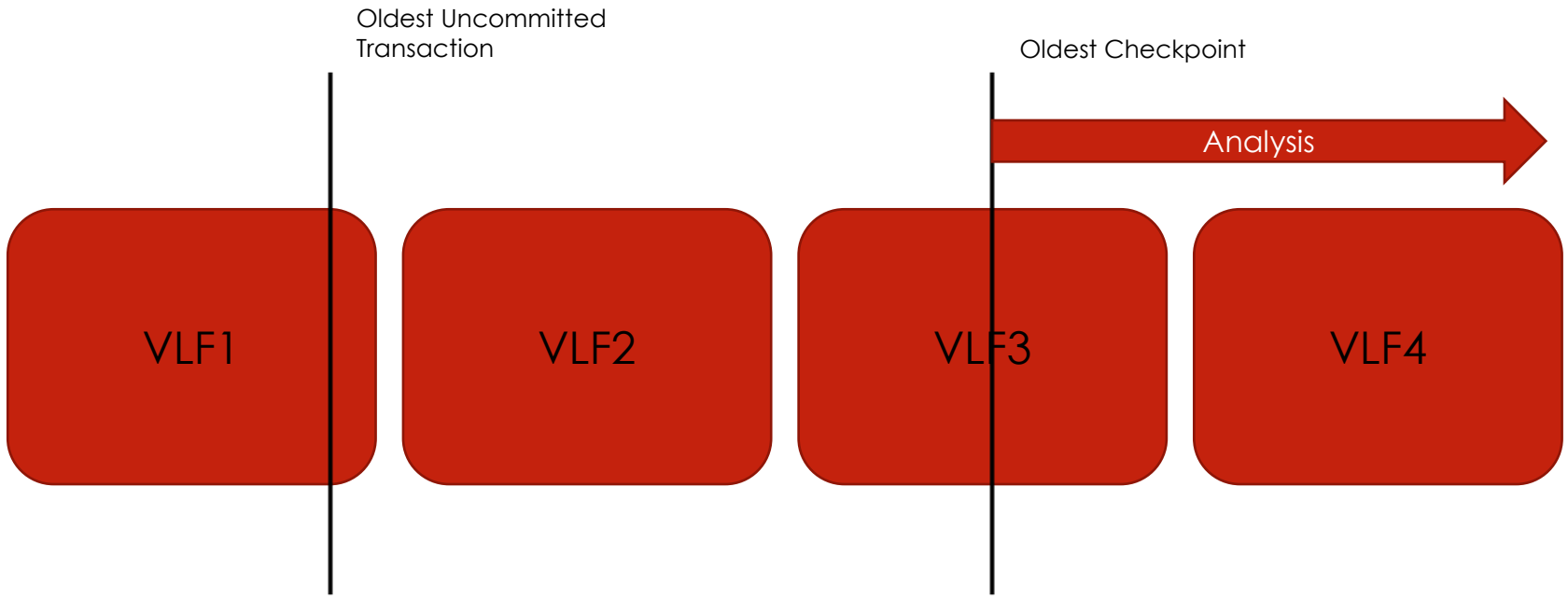
Undo

- Uncommitted transactions rolled back

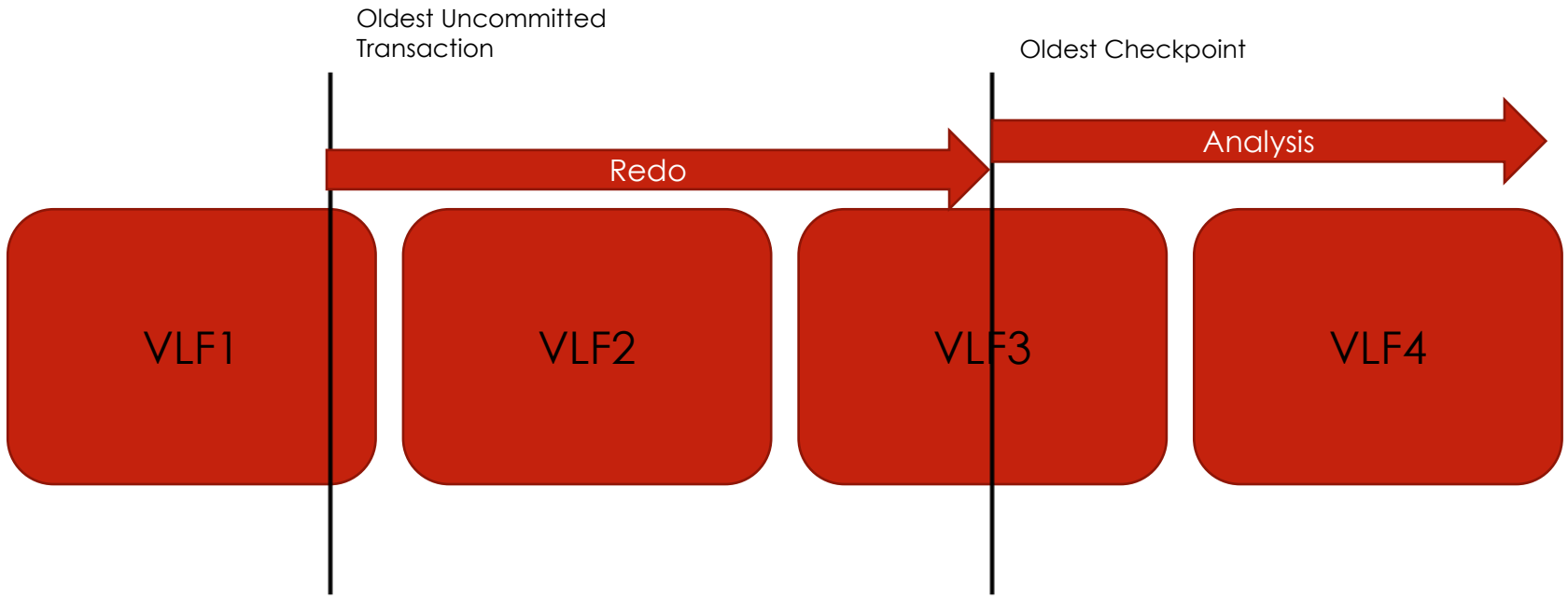
CRASH RECOVERY



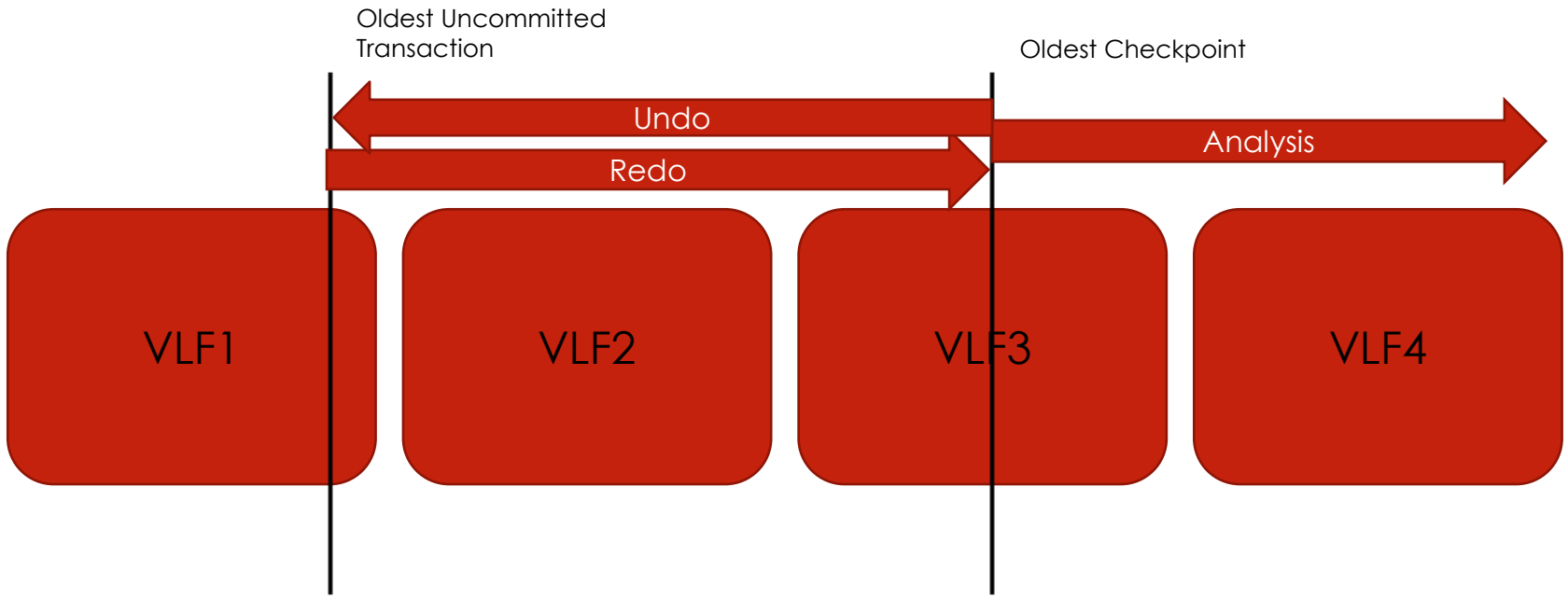
ANALYSIS


Oldest Uncommitted Transaction
Oldest Checkpoint
Analysis
VLF1
VLF2
VLF3
VLF4

REDO


Oldest Uncommitted Transaction
Oldest Checkpoint
Redo
Analysis
VLF1
VLF2
VLF3
VLF4

