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Overview of Concurrency in L-Store:
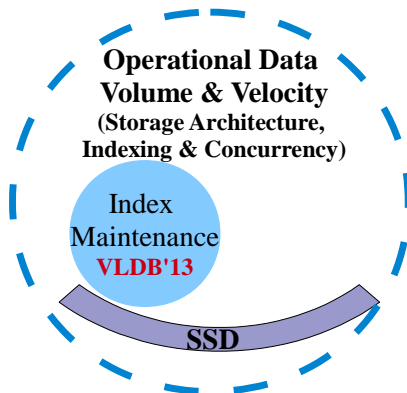# 2VCC - Two-version Concurrency Control

Mohammad Sadoghi

Exploratory Systems Lab
University of California, Davis

ECS165a - Winter 2021

1 Data Velocity: Index Maintenance

2 Data Volume: MVCC Concurrency

3 Decentralized & Democratic Data Platform

4 References

Extending Storage Hierarchy with Indirection Layer

Observed Trends

In the absence of in-place updates in operational multi-version databases, the cost of index maintenance becomes a major obstacle to cope with data velocity.

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# Reducing Index maintenance: Velocity Dimension

Observed Trends

In the absence of in-place updates in operational multi-version databases, the cost of index maintenance becomes a major obstacle to cope with data velocity.

Extending storage hierarchy (using fast non-volatile memory) with *an extra level of indirection* in order to

Reducing Index maintenance: Velocity Dimension

Observed Trends

In the absence of in-place updates in operational multi-version databases, the cost of index maintenance becomes a major obstacle to cope with data velocity.

Extending storage hierarchy (using fast non-volatile memory) with *an extra level of indirection* in order to
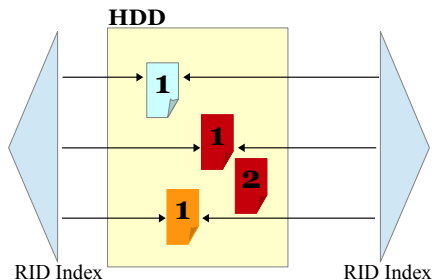Decouple Logical and Physical Locations of Records to
Reduce Index Maintenance

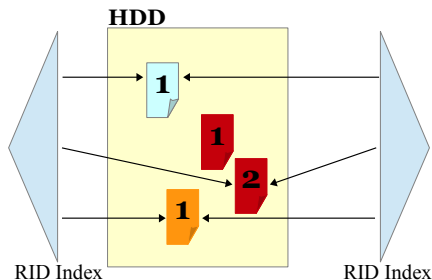# Traditional Multi-version Indexing: Updating Records
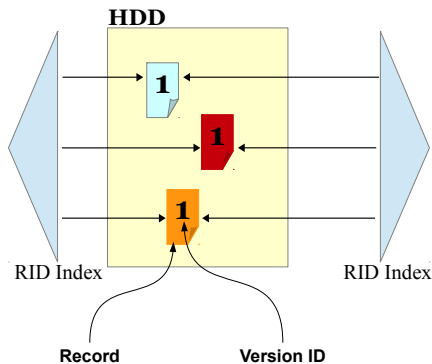
Updating random leaf pages

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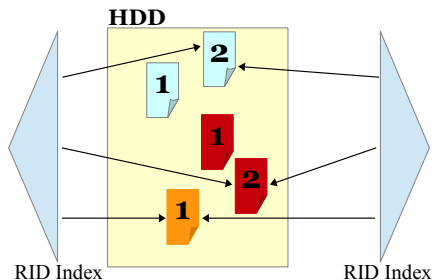# Traditional Multi-version Indexing: Updating Records

Updating random leaf pages

Traditional Multi-version Indexing: Updating Records

Updating random leaf pages
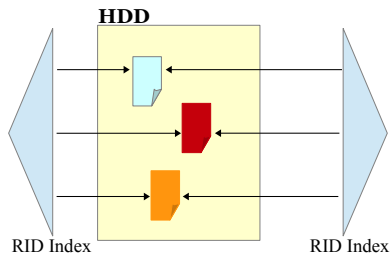
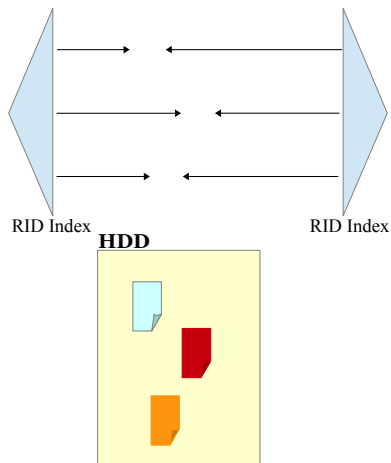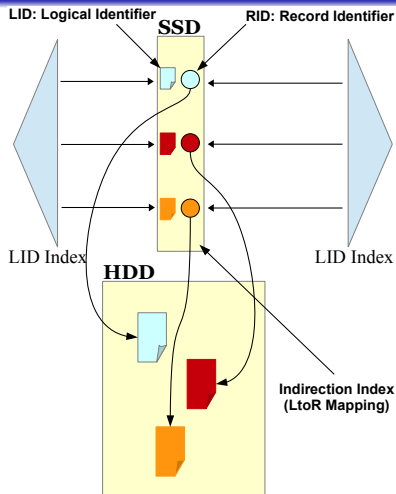# Traditional Multi-version Indexing: Updating Records

