Proteus:
Autonomous Adaptive Storage for Mixed Workloads

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Mixed Workloads

SELECT
book, **SUM**(qnt)
GROUP BY book

INSERT
(104, LoTR, John,
2, $21)

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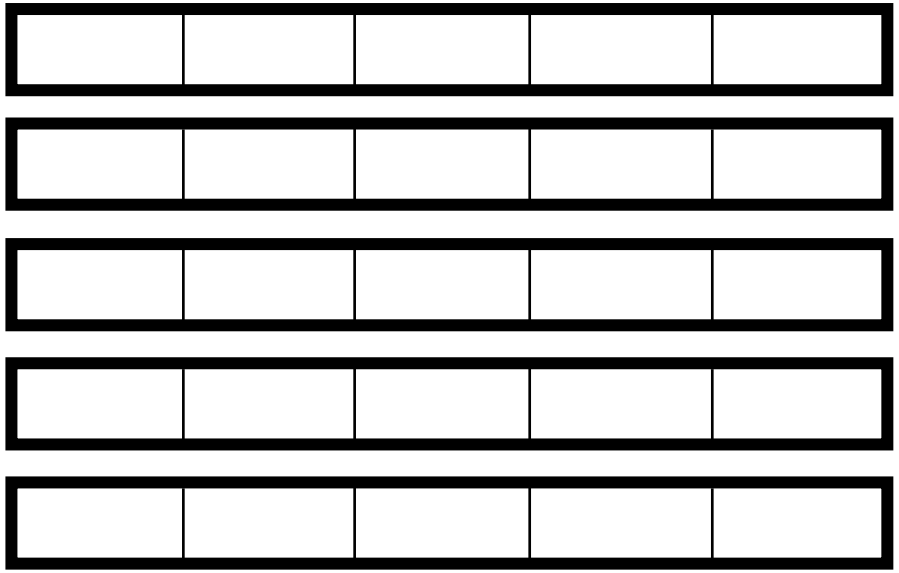
Mixed Workloads and Storage

Row Layout



Updates (OLTP)

INSERT
(104, LoTR, John,
2, $21)

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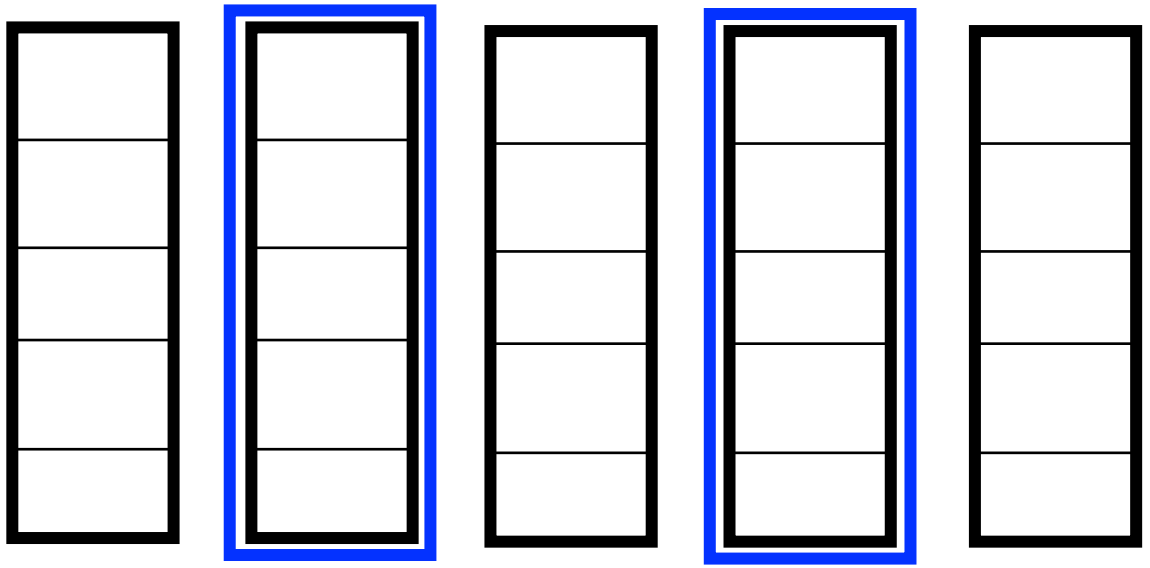
Mixed Workloads and Storage

Columnar Layout



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Analytics (OLAP)