UNDO


Oldest Uncommitted Transaction
Oldest Checkpoint
Undo
Redo
Analysis
VLF1
VLF2
VLF3
VLF4

ACCELERATED DATABASE RECOVERY – NEW CONCEPTS

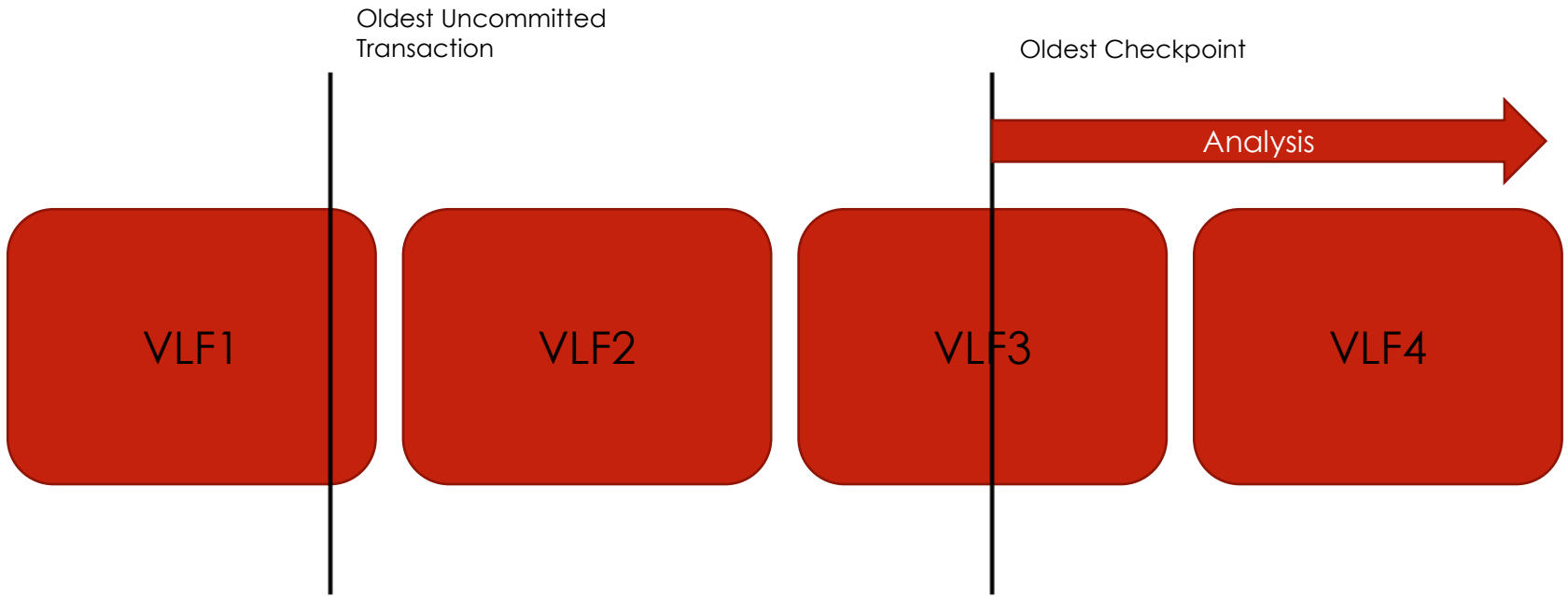
Persisted Version Store (PVS) – contains previous versions of modified rows, stored in the user database

Logical revert – On rollback, running transactions pull row version from the PVS

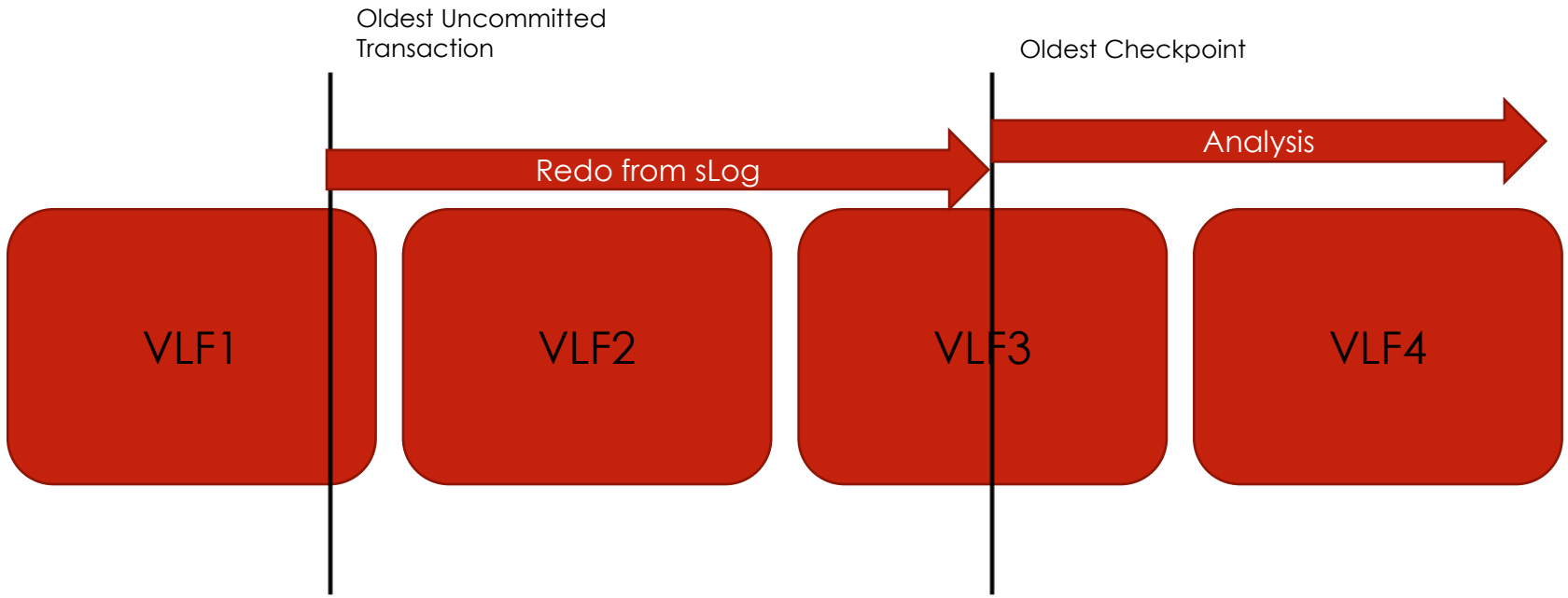
sLog – In-memory log stream that stores non-versioned activity (system metadata changes, locks for DDL, cache invalidation)