Updating random leaf pages

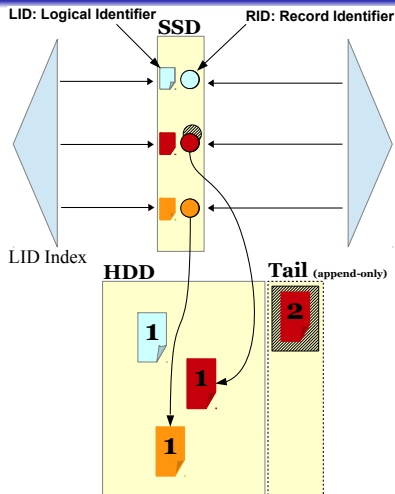## Indirection Indexing: Updating Records

Indirection Indexing: Updating Records

Indirection Indexing: Updating Records

Indirection Indexing: Updating Records

Eliminating random leaf-page updates

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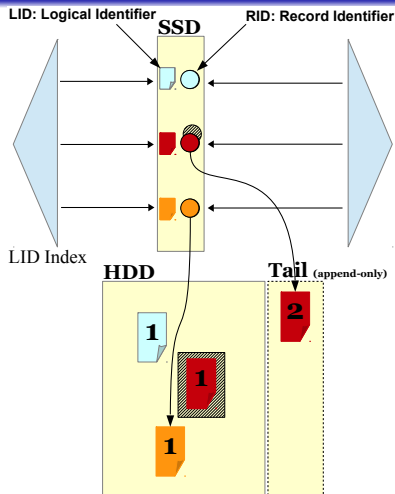2VCC
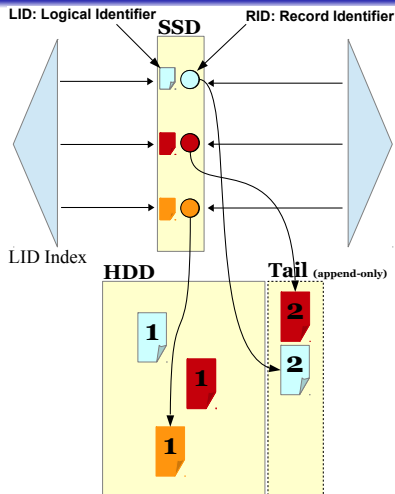00000000
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Indirection Indexing: Updating Records

Eliminating random leaf-page updates

Indirection Indexing: Updating Records

Eliminating random leaf-page updates

Analytical & Experimental Evaluations

Indirection Time Complexity Analysis

	Legend
K	Number of indexes
LB	LIDBlock size
M	Number of matching records

Method	Type	Imm. SSD	Def. SSD	Imm. HDD	Def. HDD
Base	Deletion	0	0	$2 + K$	$\leq 1 + K$
	Single-attr. update	**0**	**0**	$3 + K$	$\leq 2 + K$
	Insertion	0	0	$1 + K$	$\leq 1 + K$
	Search Uniq.	0	0	2	0
	Search Mult.	0	0	$1 + M$	0
Indirection	Deletion	2	0	2	≤ 3
	Single-attr. update	**2**	**0**	**4**	≤ 3
	Insertion	$2 + 2K$	$2K/LB$	1	$\leq 1 + 2K/LB$
	Search Uniq.	2	0	2	0
	Search Mult.	$1 + M$	0	$1 + M$	0

Experimental Setting

- Hardware:
 - (2 × 8-core) Intel(R) Xeon(R) CPU E7-4820 @ 2.00GHz, 32GB, 2 × HDD, SSD Fusion-io

- Software:
  - Database: IBM DB2 9.7
  - Prototyped in a commercial proprietary database
  - Prototyped in Apache Spark by UC Berkeley
  - LIBGist v.1.0: Generalized Search Tree C++ Library by UC Berkeley (**5K LOC**) (Predecessor of Generalized Search Tree (GiST) access method for PostgreSQL)
  - **LIBGist^{mv} Prototype:** Multi-version Generalized Search Tree C++ Library over LIBGist supporting Indirection/LIDBlock/DeltaBlock (**3K LOC**)

