Exploring Optimized Locking

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Objectives

- Current problems
- Lock refresher
- Optimized Locking Components
- How does it work
- Limitations
- Q&A

Slides & Demos

Current Problems

- ACID Compliance
- Lock escalation
- Long-term locking
- Excessive blocking
- Excessive memory utilization

What can be locked?

Resource Lock	Description
Key	Lock on a row in an index
Object	Lock on table, procedure, view, etc
Page	Lock on an 8-KB page
RID	Lock on a single row in a heap
Xact	Lock on a transaction

Locking Refresher

Lock	Purpose
IX/IU – Intent Lock	Establishes a lock hierarchy,
U – Update Lock	Used on resources that can be updated.
X – Exclusive Lock	Used for data-modification operations, such as INSERT, UPDATE, or DELETE.
S – Shared Lock	Used for read operations that do not change or update data

Lock Compatibility Matrix

Existing/Request Lock	IS	S	U	IX	X
Intent shared (IS)	Yes	Yes	Yes	Yes	No
Shared (S)	Yes	Yes	Yes	No	No
Update (U)	Yes	Yes	No	No	No
Intent exclusive (IX)	Yes	No	No	Yes	No
Exclusive (X)	No	No	No	No	No

Traditional Locking

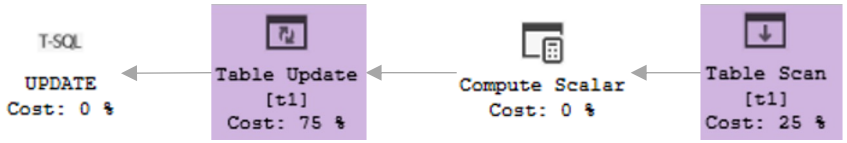
- Update lock taken on rows to allow for predicate evaluation
- If predicate is satisfied, then an exclusive lock is taken on the row
- Locks are held until the end of the transaction

Traditional Locking

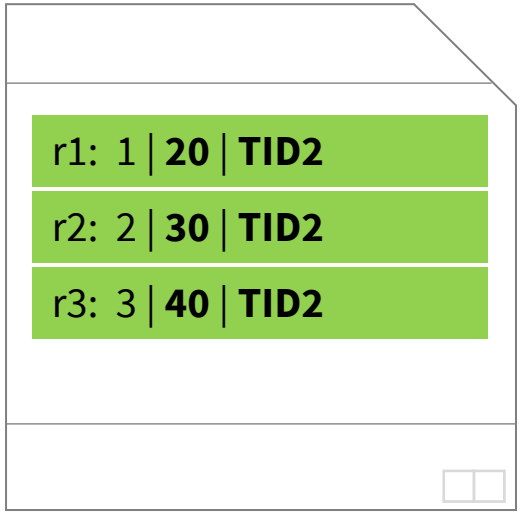
```
ALTER DATABASE [Locking] SET READ_COMMITTED_SNAPSHOT OFF;
SET TRANSACTION ISOLATION LEVEL READ COMMITTED;

CREATE TABLE t1 (a int, b int);
INSERT INTO t1 VALUES (1,10), (2,20), (3,30);

-- TID2: Increase b by 10
BEGIN TRAN UPDATE t1 SET b=b+10;
```



p1: Data Page for t1



Lock Manager

Lock Mode	Lock Type	Lock Resource
IX	OBJECT	t1
IX	PAGE	p1
X	RID	r1
X	RID	r2
X	RID	r3

Slide Credit: Perry Skountrianos/Prashanth Purnananda & the Microsoft team who brought you optimized locking

Old School

Updating 1 million rows might require 1 million exclusive (X) row locks held until the end of the transaction.

https://learn.microsoft.com/en-us/sql/relational-databases/performance/optimized-locking?view=azuresqldb-current

Optimized Locking Components

- Accelerated Database Recovery
- Transaction ID (TID)
- Lock After Qualification (LAQ)

ADR Overview

- Persisted Version Store (PVS) lives in user databases
- In-row versions versus off-row versions (PVS)
- Facilitates much faster rollback operations
- Eliminates long-running transaction rollbacks

Transaction ID (TID)

- A unique identifier
- Each row will contain the TID that last modified it
- Lock will be held on the transaction ID versus row key

Lock After Qualification (LAQ)

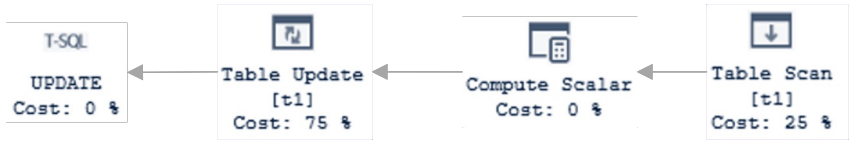
- Predicate is applied to the row using the latest version of the row
- If the predicate is not satisfied, move to the next row
- If the predicate is satisfied, an exclusive (X) lock is placed on the row
- Can retry predicate evaluation as needed due to previous exclusive lock

