Transaction Log Internals and Troubleshooting

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About me

- Solutions architect, SQL & .NET developer
- 20 years in IT industry
- Worked with SQL Server since 7.0 back in 2001
- Developed in C#, ASP.NET, MVC, JavaScript, SharePoint
- MCDBA, MCSE, MCSD
- MCT since 2008
- PASS speaker

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About Krasnodar

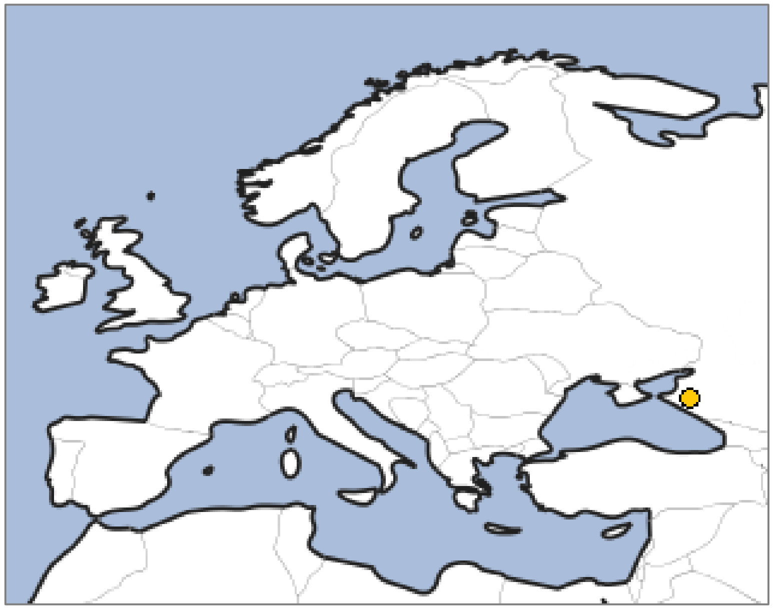
Regional center

Was founded in 1793, renamed in 1920

Original name Yekaterinodar – Catherine’s gift

Distances:

Istanbul	929 km
Moscow	1196 km
Warsaw	1541 km
Copenhagen	2200 km
Brussels	2640 km
Paris	2793 km
Lisbon	3995 km



Contents

Transaction Log. What for?

- Supports ACID properties
- Recovery in case of database crash or SQL Server startup
- Rolling a restored database, file, filegroup, or page forward to the point of failure
- Supporting transactional replication
- Supporting high availability and disaster recovery solutions

Logical Architecture

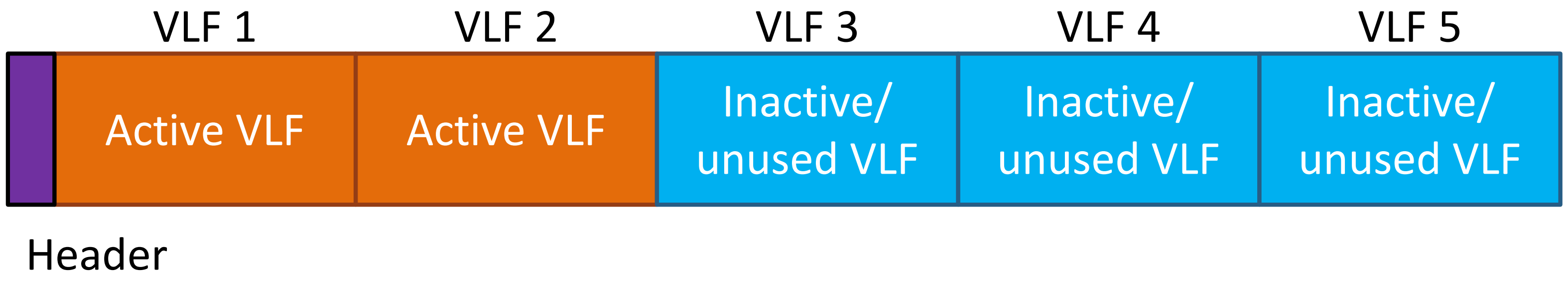
- Just a list of log records
- Identified by Log Sequence Number (LSN)