Cleaner – periodic process that cleans up unneeded row versions

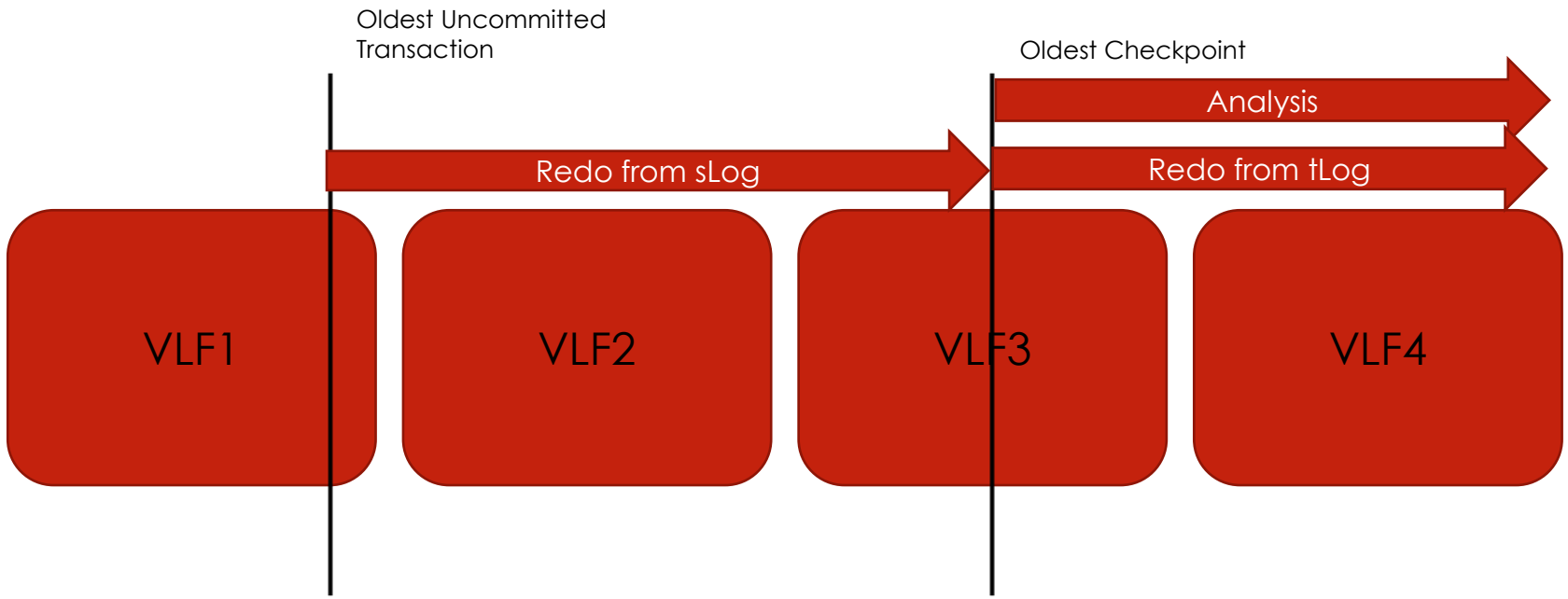
ADR ANALYSIS



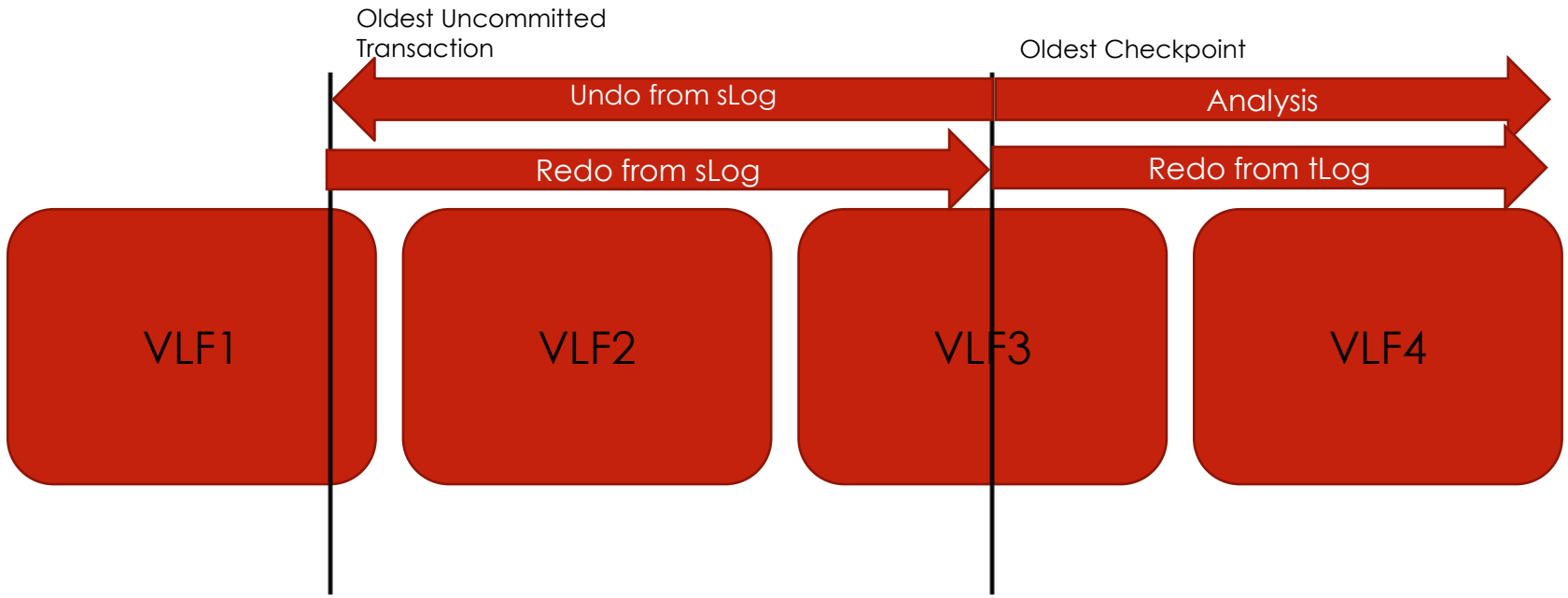
REDO FROM SLOG



REDO FROM TLOG



REDO FROM TLOG



BENEFITS OF ADR

Faster crash recovery

Faster AG failover

Faster rollback

Fast log truncation means smaller logs

BENEFITS OF ADR

Faster crash recovery

Faster AG failover

Faster rollback

Fast log truncation means smaller logs

AND!

BENEFITS OF ADR

Faster crash recovery

Faster AG failover

Faster rollback

Fast log truncation means smaller logs

AND!

It is available in Standard Edition!!!

Source: http://www.quickmeme.com/meme/3q7ogq

ACCELERATED DATABASE RECOVERY DEMO

IN-MEMORY TEMPDB METADATA TABLES

WHAT IS TEMPDB?

tempdb is one of the system databases in SQL Server

Used to create temporary objects

Used for sort space

Used by everybody

Can cause contention

ONE MAN'S OPINION

"TempDB – or as I call it…. SQL Server's public toilet. You have no idea what other filthy, disgusting things people are doing in TempDB." –Brent Ozar

Source: https://ozar.me/2013/02/why-not-everybody-loves-my-sessions/

THE OLD CONTENTION PROBLEM

Each data file contains pages to manage page allocation in the database

Because everyone uses tempdb, these pages can act as a bottleneck

THE OLD CONTENTION SOLUTION

Add data files to tempdb

This increases the number of metadata pages

SQL Server can parallelize activity

THE NEW CONTENTION PROBLEM

Each database contains system tables that store metadata about objects

Normally, this isn't a problem because objects are usually static

Because temp tables are constantly created and deleted, these tables can be bottlenecks