Traditional Blocking

```
ALTER DATABASE [db1] SET READ_COMMITTED_SNAPSHOT ON;
SET TRANSACTION ISOLATION LEVEL READ COMMITTED;

CREATE TABLE t1 (a int, b int);
INSERT INTO t1 VALUES (1,10), (2,20), (3,30);
```

```
-- TID2 [SESSION 1]: Increase b by 10 where a=1
BEGIN TRAN UPDATE t1 SET b=b+10 where a=1;
```




```
-- TID3 [SESSION 2]: Increase b by 10 where a=2
BEGIN TRAN UPDATE t1 SET b=b+10 where a=2;
```

p1: Data Page for t1

Row does not qualify

r1: 1 | **20** | **TID2** ✓

r2: 2 | 20 | TID1 ✗

r3: 3 | 30 | TID1 ✗

Row version store

r1: 1 | 10 | TID1

Lock Manager

Lock Mode	Lock Type	Resource	Owner	Status
IX	OBJECT	t1	TID2, TID3	GRANT
IX	PAGE	p1	TID2	GRANT
X	RID	r1	TID2	GRANT
IU	PAGE	p1	TID3	GRANT
U	RID	r1	TID3	WAIT

Session 2 is blocked waiting for Session 1 to commit

Slide Credit: Perry Skountrianos/Prashanth Purnananda & the Microsoft team who brought you optimized locking

Optimized Locking

```
ALTER DATABASE [db1] SET READ_COMMITTED_SNAPSHOT ON;
SET TRANSACTION ISOLATION LEVEL READ COMMITTED;

CREATE TABLE t1 (a int, b int);
INSERT INTO t1 VALUES (1,10), (2,20), (3,30);
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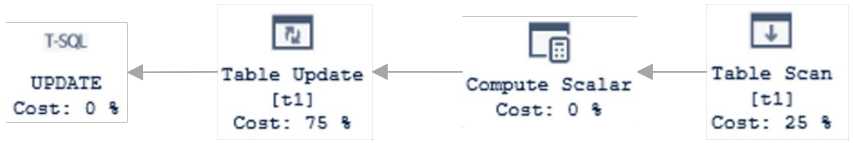


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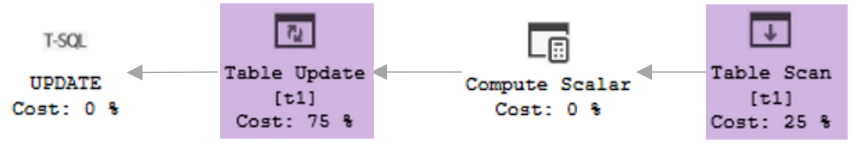

p1: Data Page for t1

Row does not qualify

r1: 1 | **20** | **TID2** ✓

r2: 2 | **30** | **TID3**

r3: 3 | 30 | TID1 ✗

Row version store

Row does not qualify

r1: 1 | 10 | TID1 ✗

r2: 2 | 20 | TID1

Lock Manager

Lock Mode	Lock Type	Resource	Owner	Status
X	XACT	TID2	TID2	GRANT
IX	OBJECT	t1	TID2, TID3	GRANT
IX	PAGE	p1	TID2	GRANT
IX	PAGE	p1	TID3	GRANT
X	RID	r2	TID3	GRANT

✓ Session 2 is not blocked by Session 1

Slide Credit: Perry Skountrianos/Prashanth Purnananda & the Microsoft team who brought you optimized locking

New School

Updating 1 million rows might require 1 million X row locks but each lock is released as soon as each row is updated,

Only one TID lock will be held until the end of the transaction.

https://learn.microsoft.com/en-us/sql/relational-databases/performance/optimized-locking?view=azuresqldb-current

Warning

> *Even without LAQ, applications should not assume that SQL Server (under versioning isolation levels) will guarantee strict ordering, without using locking hints.*

https://learn.microsoft.com/en-us/sql/relational-databases/performance/optimized-locking?view=azuresqldb-current

Best Practices & Troubleshooting

- Avoid locking hints
- Make sure RCSI is enabled
- New entries for Deadlock Graphs
- New Waits introduced:
  - LCK_M_S_XACT_READ
  - LCK_M_S_XACT_MODIFY
  - LCK_M_S_XACT

`LCK_M_S_XACT`	Occurs when a task is waiting for a shared lock on an XACT `wait_resource` type, where the intent cannot be inferred. Rare. Related to optimized locking.
`LCK_M_S_XACT_READ`	Occurs when a task is waiting for a shared lock on an XACT `wait_resource` type, with an intent to read. Related to optimized locking.
`LCK_M_S_XACT_MODIFY`	Occurs when a task is waiting for a shared lock on an XACT `wait_resource` type, with an intent to modify. Related to optimized locking.

Limitations

- Azure SQL Database Only (for now)
  - DTU service tier
  - vCore Provisioned tier (including serverless)
- Accelerated Database Recovery Required
- Repeatable Read & Serializable Isolation forces the lock to be held on the row or page until the end of the transaction

Summary

- Better concurrency
- Significantly reduced locking and lock memory
- On by default in Azure SQL Database
  - ADR/RCSI is enabled by default as well
- Every SQL Server DBA should be watching this feature arrive to the box product

Resources

- Optimized Locking - https://learn.microsoft.com/en-us/sql/relational-databases/sql-server-transaction-locking-and-row-versioning-guide?view=sql-server-ver16&source=recommendations

- Article - https://www.red-gate.com/simple-talk/databases/sql-server/database-administration-sql-server/optimized-locking-in-azure-sql-database/ (Simple Talk - Aaron Bertrand)

Questions?
Answers!

Got Questions?

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