- Data:
  - TPC-H benchmark
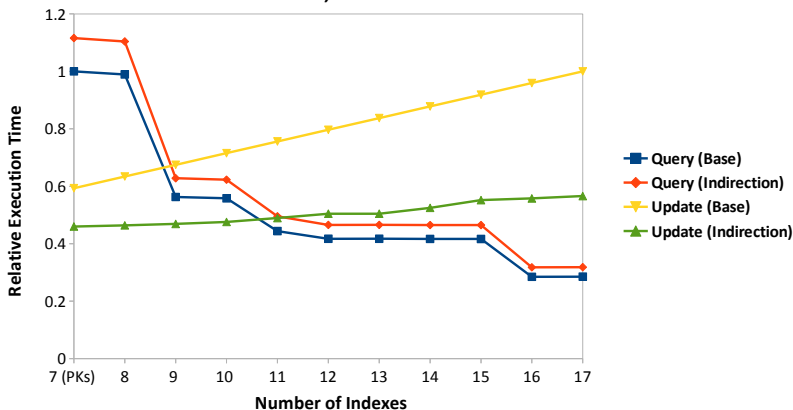 - Microsoft Hekaton micro benchmark

Indirection: Effect of Indexes in Operational Data Stores
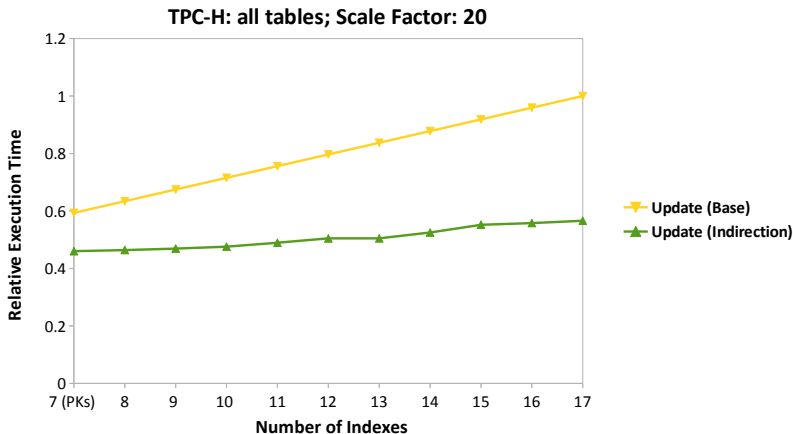
Substantially improving the update time ...

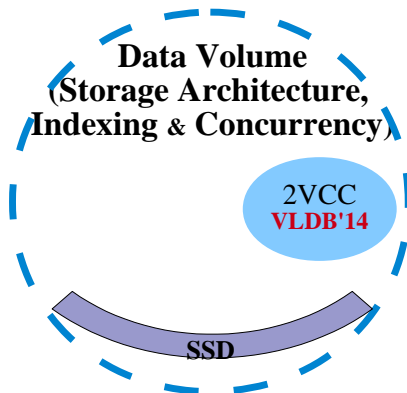## Indirection: Effect of Indexes in Operational Data Stores

TPC-H: all tables; Scale Factor: 20

Legend:
- **Query (Base)**
- **Query (Indirection)**
- **Update (Base)**
- **Update (Indirection)**

X-axis: **Number of Indexes**
Y-axis: **Relative Execution Time**

… Consequently affording more indexes and significantly reducing the query time

1 Data Velocity: Index Maintenance

2 Data Volume: MVCC Concurrency

3 Decentralized & Democratic Data Platform

4 References

Introducing Multi-version Concurrency Control

Generalized Concurrency Control: Volume Dimension

Observed Trends

In operational multi-version databases, there is a tremendous opportunity to avoid clashes between readers (scanning a large volume of data) and writers (frequent updates).

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## Generalized Concurrency Control: Volume Dimension

Observed Trends

In operational multi-version databases, there is a tremendous opportunity to avoid clashes between readers (scanning a large volume of data) and writers (frequent updates).

Introducing a (latch-free) *two-version concurrency control (2VCC)* by extending indirection mapping (i.e., central coordination mechanism) and exploiting existing two-phase locking (2PL) in order to

Generalized Concurrency Control: Volume Dimension

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In operational multi-version databases, there is a tremendous opportunity to avoid clashes between readers (scanning a large volume of data) and writers (frequent updates).

Introducing a (latch-free) *two-version concurrency control (2VCC)* by extending indirection mapping (i.e., central coordination mechanism) and exploiting existing two-phase locking (2PL) in order to
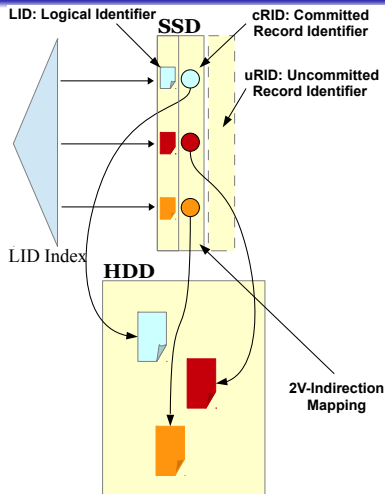Decouple Readers/Writers to Reduce Contention
(Pessimistic and Optimistic Concurrency Control Coexistence)