The problem is PAGELATCH waits

THE NEW CONTENTION SOLUTION

Create the tempdb system tables in memory

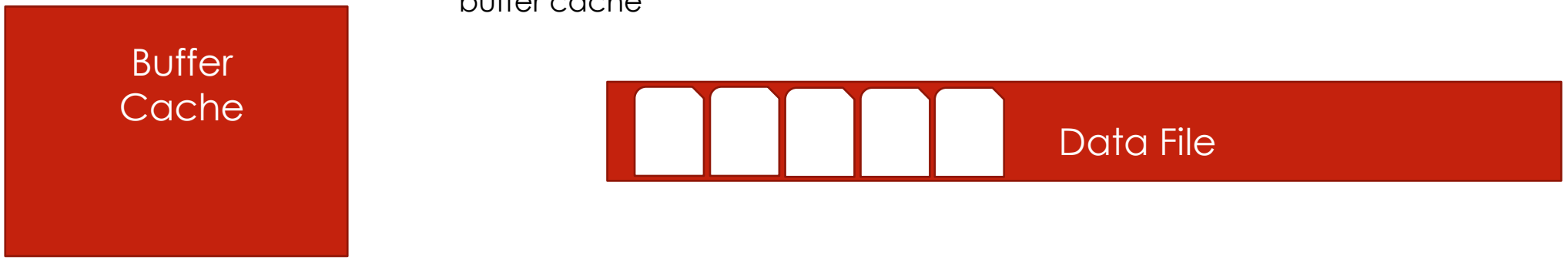
Eliminates latch contention

IN-MEMORY TEMPDB METADATA DEMO

HOW LATCHING WORKS

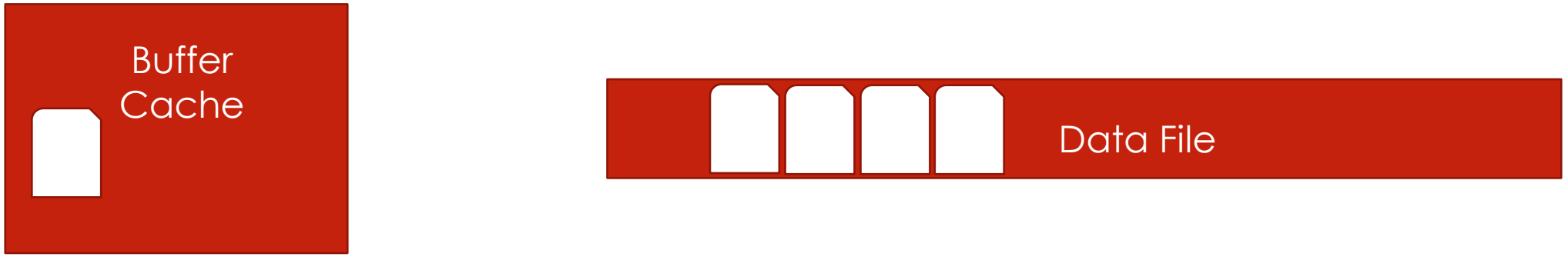
PAGE IS READ FROM DISK

SQL Server executes an UPDATE to a page not in the buffer cache



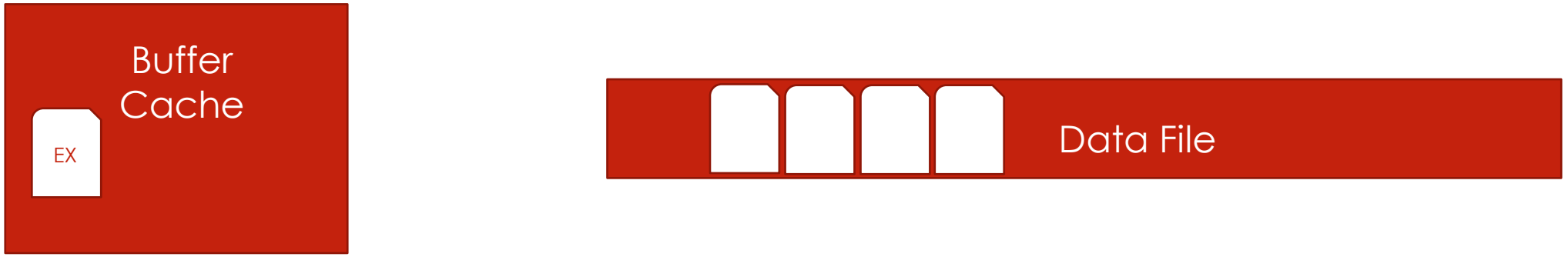
DATA IS READ

Page read into the buffer from disk



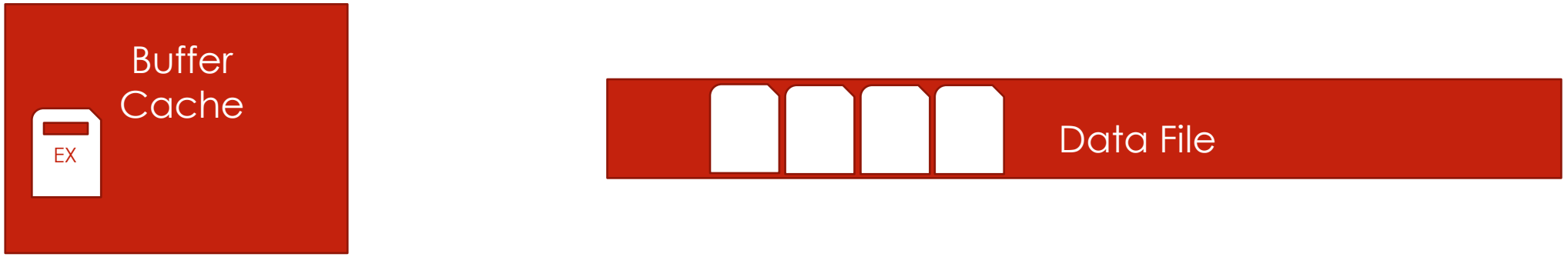
PAGELATCH_EX IS TAKEN

SQL Server takes an exclusive latch on the page to prevent collisions in-memory
While the exclusive latch is held no other processes can access the page
In the demo, all activity is updating the same row, so a single page is a bottleneck



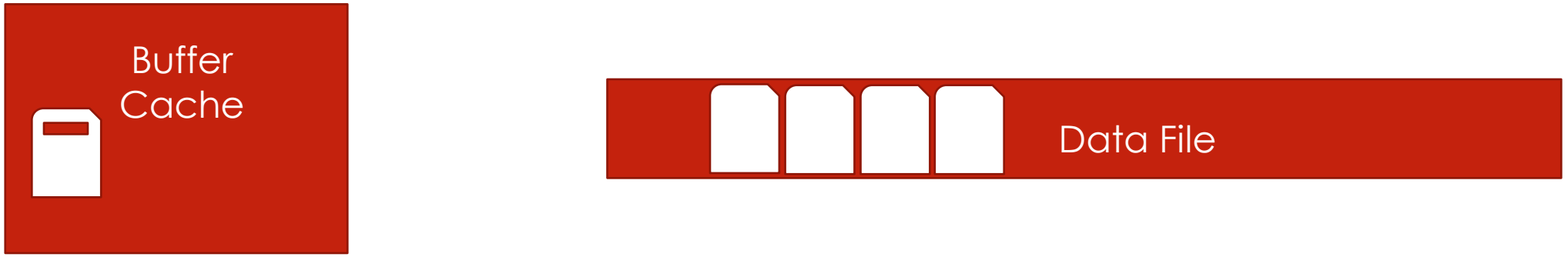
DATA IS WRITTEN TO THE PAGE

SQL Server updates data on the page



LATCH IS RELEASED

Latch is released and update completes



TEMPDB LATCHING CONTENTION

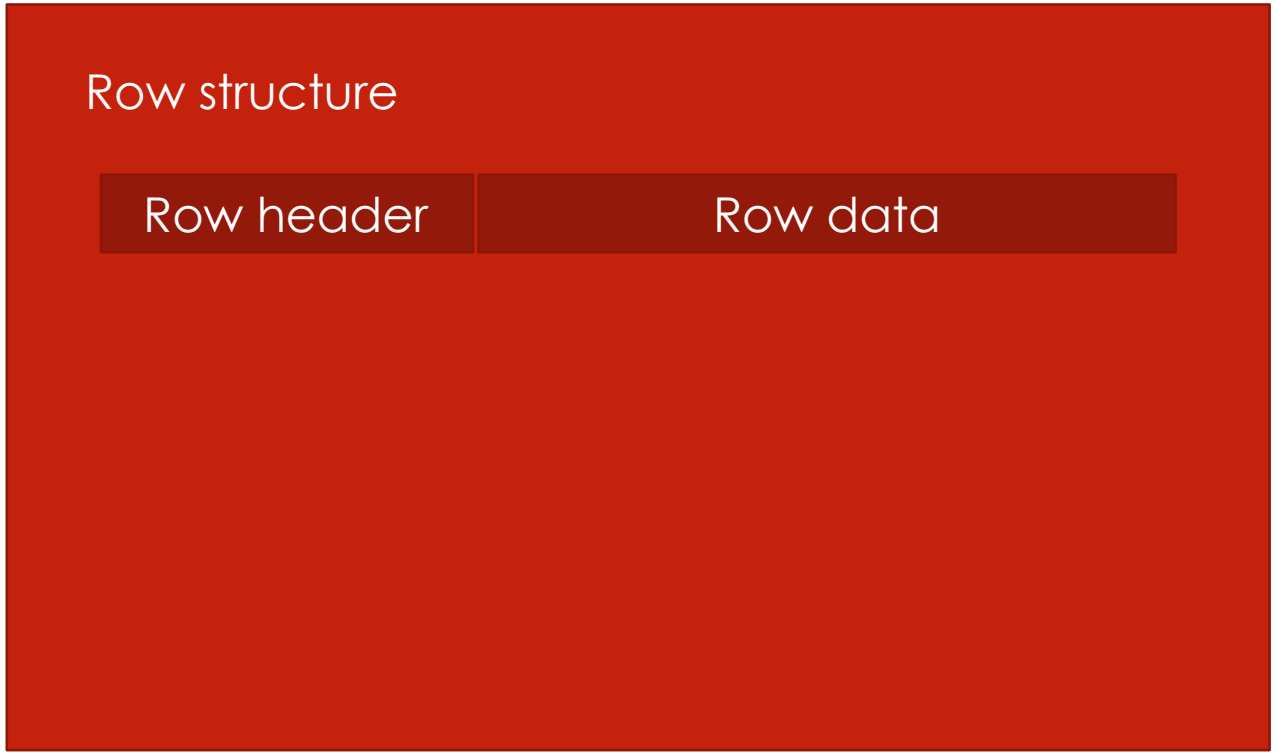
tempdb metadata pages are accessed for each creation or deletion of a temp table