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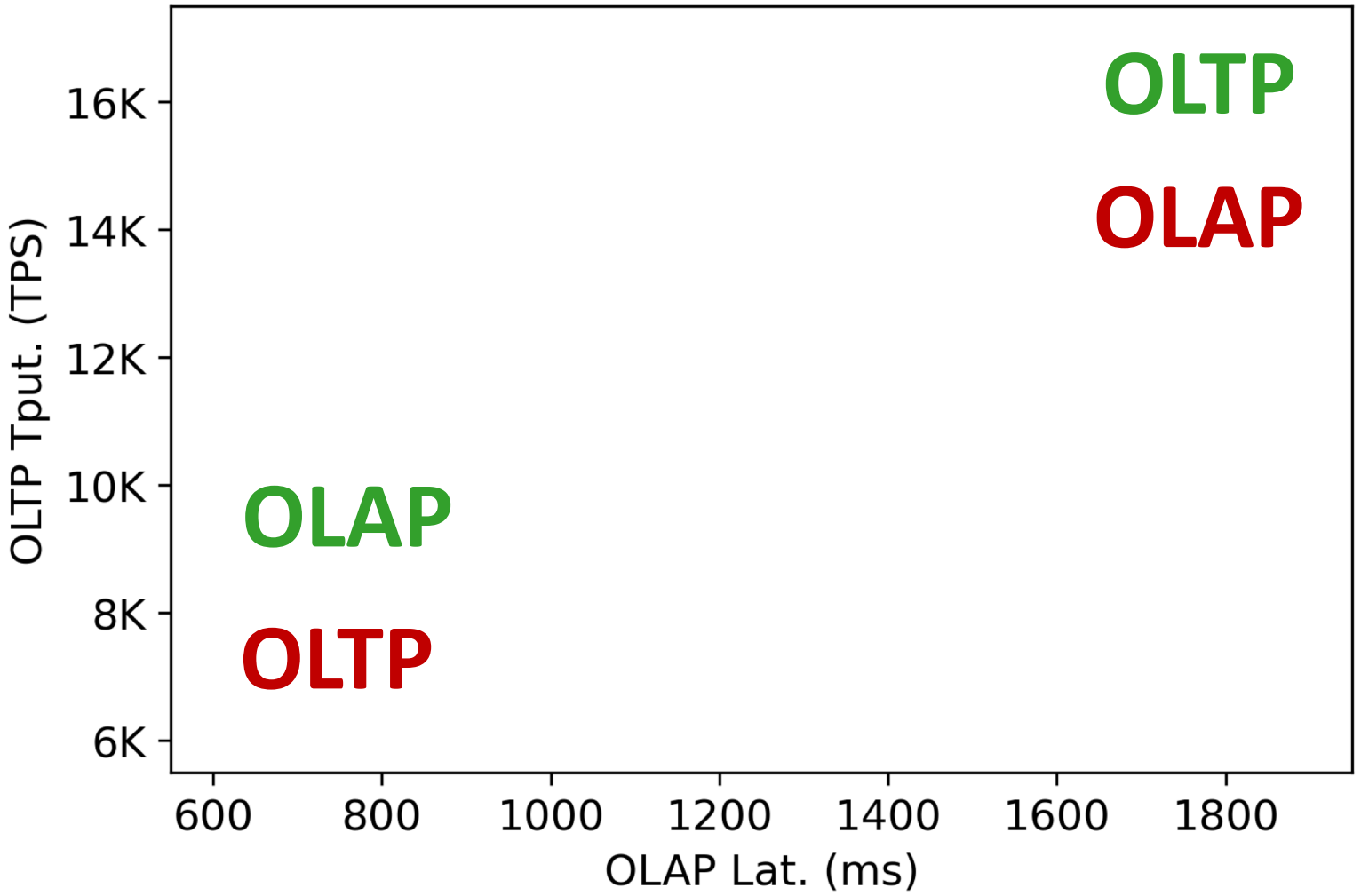
Performance Trade-Off



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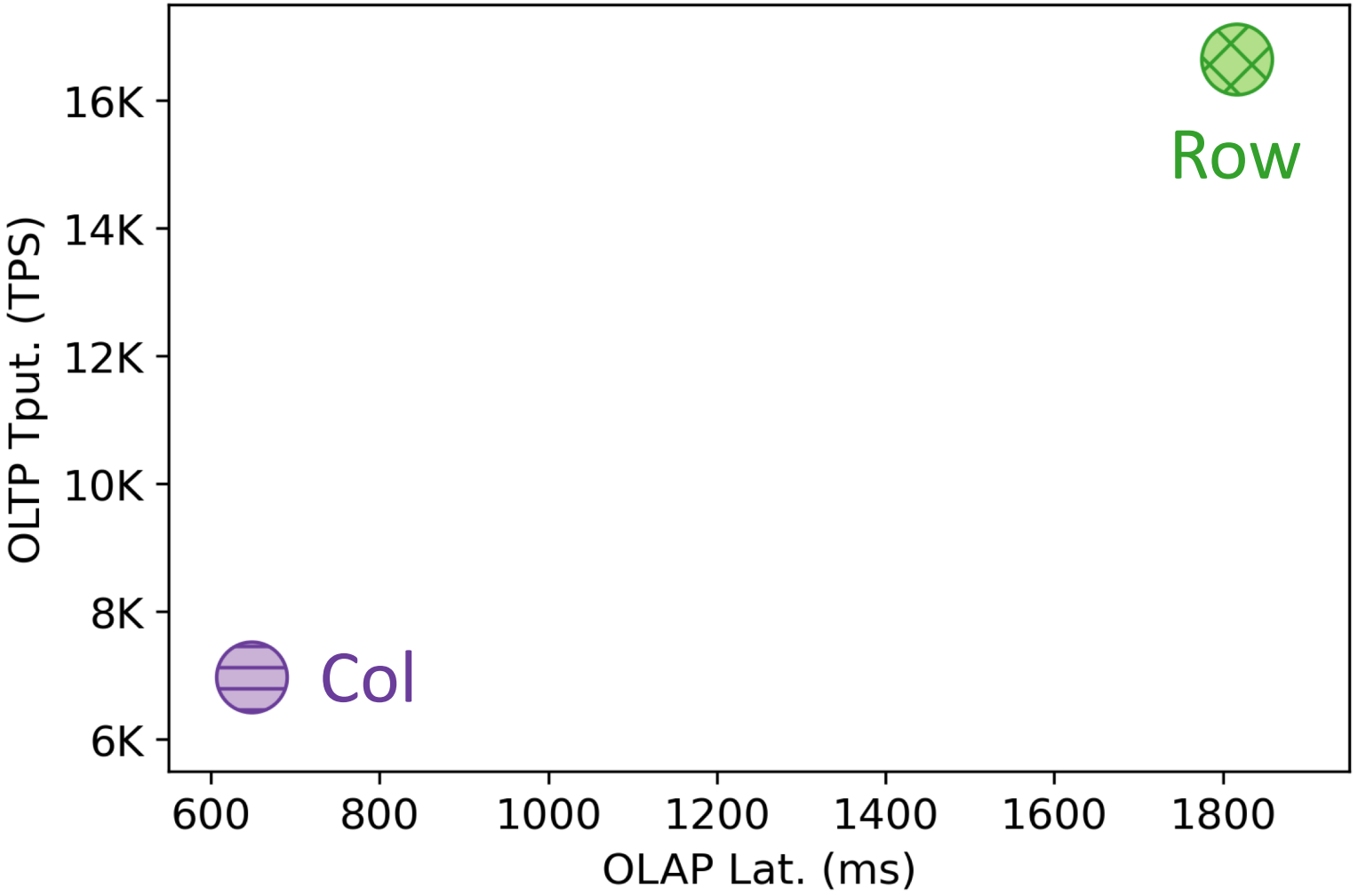
Performance Trade-Off