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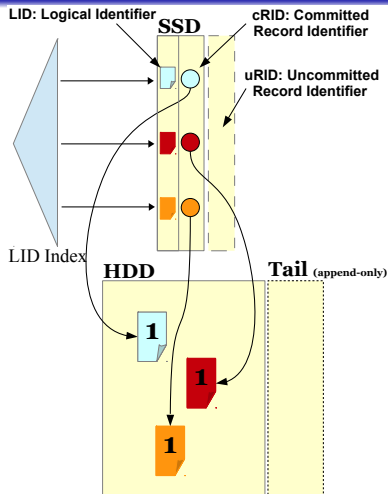# 2V-Indirection Indexing: Updating Records
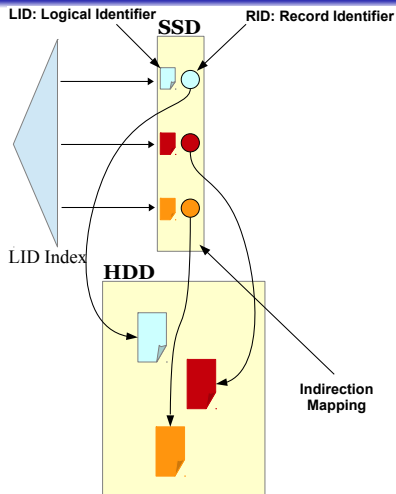
Recap: Indirection technique for reducing index maintenance
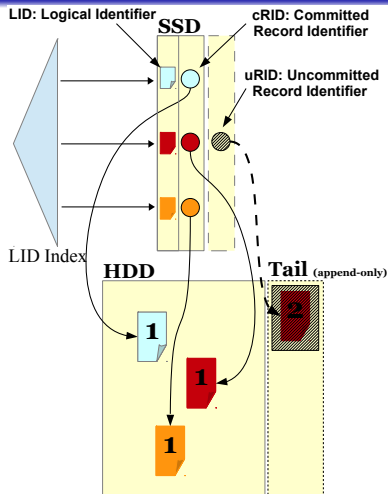
2V-Indirection Indexing: Updating Records

Extending the indirection to committed/uncommitted records

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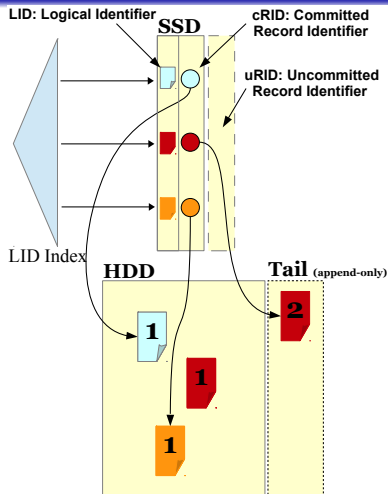
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2V-Indirection Indexing: Updating Records

Extending the indirection to committed/uncommitted records

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2V-Indirection Indexing: Updating Records

Decoupling readers/writers to eliminate contention

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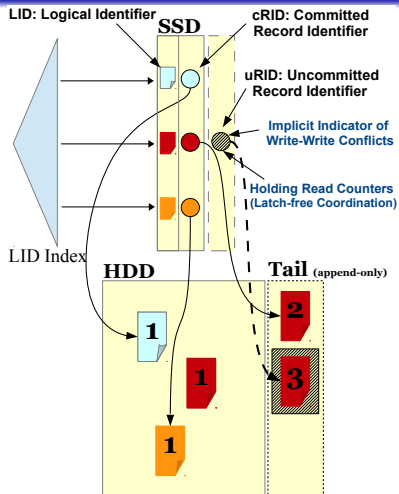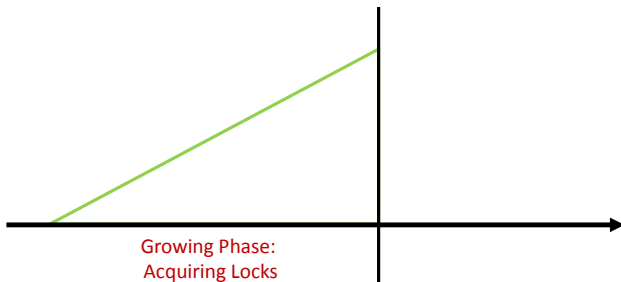○

2V-Indirection Indexing: Updating Records

Decoupling readers/writers to eliminate contention

2V-Indirection Indexing: Updating Records

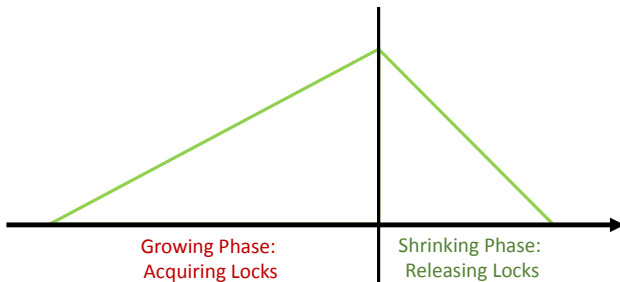Decoupling readers/writers to eliminate contention