Each access requires a latch

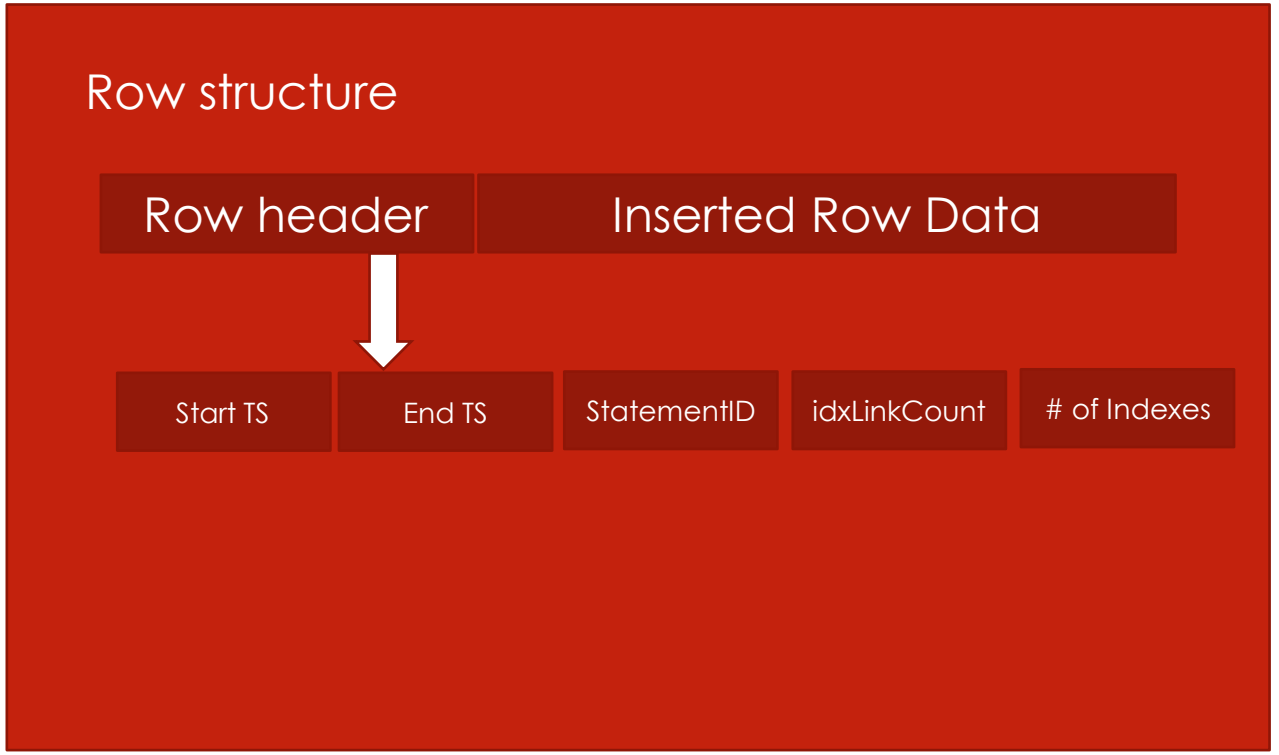
Latch contention can occur

Negative impact to performance

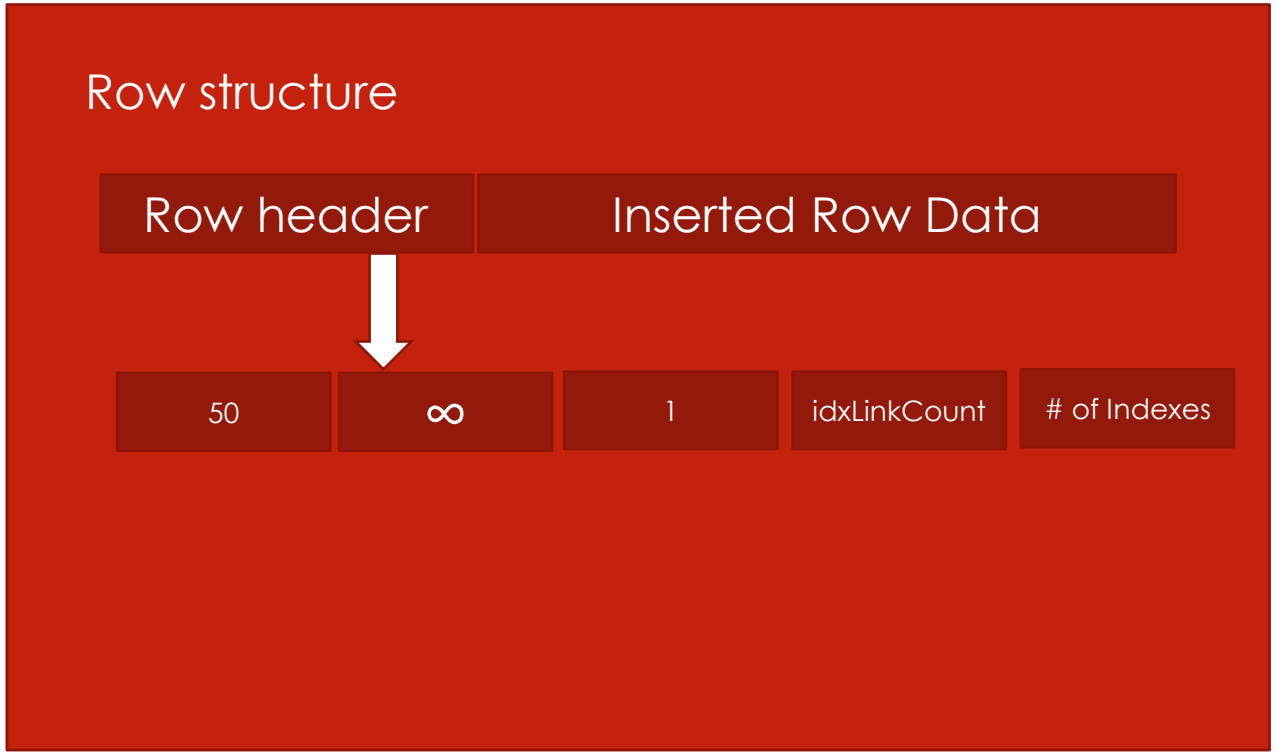
IN-MEMORY ROW STRUCTURE



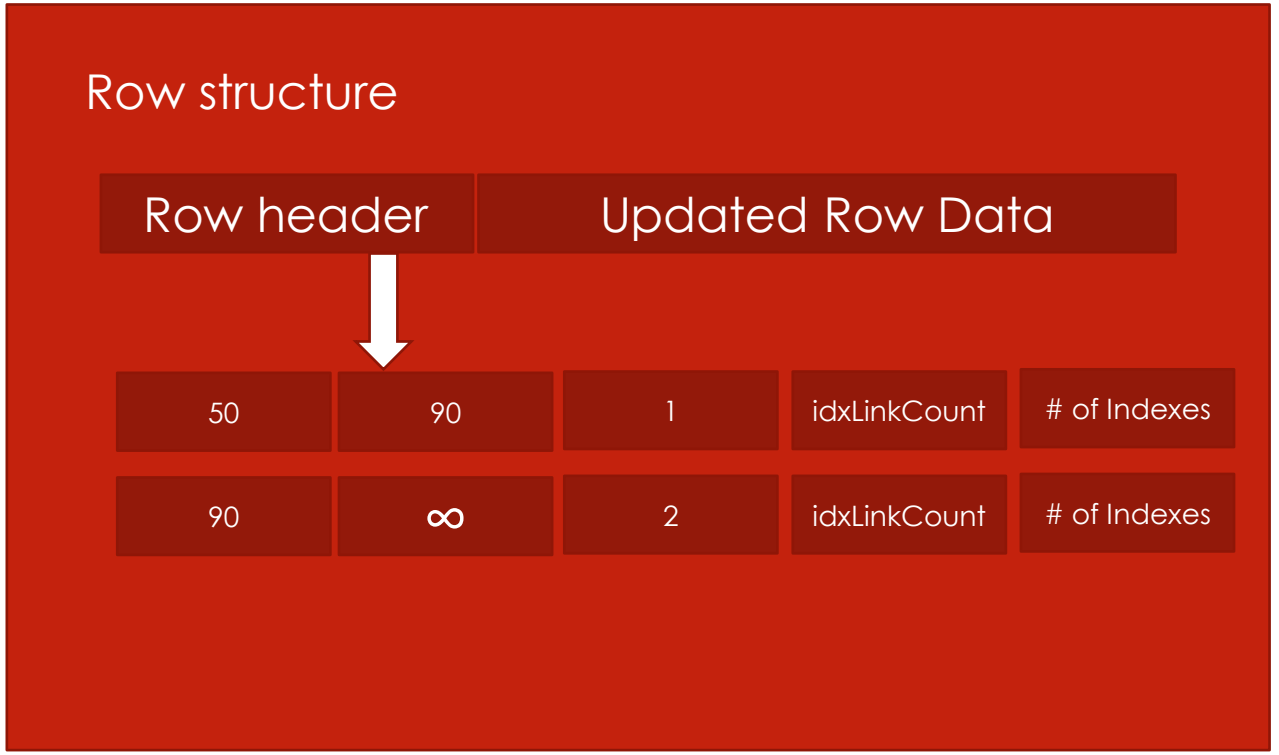
ROW HEADER


Row structure
Row header
Inserted Row Data
Start TS
End TS
StatementID
idxLinkCount
# of Indexes