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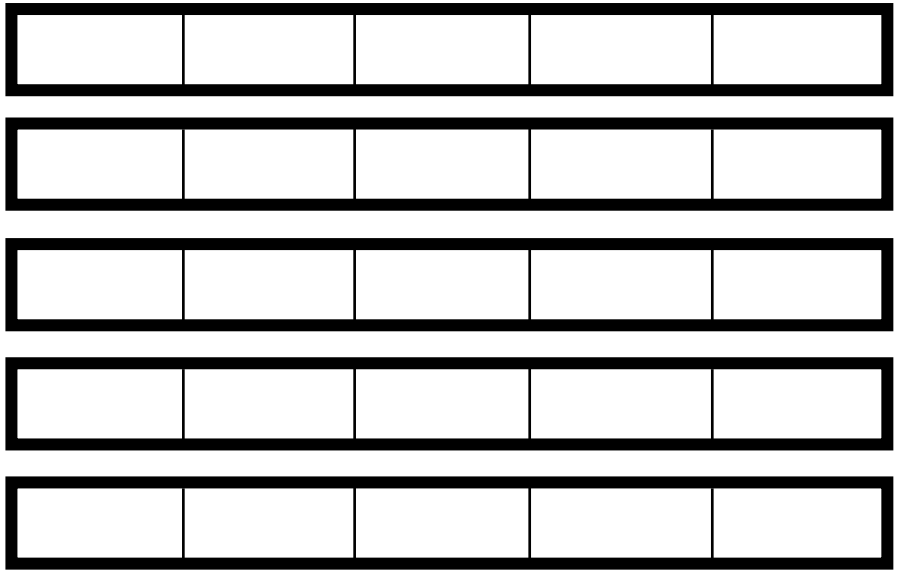
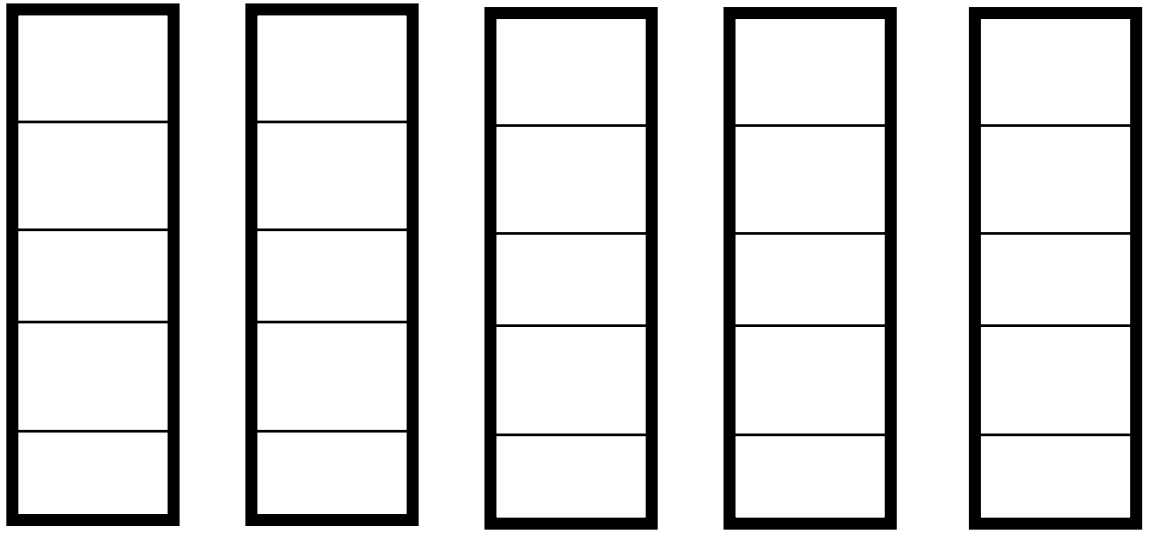
Keep Data in Both Layouts