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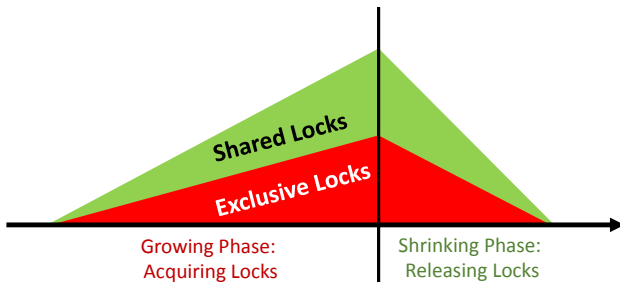# Overview of Two-version Concurrency Control Protocol

Growing Phase:
Acquiring Locks

Two-phase locking (2PL) consisting of growing and shrinking phases

Overview of Two-version Concurrency Control Protocol

Growing Phase: Shrinking Phase:
Acquiring Locks   Releasing Locks

Two-phase locking (2PL) consisting of growing and shrinking phases

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Overview of Two-version Concurrency Control Protocol

Two-phase locking (2PL) consisting of growing and shrinking phases

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Overview of Two-version Concurrency Control Protocol
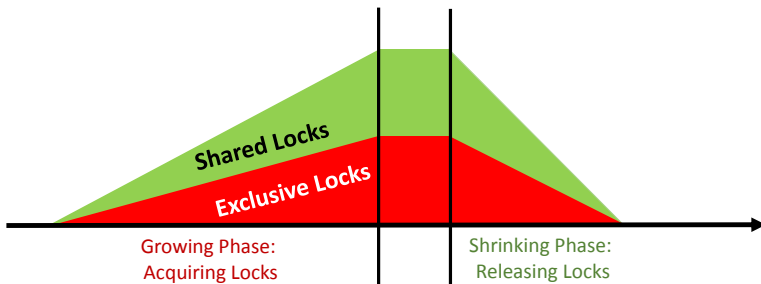
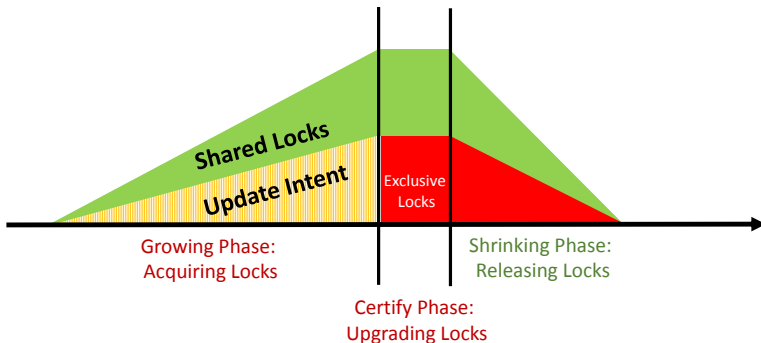Extending 2PL with certify phase
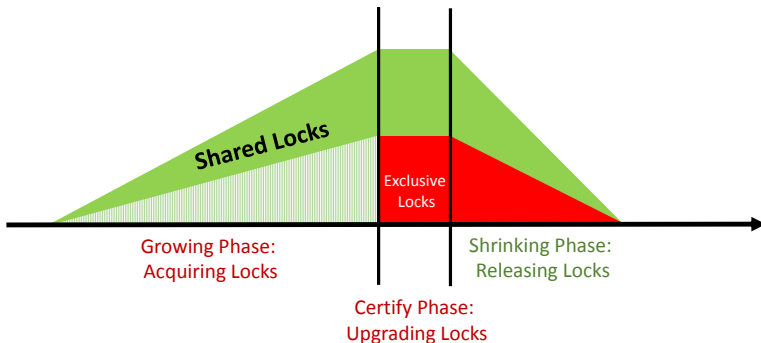
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Overview of Two-version Concurrency Control Protocol

Exclusive locks held for shorter period (inherently optimistic)

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Overview of Two-version Concurrency Control Protocol

Exclusive locks held for shorter period (inherently optimistic)

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Overview of Two-version Concurrency Control Protocol
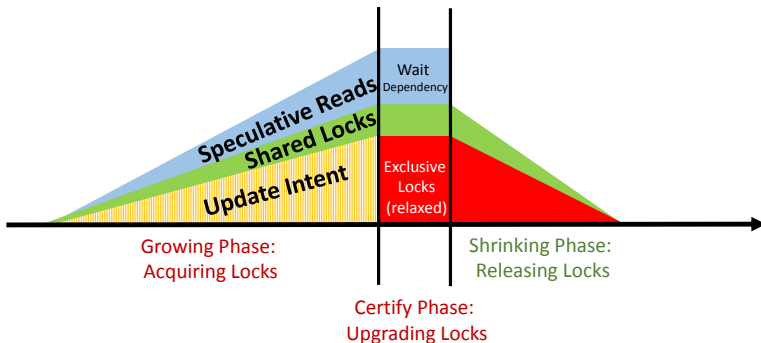
Relaxed exclusive locks to allow speculative reads (increased optimism)