00000028 : 00000120 : 0002

VLF number Log block number Log record number

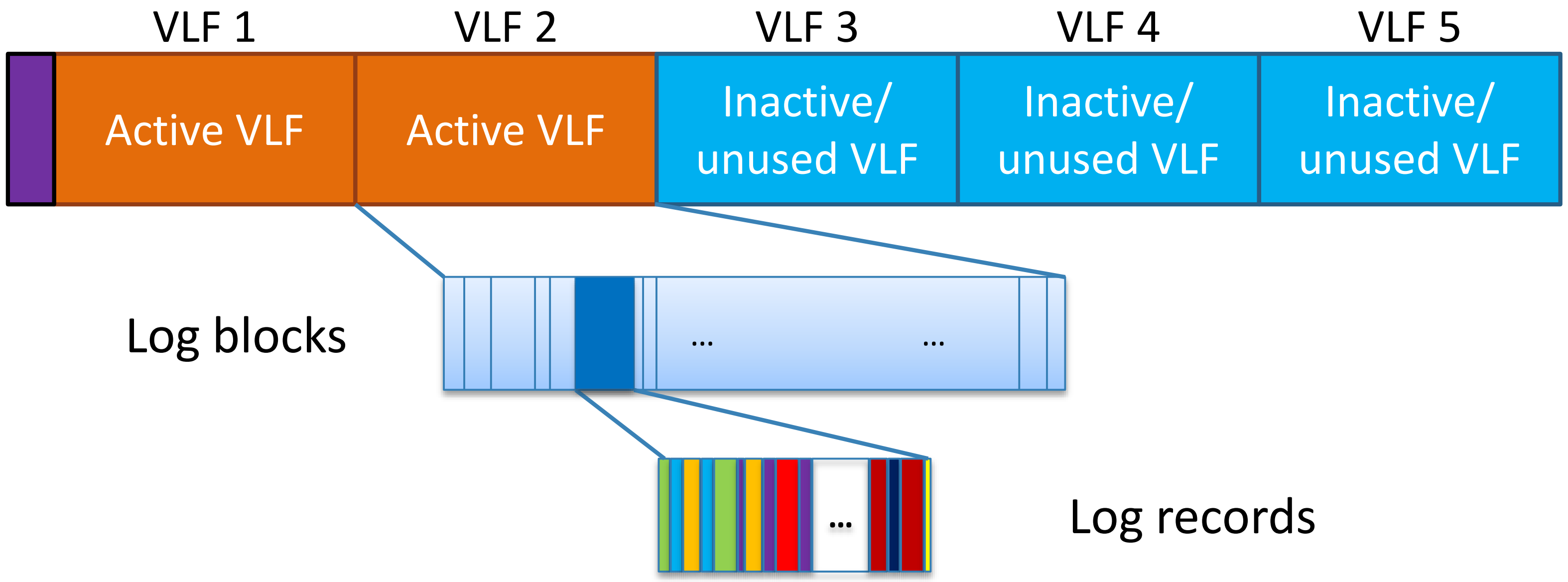
- Log record contains:
  - Info about transaction
  - Before and after images
  - Allocation information, etc.
- Can be viewed by fn_dblog()

Physical Architecture (1)



- 8KB file header with metadata
- Consists of Virtual Log Files (VLF)
- VLF has logical sequence number (FSeqNo)
- Minimum 2 VLFs, minimal VLF size = 248KB
- Filled by zero on creation

Physical Architecture (2)



- Each VLF is splitted into log blocks
- Log block size = from 512B to 60 KB
- Contains log records from multiple transactions