Row Layout



Updates

Columnar Layout



Analytics

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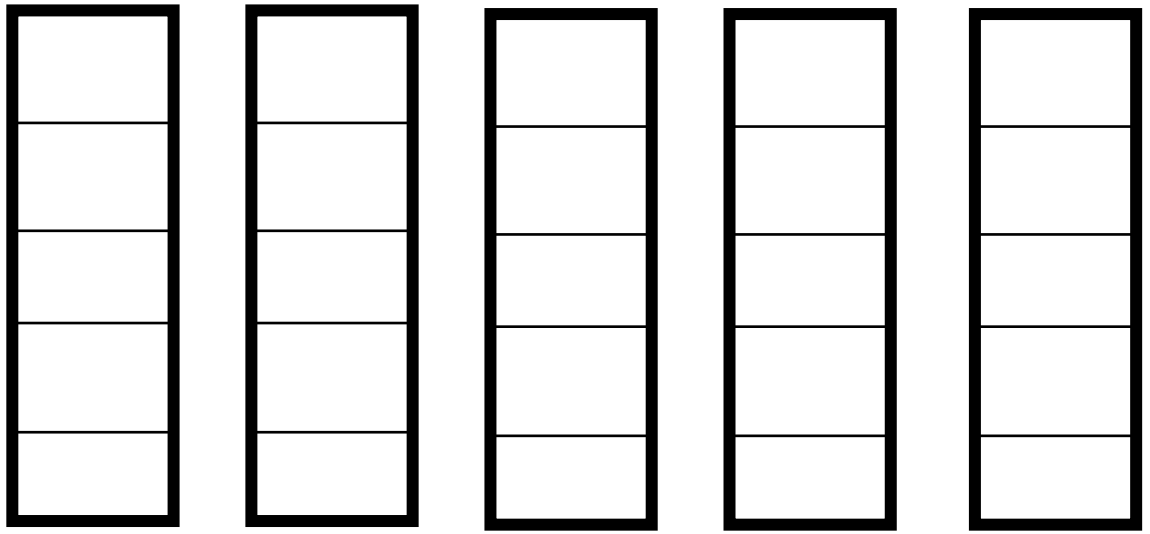
Keep Data in Both Layouts

Row Layout

Columnar Layout



Missing data

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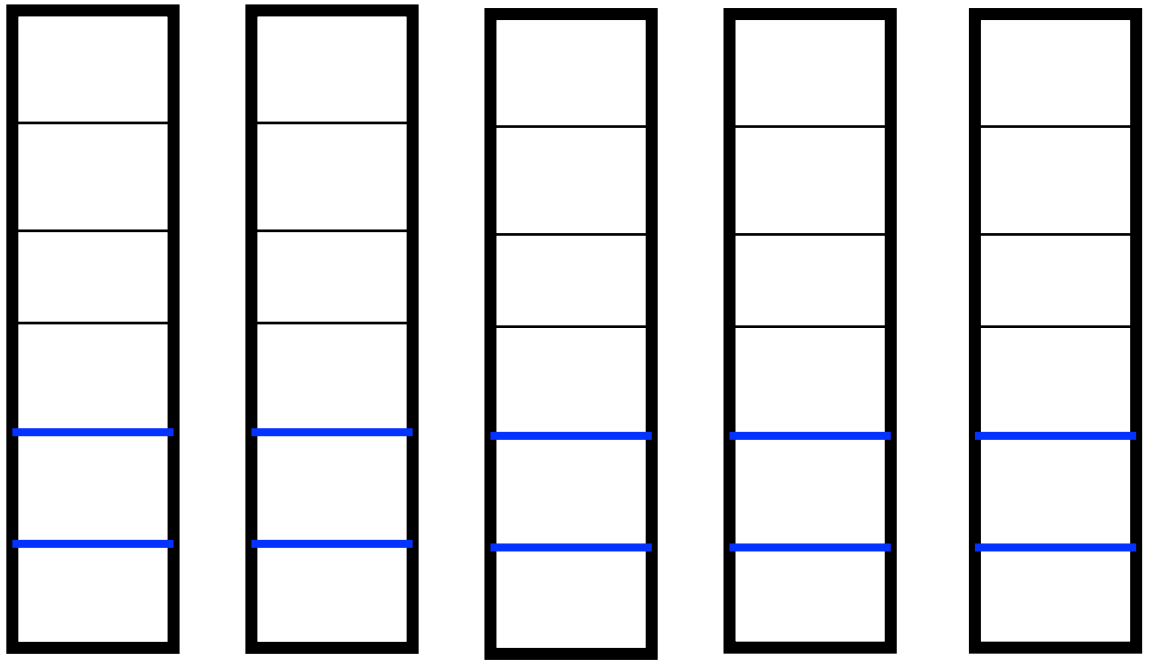
Keep Data in Both Layouts