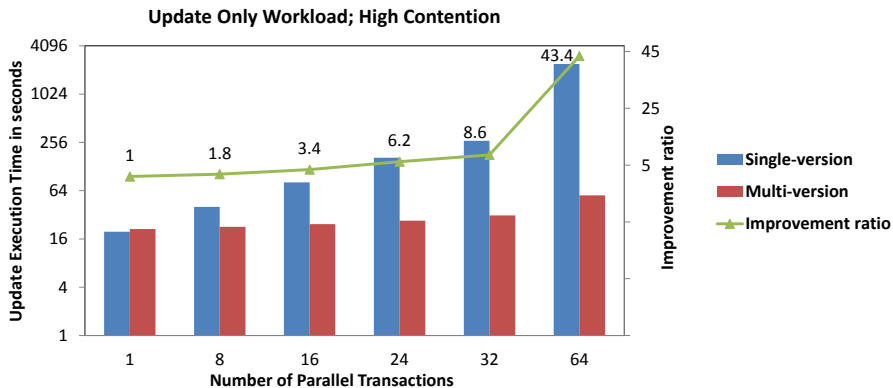Indirection
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Overview of Two-version Concurrency Control Protocol
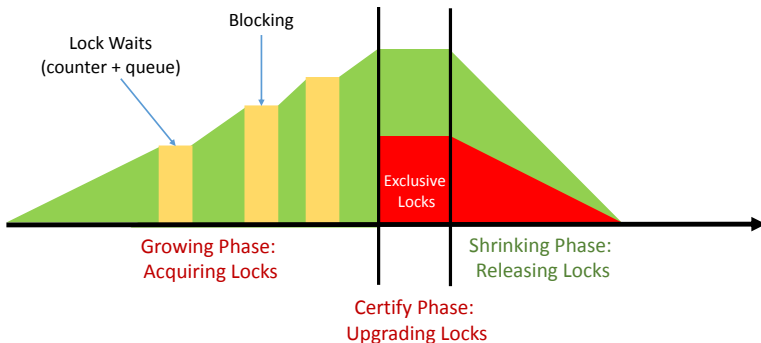
Trade-offs between blocking (i.e., locks) vs. non-blocking (i.e., read counters)

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Experimental Analysis

2VCC: Effect of Parallel Update Transactions

Update Only Workload; High Contention

Substantial gain by reducing the read/write contention & using non-blocking operations

2VCC: Effect of Parallel Update Transactions

**Lock Statistics Comparison; High Contention**

- ◆ Deadlock Ratio
- ■ Number of Lock Waits Ratio
- ▲ Lock Wait Time Ratio
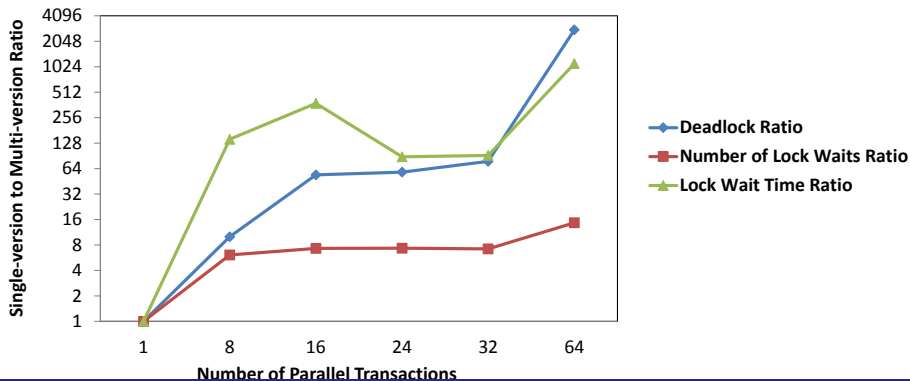
Substantial gain by reducing the read/write contention & using non-blocking operations

1 Data Velocity: Index Maintenance

2 Data Volume: MVCC Concurrency

3 Decentralized & Democratic Data Platform

4 References

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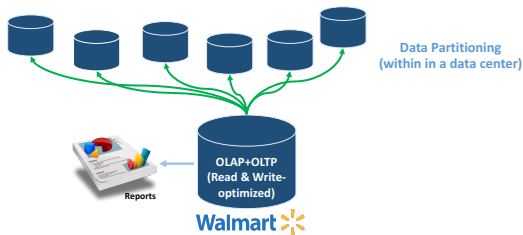
References
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Recap: Data Management Challenges at Microscale
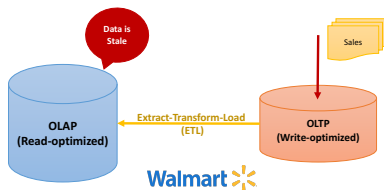
OLTP and OLAP data are isolated at microscale
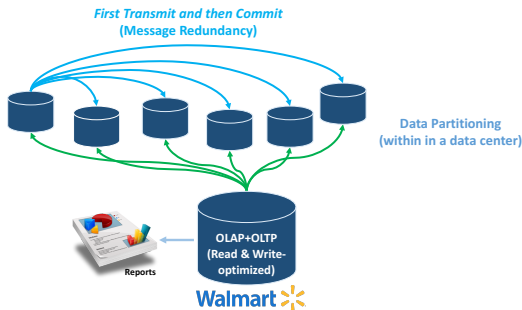
Recap: Data Management Challenges at Microscale
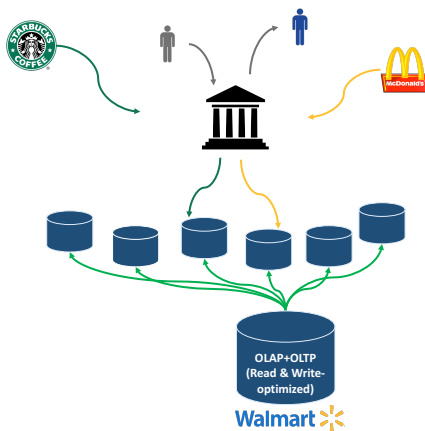