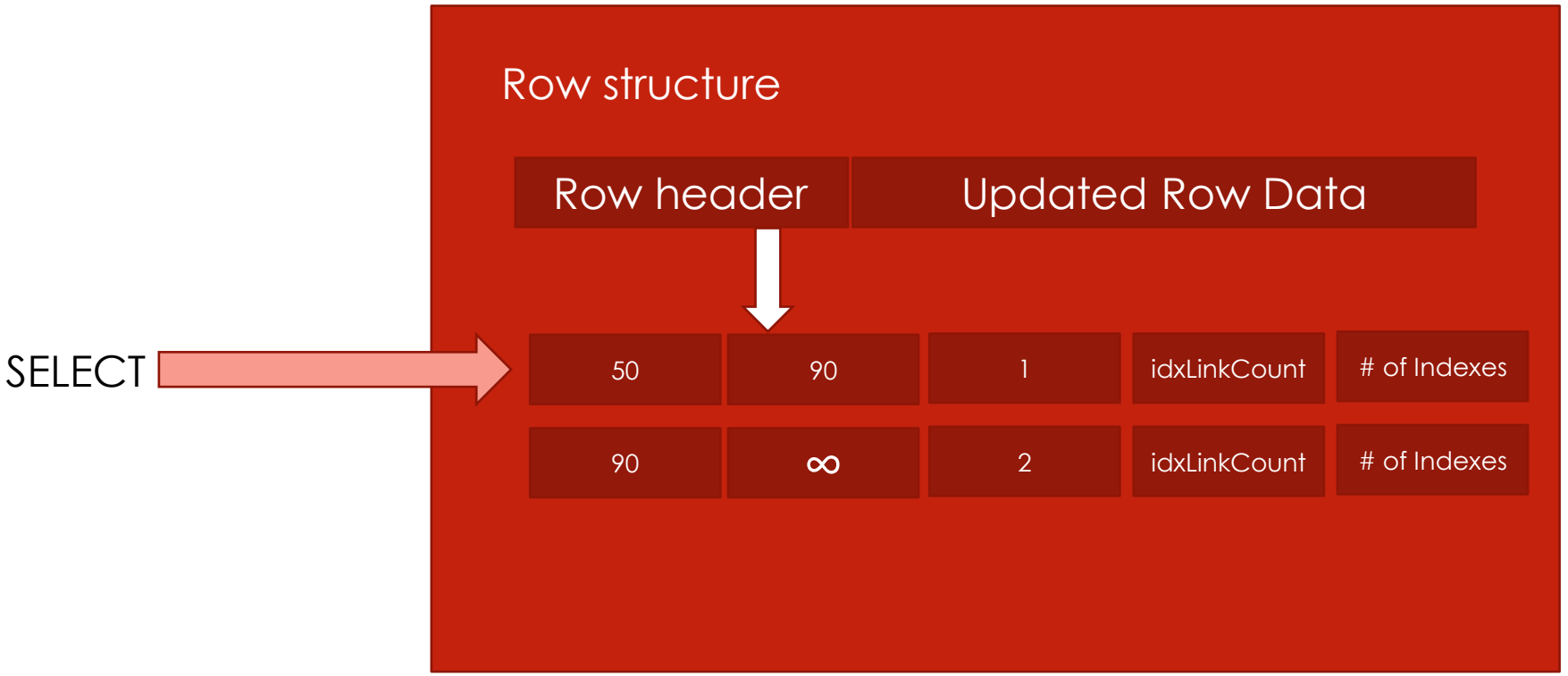
IN-MEMORY INSERT



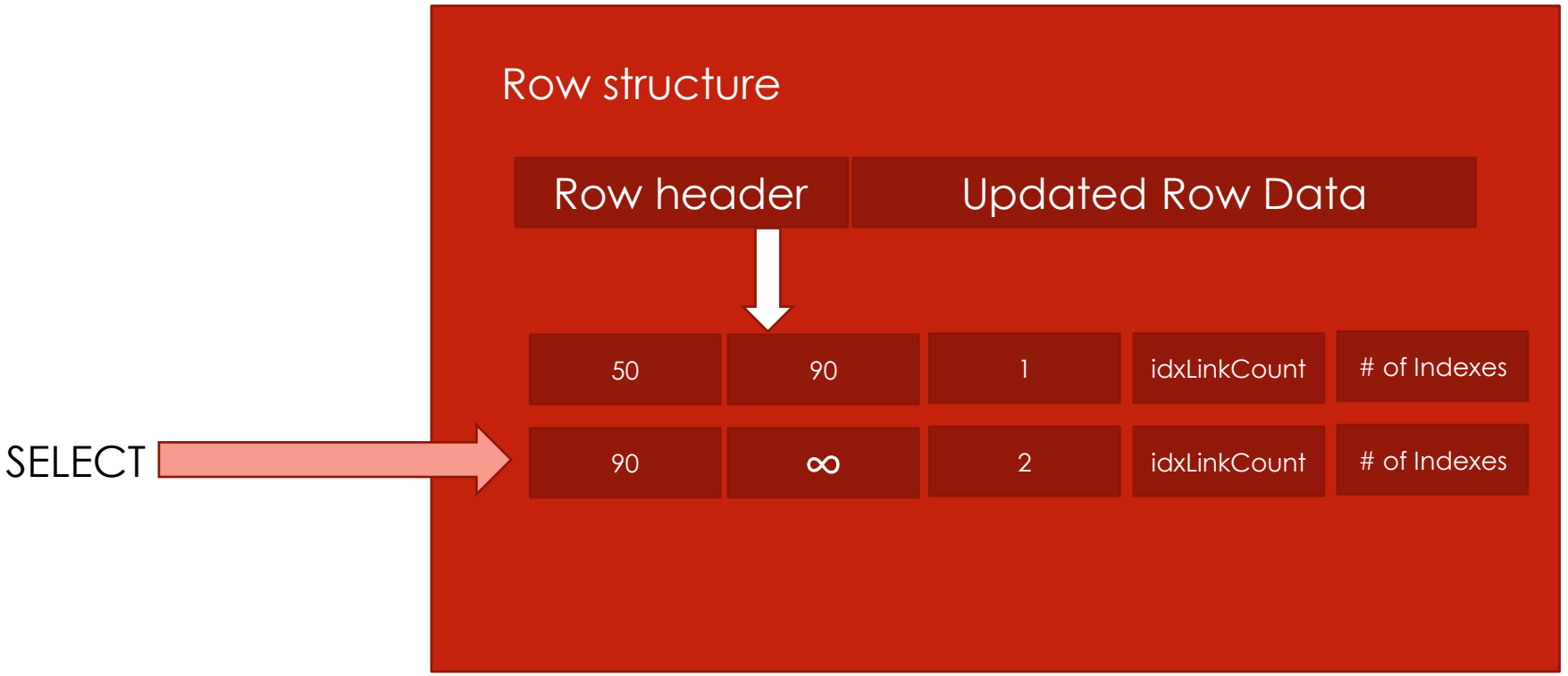
IN-MEMORY UPDATE



SELECT WITH TIMESTAMP 60



SELECT WITH TIMESTAMP 120



PERSISTENT MEMORY

BEFORE PERSISTENT MEMORY

Historically, RAM has been transient

On shutdown, data in RAM is lost

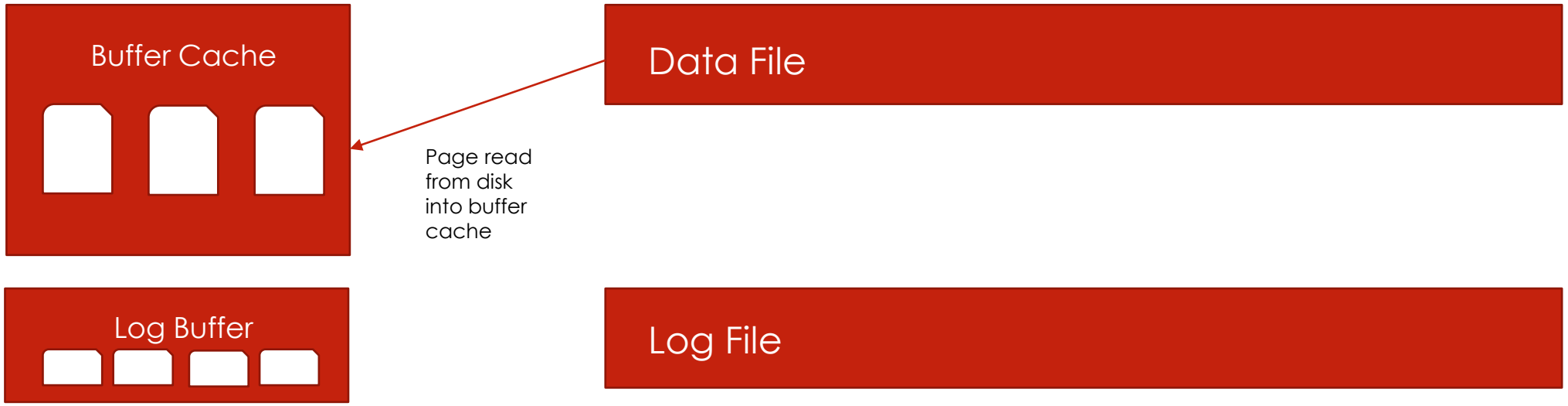
As a result, the transaction log buffer is flushed to disk on COMMIT