Row Layout

Slow Updates

Columnar Layout



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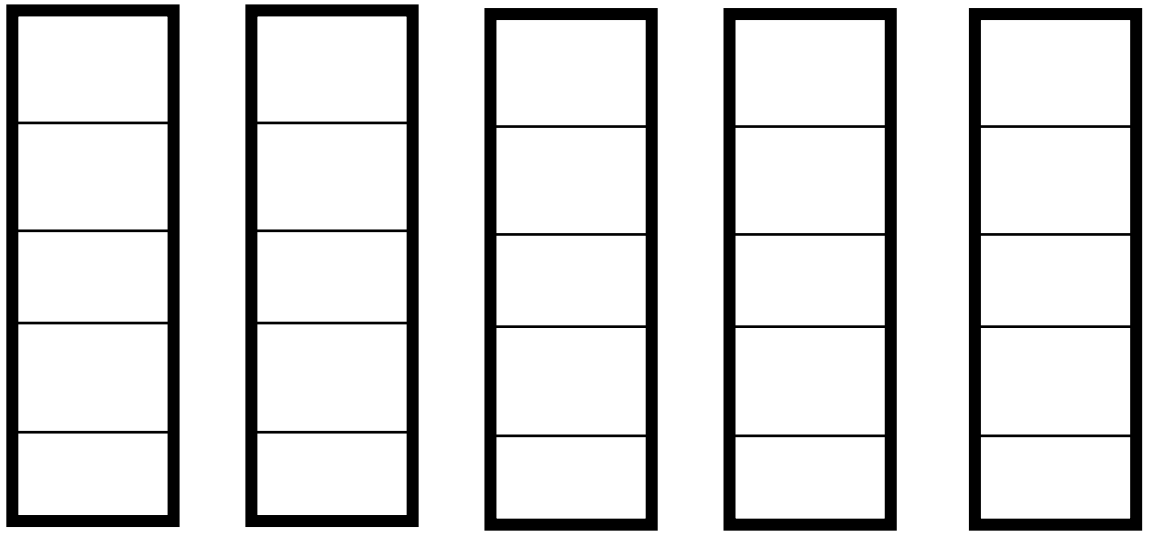
Keep Data in Both Layouts

Row Layout

Columnar Layout



Increased Storage Costs

Missing recent data

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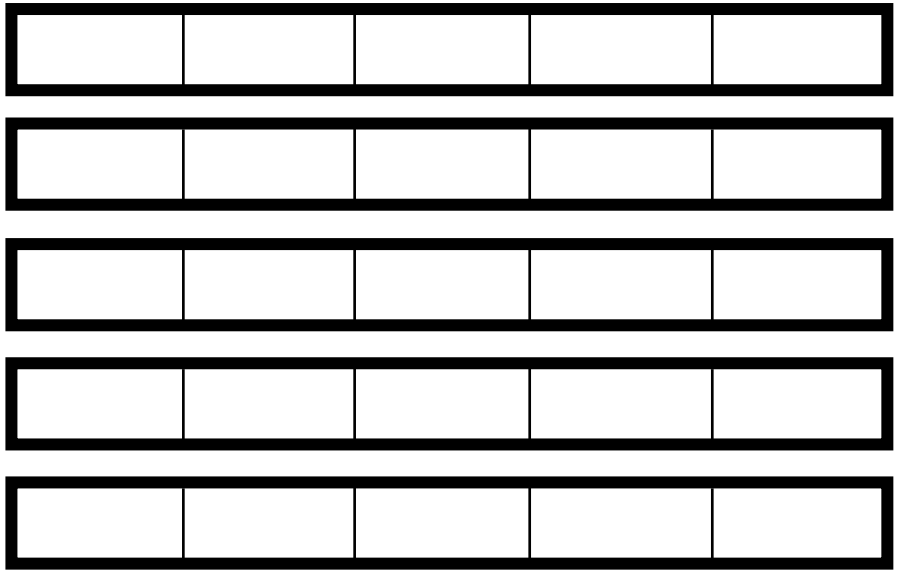
Which data in which layout?

Row Layout



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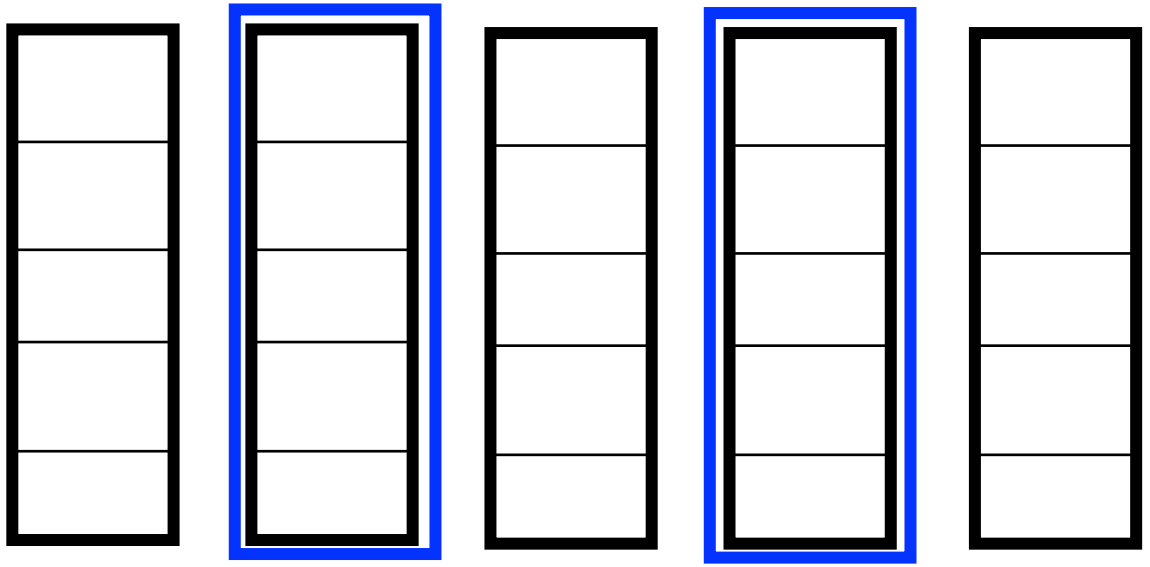