First step is to unify OLTP and OLAP

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Platform Scaling: Data Partitioning

Moving towards distributed environment

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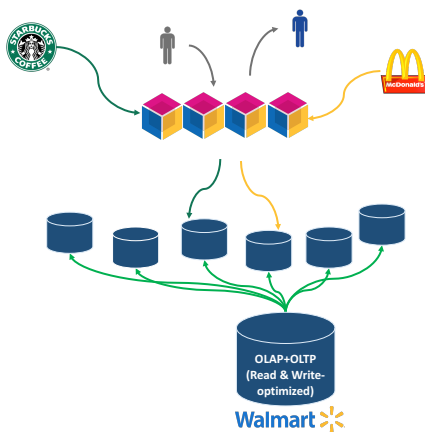# Platform Scaling: Non-blocking Agreement Protocols

Message redundancy vs. latency trade-offs [EasyCommit, EDBT'18]
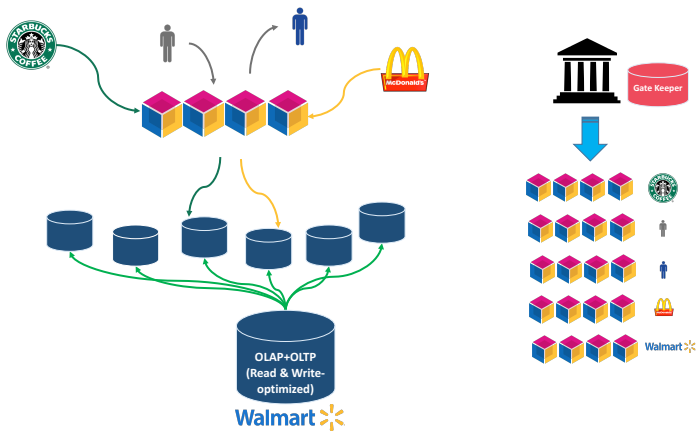
Central Control: Data Gate Keeper

Conform to trusting the central authority and governance

Decentralized Control: Removing Data Barrier

Seek trust in *decentralized* and *democratic* governance [PoE (EDBT'21), RCC (ICDE'21)]

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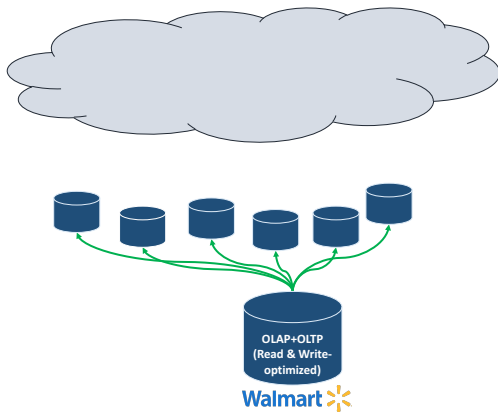# Democratic Control: Removing Trust Barrier

Seek trust in *decentralized* and *democratic* governance [PoE (EDBT'21), RCC (ICDE'21)]

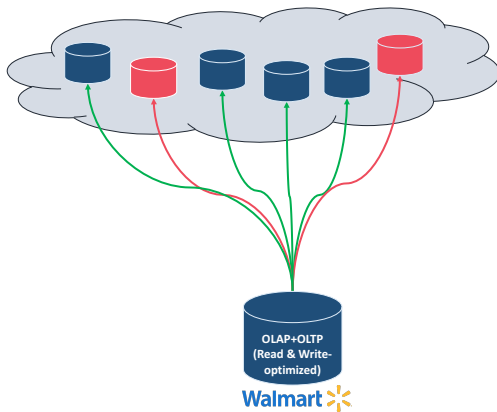# Global-scale Reliable Platform over Unreliable Hardware

Self-managed infrastructure

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Global-scale Reliable Platform over Unreliable Hardware
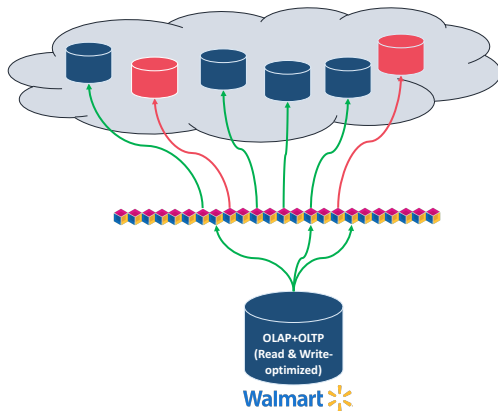