SQL Server must wait for confirmation that the flush has completed

This allows redo and undo to take place in the event of a crash

LOG BUFFER AND TRANSACTIONS

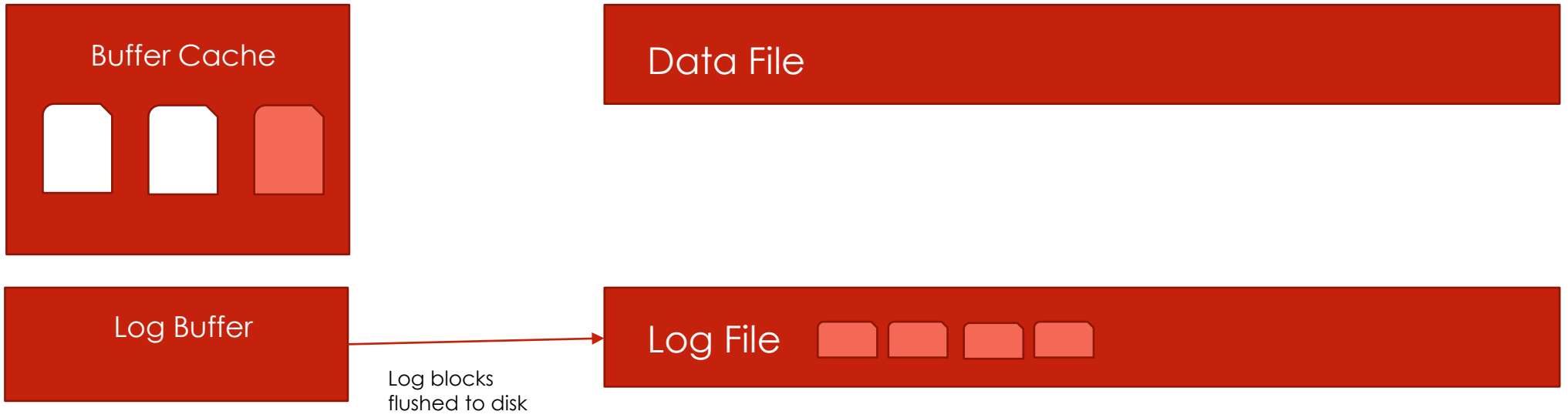
READ PAGE INTO BUFFER CACHE



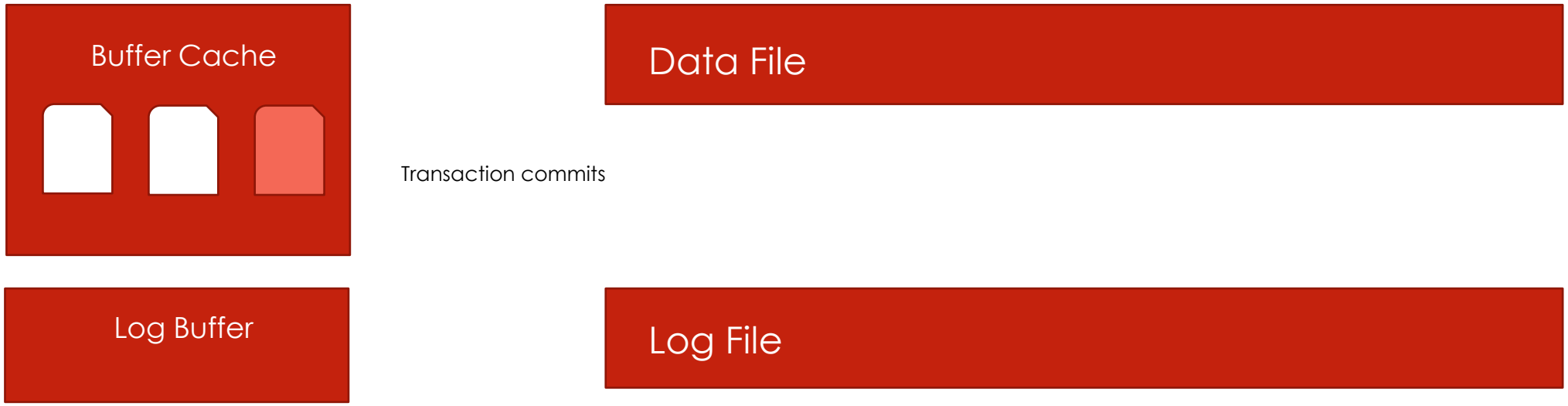
CHANGE PAGE IN MEMORY

WRITE LOG RECORDS TO LOG CACHE

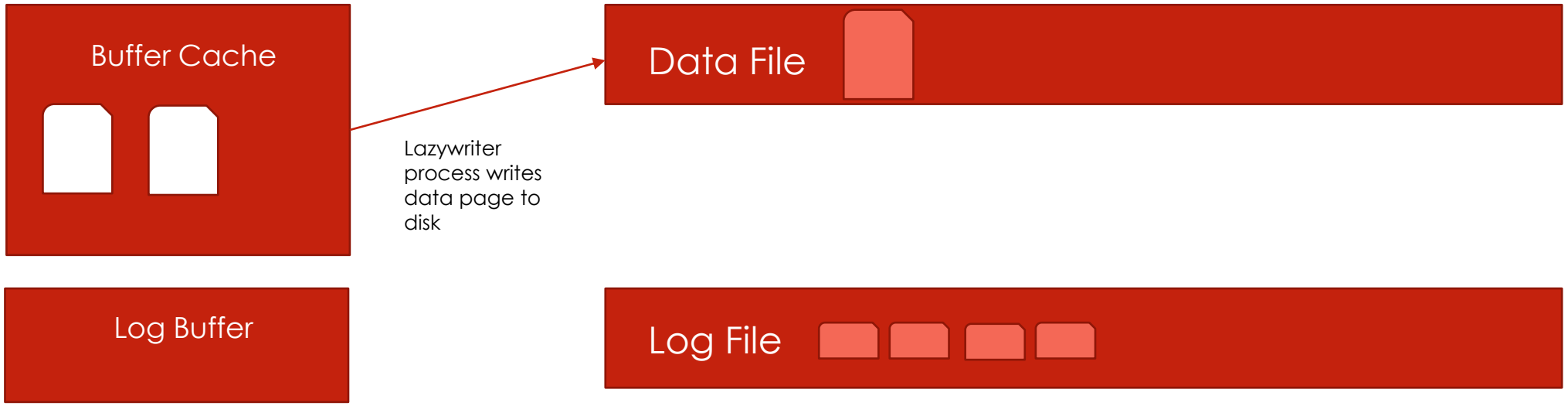
FLUSH LOG CACHE TO DISK



WRITE LOG RECORDS TO LOG CACHE



DATA PAGES FLUSHED ASYNCHRONOUSLY



PERSISTENT MEMORY

New development in hardware

RAM with a battery

Data stored in RAM can survive a restart

This provides several opportunities for performance enhancements

PERSISTENT LOG BUFFER CACHE

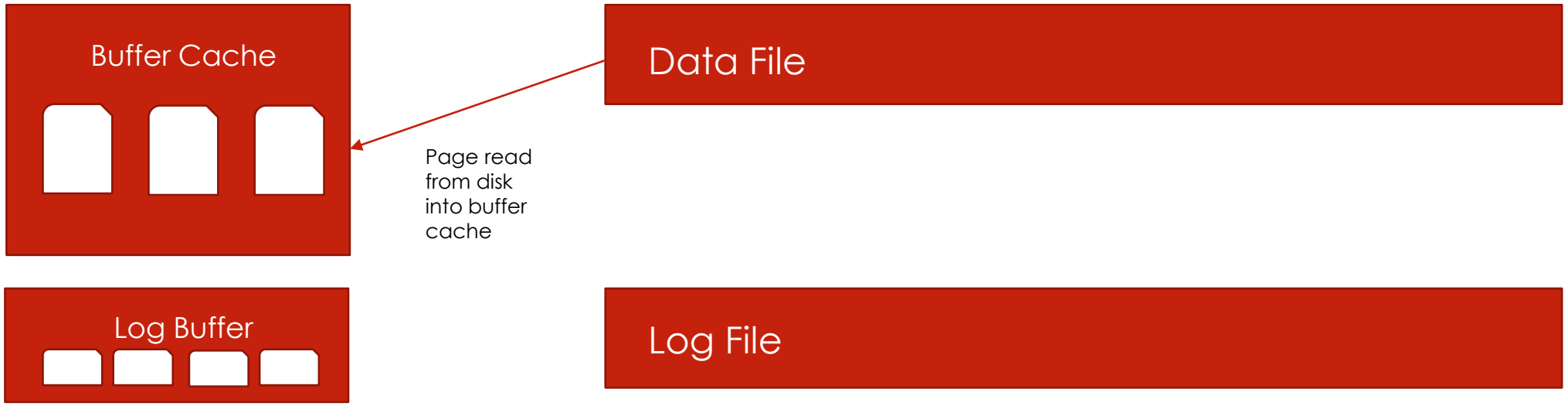
Log flush is no longer necessary on COMMIT