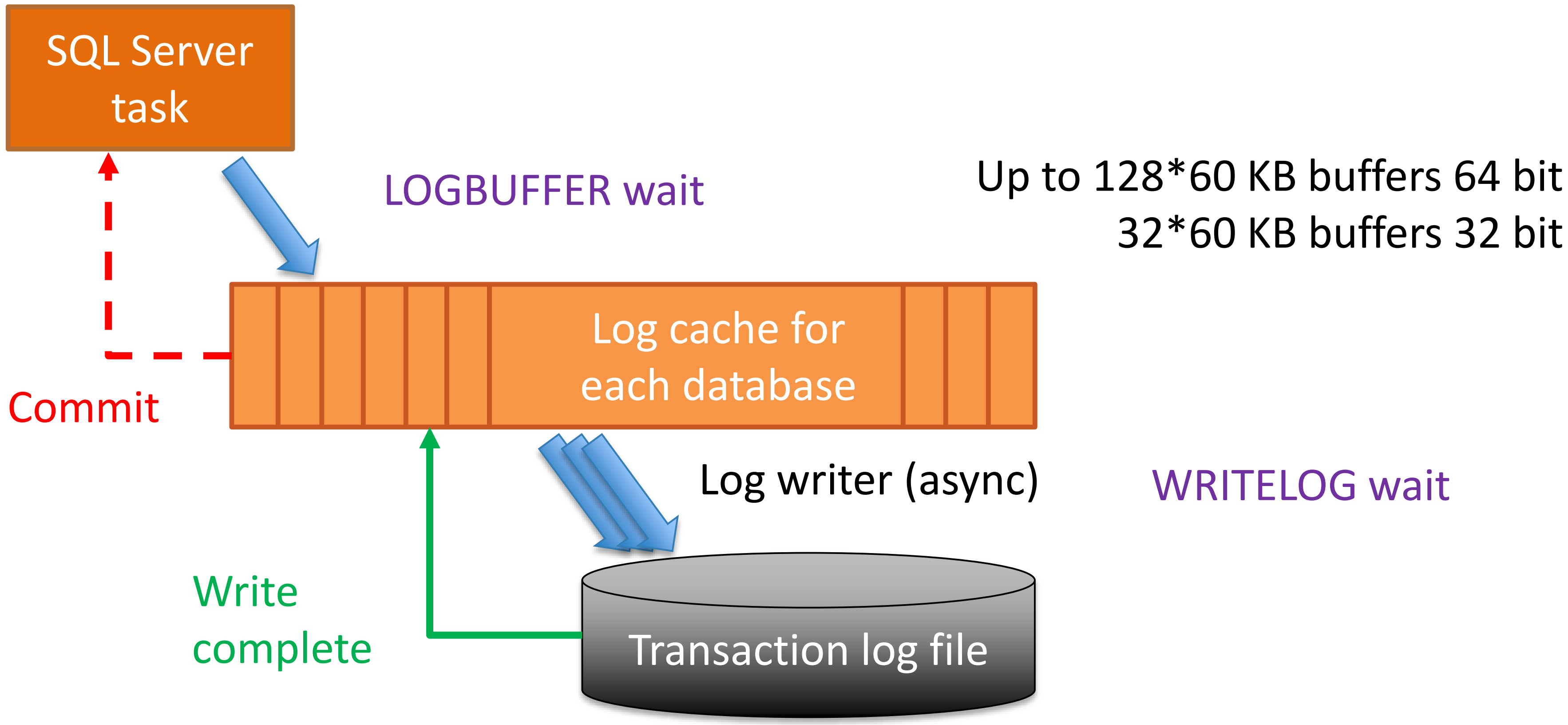
Transactions and Transaction Log

- Records all modifications made by each transaction
- Single transaction produces some log records
- Written to transaction log file
- Implements Write-Ahead Log (WAL) by default
    - Can be changed by Delayed Durability

Transaction Commit

- All log records up to the LSN of LOP_COMMIT_XACT must be written to disk
- Waits for acknowledgement from the synchronous mirror or Availability Group server (if applicable)
- Release all locks placed by the transaction
- Acknowledge the commit to user