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GROUP BY book
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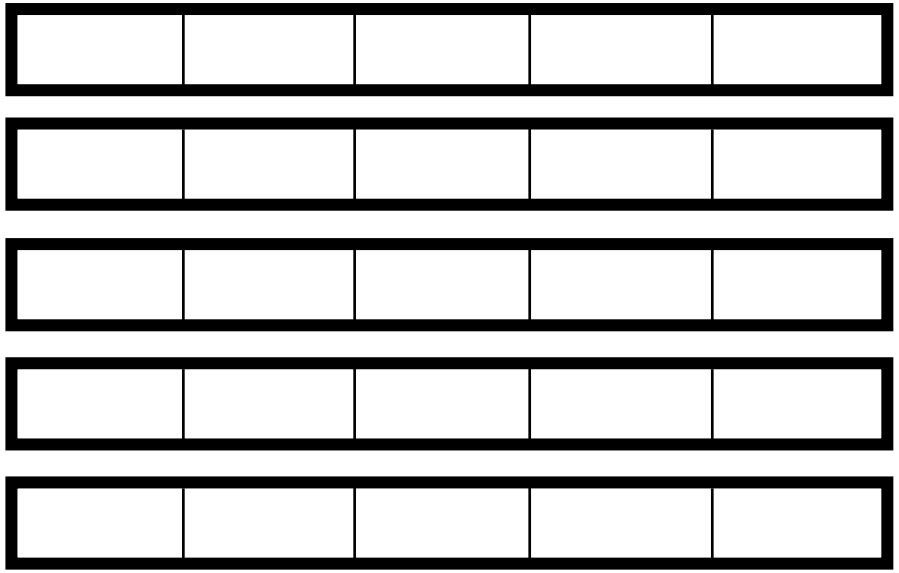

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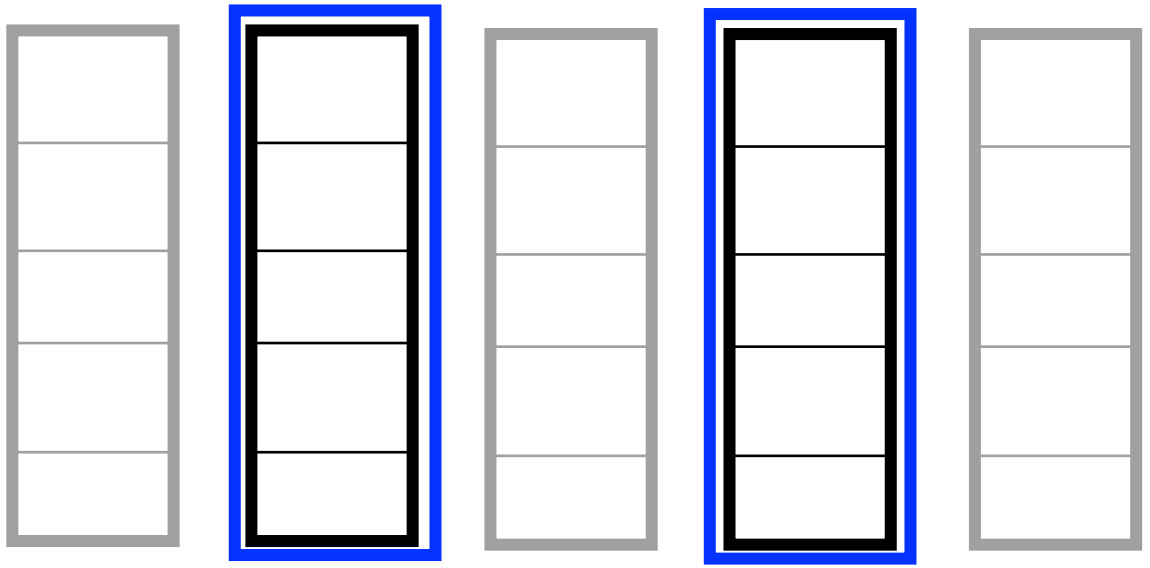

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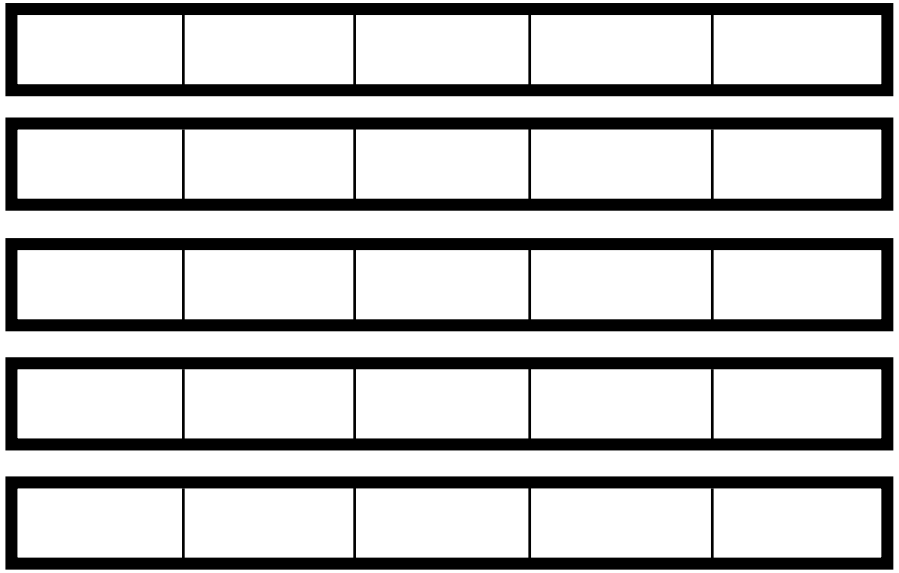