Cloud-managed infrastructure (trust the provider)

Global-scale Reliable Platform over Unreliable Hardware

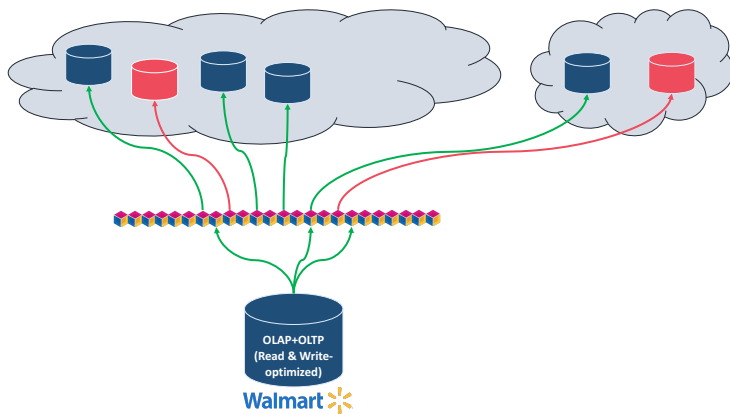Cloud-managed infrastructure (trust the provider)

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Global-scale Reliable Platform over Unreliable Hardware

Light-weight, fault-tolerant, trusted middleware [Blockplane, (ICDE'18)]

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Global-scale Reliable Platform over Unreliable Hardware

Global Scale fault-tolerant protocols [GeoBFT (VLDB'20), Delayed Replication (ICDT'20)]

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References
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Questions?
Thank you!

Exploratory Systems Lab (ExpoLab)
Website: https://expolab.org/

Related Publications (Patents Omitted)

I. Abdelaziz, A. Fokoue, O. Hassanzadeh, P. Zhang, M. Sadoghi.
Large-scale structural and textual similarity-based mining of knowledge graph to predict drug-drug interactions.
In *J. Web Sem.* pages 104–117, 2017.

A. Fokoue, O. Hassanzadeh, **M. Sadoghi**, and P. Zhang.
Predicting drug-drug interactions through similarity-based link prediction over web data.
In *Proceedings of the 25th International Conference on World Wide Web, WWW 2016, Montreal, Canada, April 11-15, 2016, Companion Volume*, pages 175–178, 2016.

A. Fokoue, **M. Sadoghi**, O. Hassanzadeh, and P. Zhang.
Predicting drug-drug interactions through large-scale similarity-based link prediction.
In *The Semantic Web. Latest Advances and New Domains - 13th International Conference, ESWC 2016, Heraklion, Crete, Greece, May 29 - June 2, 2016, Proceedings*, pages 774–789, 2016.

Rajesh R. Bordawekar and **M. Sadoghi**.
Accelerating database workloads by software-hardware-system co-design.
In *32nd IEEE International Conference on Data Engineering, ICDE 2016, Helsinki, Finland, May 16-20, 2016*, pages 1428–1431, 2016.

A. Chandel, O. Hassanzadeh, N. Koudas, **M. Sadoghi**, and D. Srivastava.
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A. Farroukh, **M. Sadoghi**, and H.-A. Jacobsen.
Towards vulnerability-based intrusion detection with event processing.
In *Proceedings of the 5th ACM international conference on Distributed event-based system*, DEBS 2011, pages 171–182, New York, New York, USA, 2011. ACM.

O. Hassanzadeh, **M. Sadoghi**, and R. J. Miller.
Accuracy of approximate string joins using grams.
In V. Ganti and F. Naumann, editors, *Proceedings of the Fifth International Workshop on Quality in Databases, QDB 2007 at VLDB 2007 conference, Vienna, Austria, September 23, 2007*, pages 11–18, 2007.

M. Hemmatpour, B. Montrucchio, M. Rebaudengo, and **M. Sadoghi**.
Kanzi: A distributed, in-memory key-value store.
In *Proceedings of the 17th Annual Middleware Conference, Trento, Italy, December 12–16, 2016*, 2016.

M. Jergler, **M. Sadoghi**, and H.-A. Jacobsen.
D2WORM: A management infrastructure for distributed data-centric workflows.
In *Proceedings of the 2015 ACM SIGMOD International Conference on Management of Data, Melbourne, Victoria, Australia, May 31 - June 4, 2015*, pages 1427–1432, 2015.

M. Jergler, **M. Sadoghi**, and H.-A. Jacobsen.
Geo-distribution of flexible business processes over publish/subscribe paradigm.
In *Proceedings of the 17th Annual Middleware Conference, Trento, Italy, December 12–16, 2016*, 2016.

P. Menon, T. Rabl, **M. Sadoghi**, and H. Jacobsen.
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