Transaction Log Flush



Transaction Log Writes

Always writes sequentially

- Multiple log files doesn't give any performance benefit

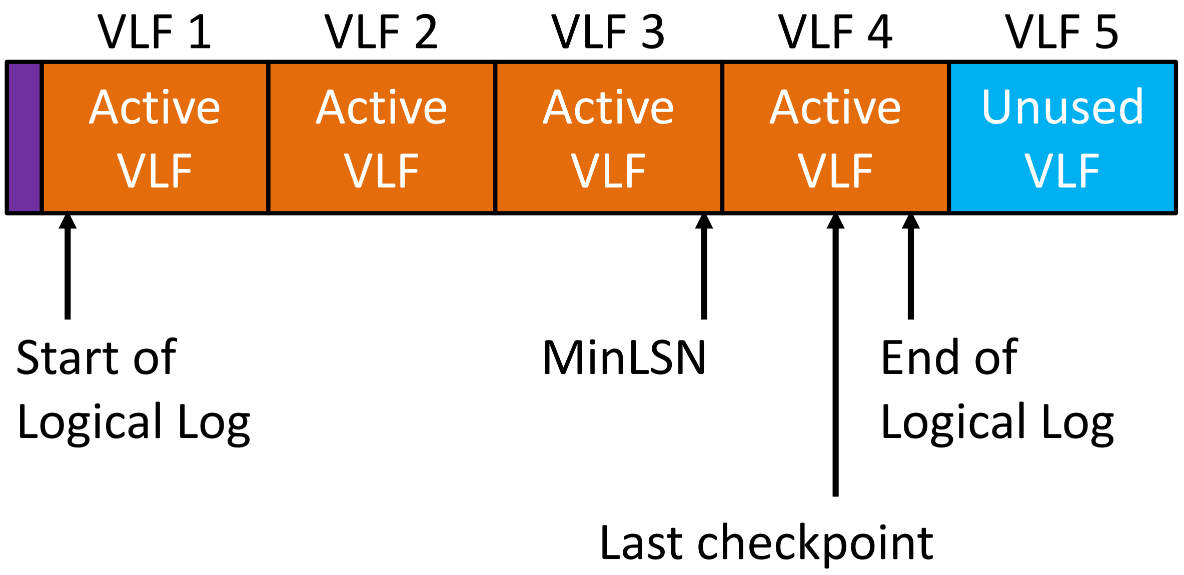
Limits on outstanding I/O:

SQL Server version	Quantity 64 bit	Quantity 32 bit	Amount, KB
Prior to 2005SP1	8	8	480
2005SP1 – 2008R2	32	8	480 (2005) 3840 (2008)
2012 and later	112	16	3840

Log File Operations

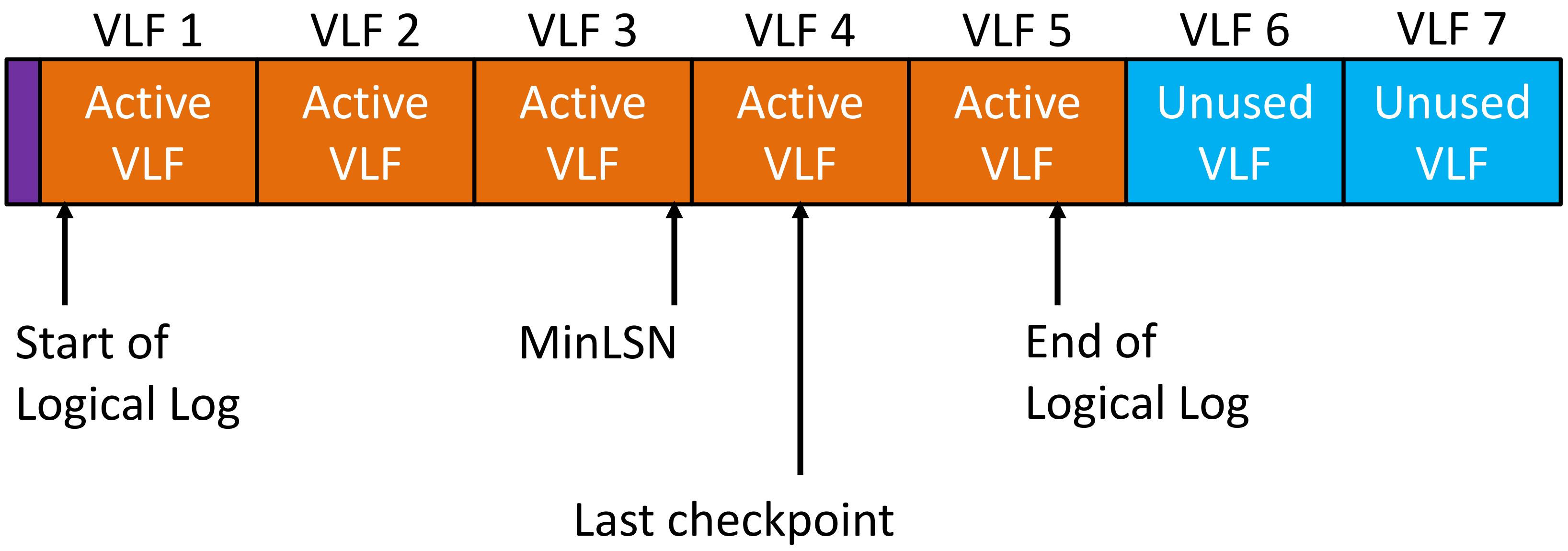
Operation	File size	Number of VLF	Comment
Growing	Increasing (expands a log file according to growth parameters)	Increasing (calculated by VLF formula)	
Truncation	Not changed	Not changed	Only marks inactive VLFs as truncated
Shrinking	Can be reduced	Can be reduced	Depends on active VLFs