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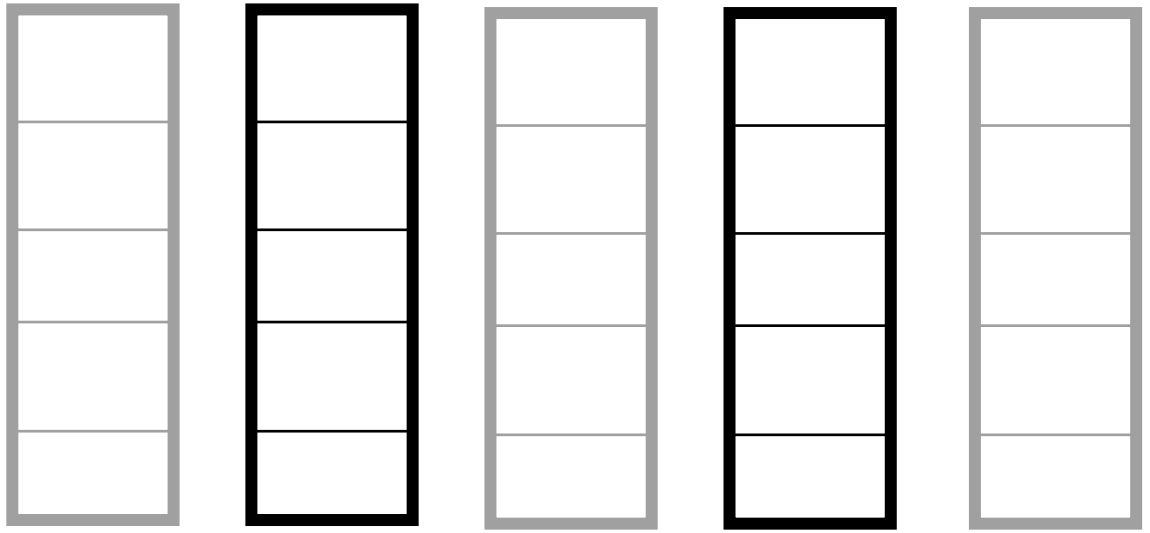

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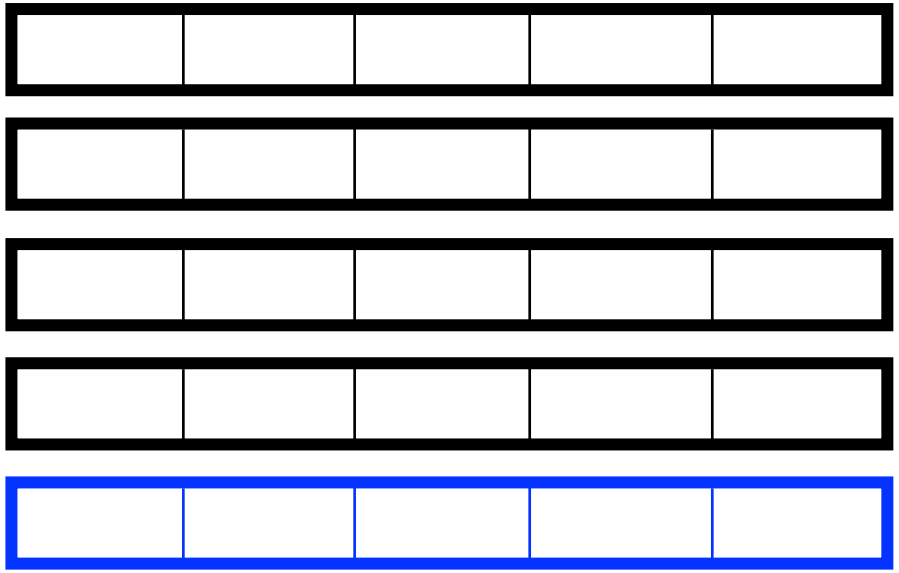