Log flush can happen in the background

Persistent buffer processed with the log file on restart

PERSISTENT LOG BUFFER CACHE

READ PAGE INTO BUFFER CACHE

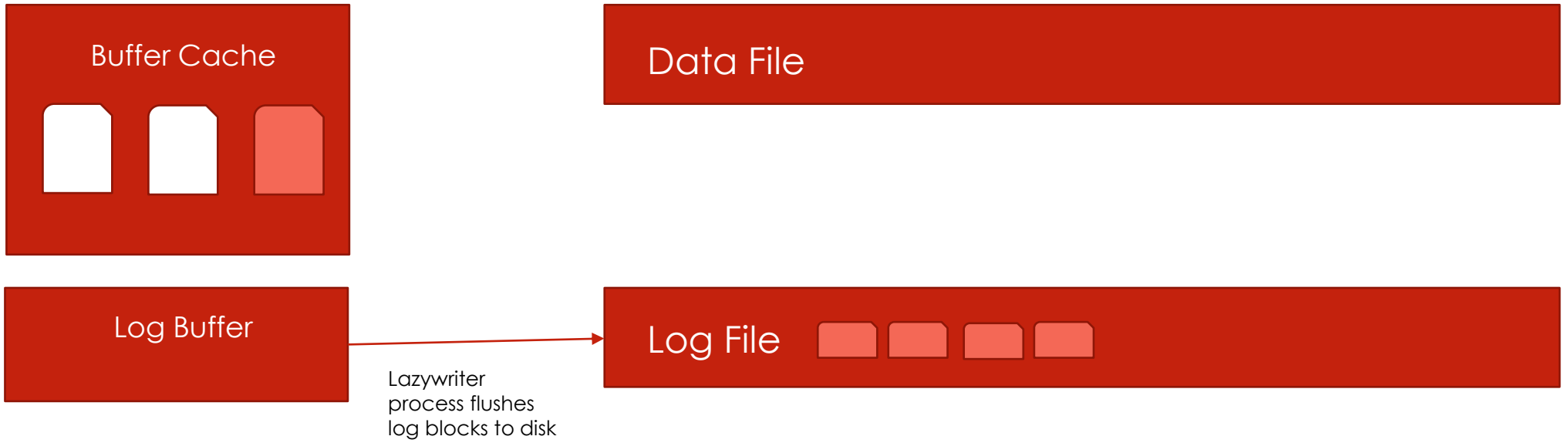


CHANGE PAGE IN MEMORY

WRITE LOG RECORDS TO LOG CACHE

TRANSACTION COMMITS

LOG CACHE FLUSHED BY BACKGROUND PROCESS



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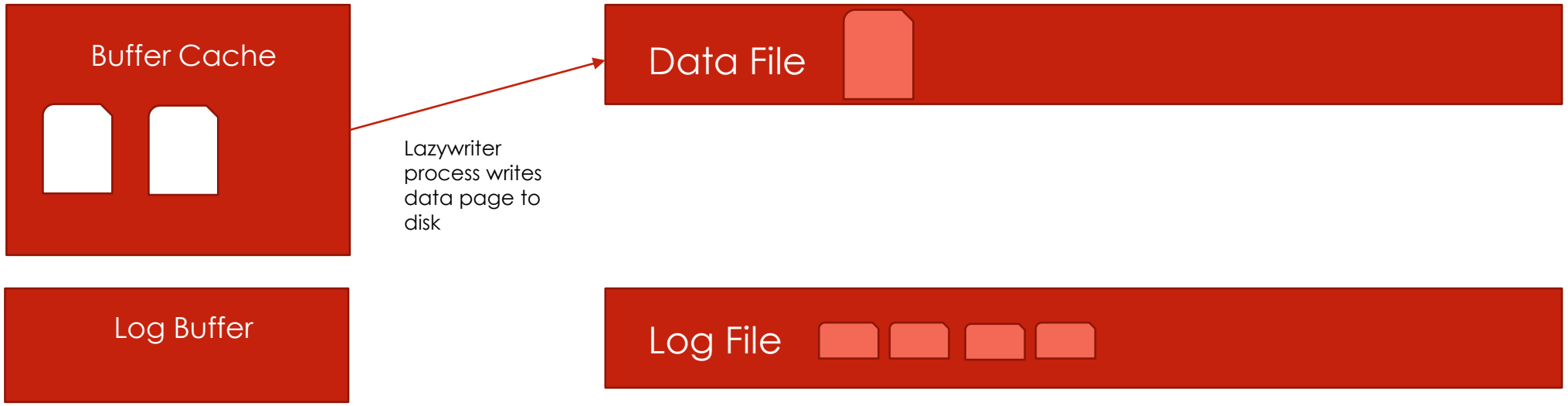

ADVANTAGES OF PERSISTENT LOG BUFFER CACHE

Log buffers not flushed to disk on commit

Speeds transactional processing

Reduces LOGWRITE waits

HYBRID BUFFER POOL

Enhancement of Buffer Pool Extension (BPE)

BPE extended the buffer pool onto fast SSD disk

Hybrid Buffer Pool extends the buffer pool onto PMEM

BPE without the IO overhead

ENLIGHTENED IO

Linux-only feature

Data and log files can be placed on PMEM

Allows the file system and storage stack to be bypassed

Note – PMEM is not as fast as traditional RAM

If your database fits in memory, this is not the solution for you

NO PERSISTENT MEMORY DEMO

WHY?

Home › Data Storage Products › Hard Drives › Solid State Drives (SSDs)

Share | Save as Favorites

cisco Partner

Intel Optane DC Persistent – DDR-T – module – 512 GB – DIMM 288-pin

Mfg.Part: UCS-MP-512GS-A0= | CDW Part: 6020774 | UNSPSC: 43201402

Availability: • 4-6 Weeks
Orders placed today will ship within 4-6 weeks by a CDW partner.

[redacted] Advertised Price

Claim up to a 5% Discount
Create an account to get My CDW Advantage today.

1 Add to Cart

Lease Option ($562.19/month)

Product Details

- DDR-T
- module
- 512 GB
- DIMM 288-pin
- 2666 MHz / PC4-21300
- 1.2 V
- for UCS C220 M5

View Full Product Details

Source: Intel Optane DC Persistent - DDR-T - module - 512 GB - DIMM 288-pin - UCS-MP-512GS-A0= - Hard Drives - CDW.com

THAT'S WHY

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WHAT WE'VE COVERED

- Accelerated Database Recovery
- In-memory tempdb metadata
- Persistent Memory
  - Persistent Log Buffer Cache
  - Hybrid Buffer Pool
  - Enlightened IO

RESOURCES

Slides and Scripts– https://github.com/skreebydba/MinnesotaPresentation

Tiger Team Materials – https://microsoft.github.io/sqlworkshops/

Hybrid Buffer Pool –

https://docs.microsoft.com/en-us/sql/database-engine/configure-windows/hybrid-buffer-pool?view=sql-server-2017

RESOURCES

Accelerated Database Recovery –

https://docs.microsoft.com/en-us/azure/sql-database/sql-database-accelerated-database-recovery

Constant Time Recovery in Azure SQL Database (White paper that gets deep into the internals of ADR, also known as CTR) –

https://www.microsoft.com/en-us/research/publication/constant-time-recovery-in-azure-sql-database/

In-memory tempdb Metadata –

https://docs.microsoft.com/en-us/sql/relational-databases/databases/tempdb-database?view=sql-server-ver15#memory-optimized-tempdb-metadata

ABOUT ME

In IT for 21 years, 13 of it working with SQL Server

Senior Data Engineer at Concurrency, Inc.

Learning more about Azure every day

Lover of all things internal to SQL Server

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