Log File Growing (1)



- SQL Server allocates so many VLFs as needed to rollback the longest active transaction
- New VLFs are filled by zero

Log File Growing (1)



- SQL Server allocates so many VLFs as needed to rollback the longest active transaction
- New VLFs are filled by zero

VLF Size Algorithm

- Used on log creation for all versions
- Used on log growth for SQL Server 2012 and earlier
- Depends on chunk size to be added

Chunk size	Number of VLF added
Size <= 1 MB	Complicated, playing with first 248 KB VLFs
1Mb < Size <= 64 Mb	4 VLFs
64 Mb < Size <= 1Gb	8 VLFs
Size > 1G	16 VLFs

New VLF Size Algorithm

- Used only on log growth since SQL Server 2014
- Depends on chunk size to be added:
  - If the chunk size less than 1/8 of the current log size, create 1 VLF equal to the growth size
  - Otherwise, create VLFs according to the old algorithm

Log File Growing (2)

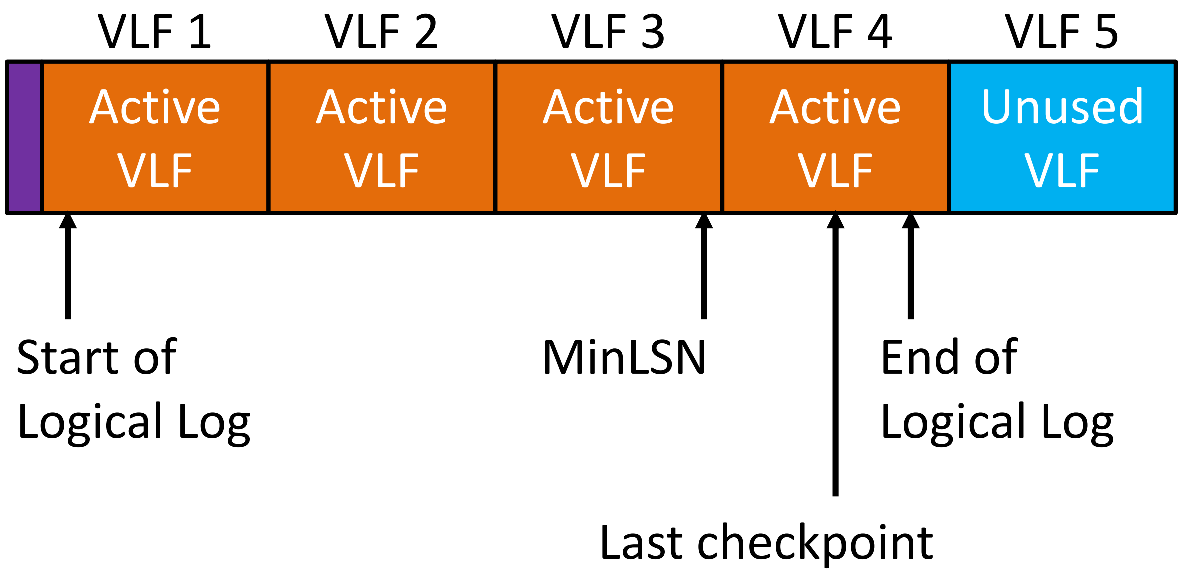
- Log file has initial and maximum sizes
- Maximum size can be fixed or unlimited*
- Log file can be expanded manually or automatically
- If log autogrowth occurs:
  - New VLFs will be added and zero-initialized
  - It leads to a wait in transaction processing

Inactive Log Record

Log record becomes inactive when:

- The transaction that this log record is part of has committed
- The database pages changed by this transaction/log record have been written to disk by checkpoint
- The log record is not needed for a backup (full, differential, or log)
- The log record is not needed for any feature that reads the log (Database mirroring, AlwaysOn Group, Transactional replication, Change Data Capture)

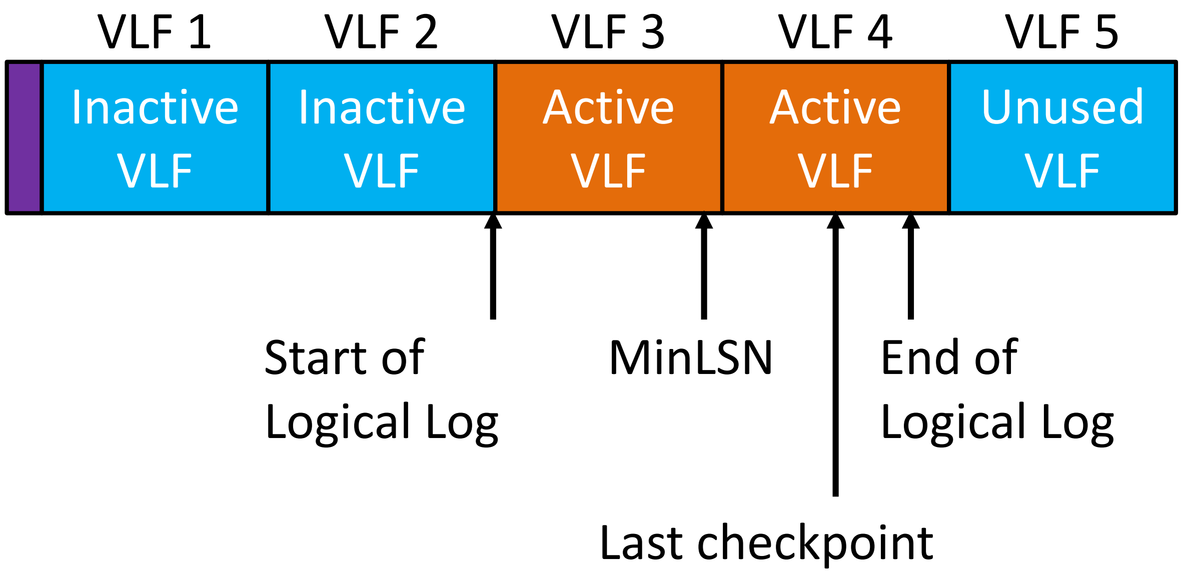
Log Truncation (1)



VLF is truncated when:

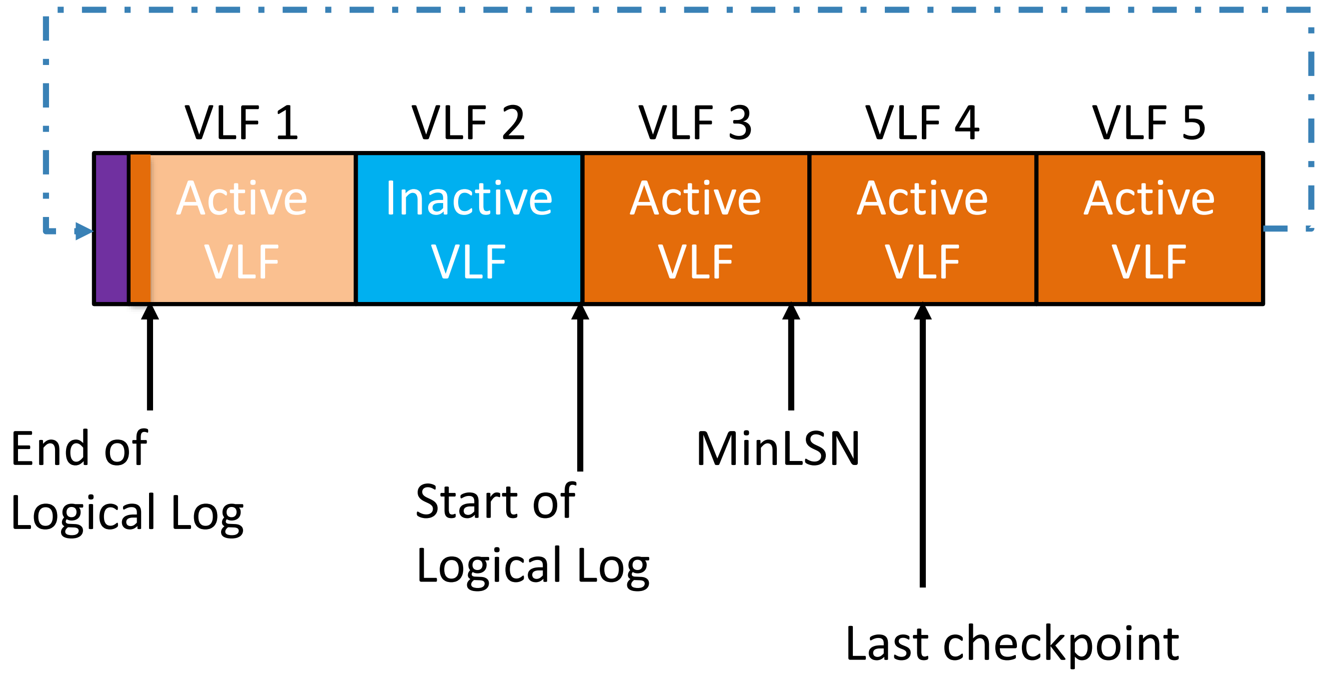
- It has NO active log records
- After checkpoint in simple/pseudo-full recovery model
- After log backup in full or bulk-logged recovery model

Log Truncation (2)



- VLF is marked as truncated
- VLF is NOT filled with zero

Circular Nature of the Log



- Inactive VLF can be overwritten
- Parity bits are flipped after roll-over

Shrinking

- Automatic
  - Database AUTO_SHRINK option
- Manual
  - DBCC SHRINKFILE
  - Shrink unused VLFs/space from the end of the log file
  - Could shrink maximum to the first 2 VLFs

Transaction Log Issues

- Excessive log growing and error 9002
- Log shrinking
- VLF fragmentation

Excessive Log Growing

There are many reasons

- Look at *log_reuse_wait_desc* in *sys.databases*
- See section "Factors That Can Delay Log Truncation" in https://msdn.microsoft.com/en-us/ms190925.aspx

How to correct:

Reason	Action
LOG_BACKUP	Take a log backup frequently
ACTIVE_BACKUP_OR_RESTORE	Re-evaluate the backup strategy/plan
ACTIVE_TRANSACTION	Kill erroneous or poorly written transaction
REPLICATION	Check transactional replication

- Consider using SIMPLE recovery model

Monitoring Transaction Log Space

- Performance Monitor
  - Log File(s) Size (KB)
  - Log File(s) Used Size (KB)
  - Percent Log Used
  - Log Growths
- DBCC SQLPERF(LOGSPACE)
- sys.dm_db_log_space_usage (since SQL Server 2012)

Error 9002

If log can’t auto-grow:

- You will receive error 9002
- Rolls back uncommitted transactions
- Stops activity (writing new transactions to log file)

How to correct:

- Check the reason, then take a corresponding action
- Extend log file (if applicable)
- Add an additional log file

DEMO

- Excessive log growing and error 9002
- Deleting additional log files

Log shrinking

Steps:

- Run DBCC LOGINFO to estimate the number of VLFs and last active VLF
- Truncate log
  - Make log backup for Full or Bulk-logged recovery model
  - Make CHECKPOINT in Simple recovery model
- Wait for log roll-over and truncate again
- Run DBCC SHRINKFILE

VLF Fragmentation

- VLF are added during log growth
  - Improper growth value leads to a big number of small or tiny VLFs
- Truncated VLFs can be in any place of transaction log
  - Leads to fragmentation in VLF sequence
- Causes problems in log activity, backups or readers
- If number of VLF is hundreds or thousands, think about VLF defragmentation

Removing VLF Fragmentation

- Manually shrink file
- Repeat shrinking to reach minimum file size
- Change transaction log file size and/or autogrowth
  - VLF size should not be bigger than 500 MB
  - Perform manual growing to get optimal log size

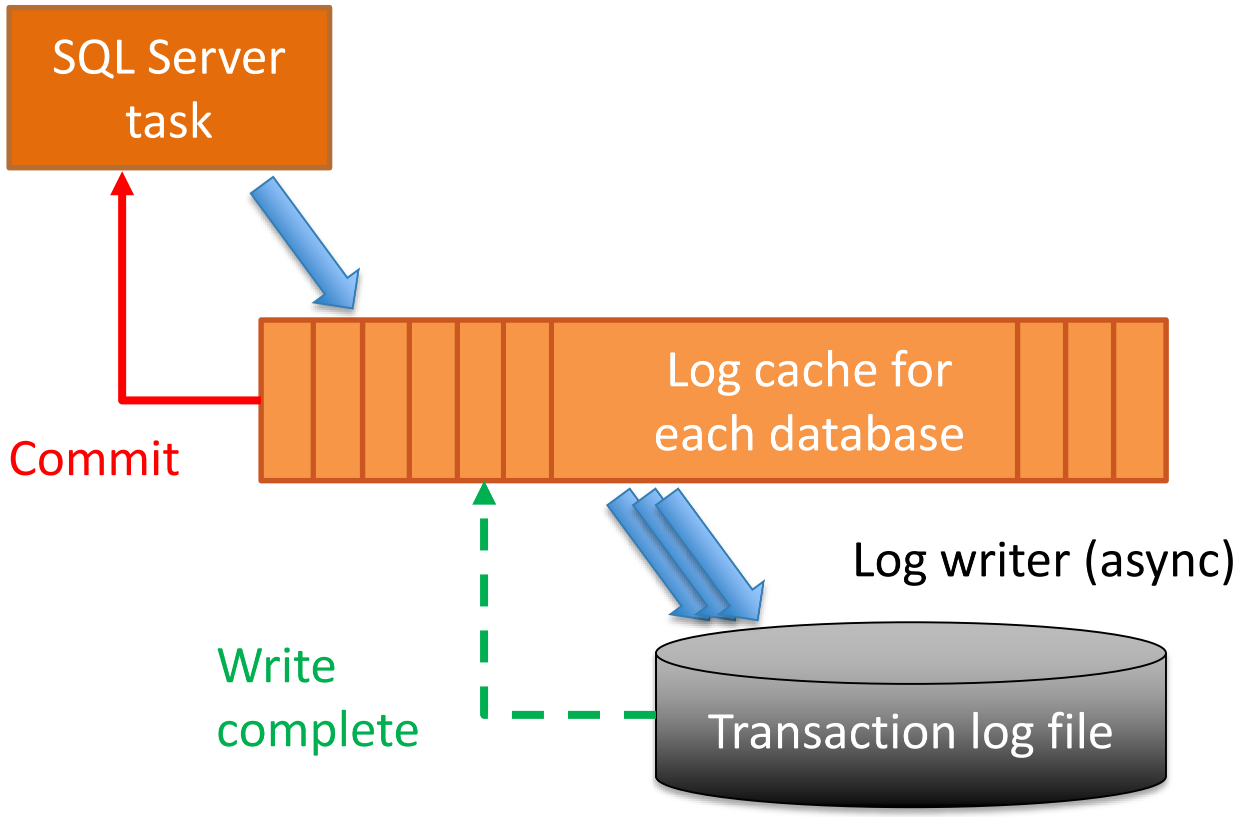
DEMO

- Shrinking log file
- Removing VLF fragmentation

Delayed Durability in SQL Server 2014

- Commit transactions BEFORE log flush
- Defined at database level
- Benefits:
  - Reducing waits
  - Increasing throughput by larger flush chunks
  - Reducing contention for log I/O
- Disadvantages:
  - Risk of data loss

Transaction Log Flush in Delayed Durability



DEMO

Speeding up transactions with Delayed Durability

Summary

- Place transaction log on separate fast physical disk
- Keep just one log file
- Monitor log size and performance
- Prevent log filling up
- Manage the number of VLFs
- Think about upgrade to the latest SQL Server versions

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Questions?

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Thank you for attending!