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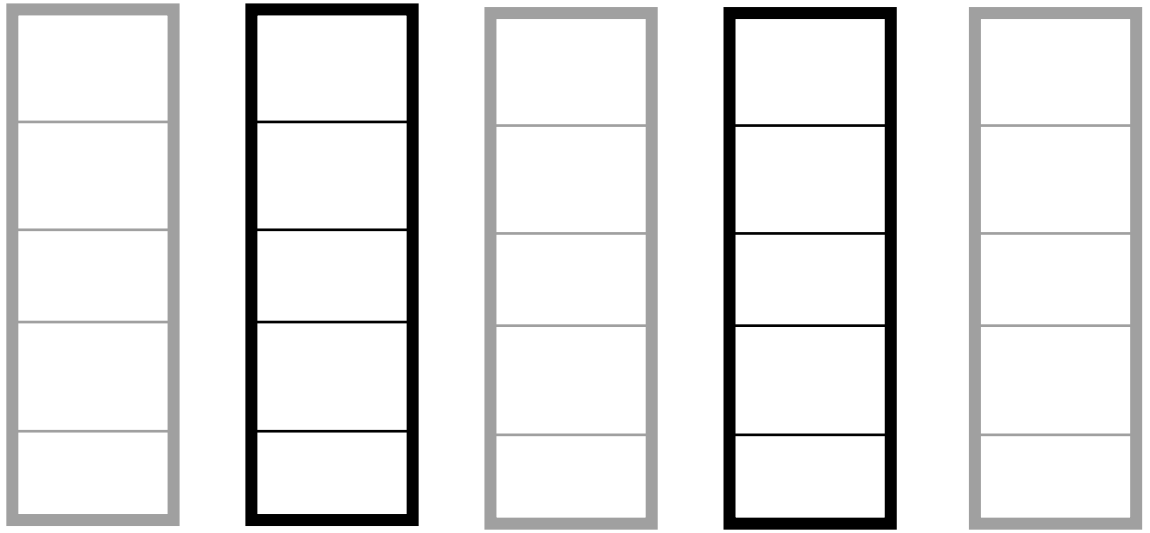

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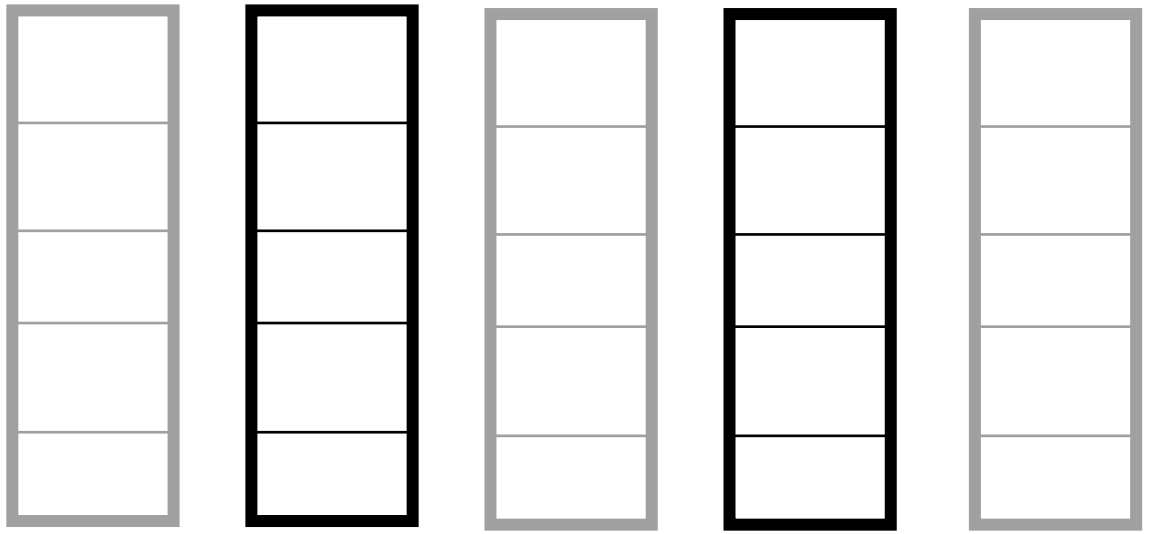

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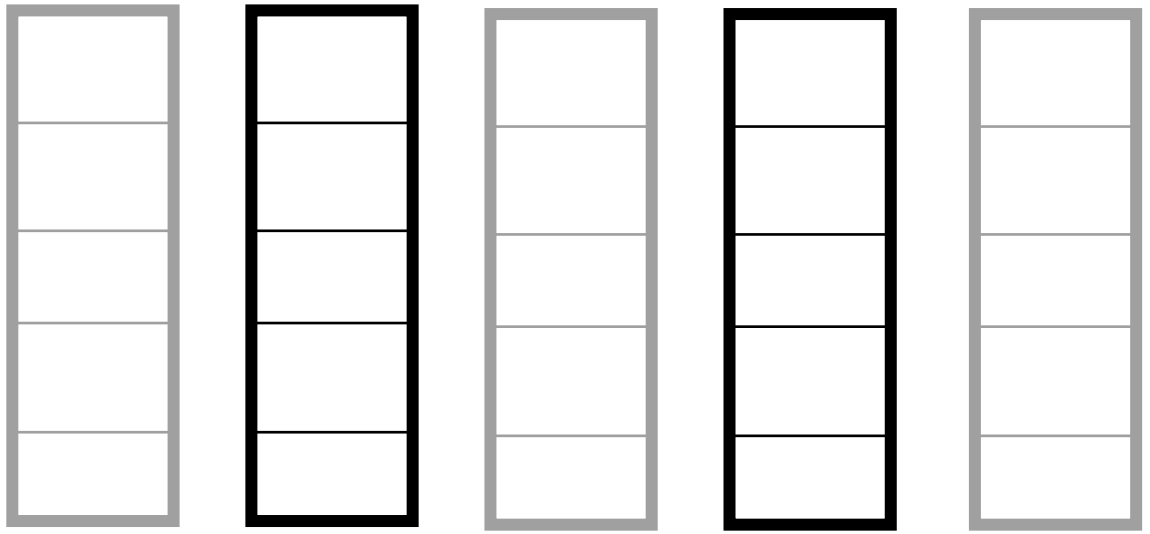
Row Layout

Columnar Layout



Need for autonomous adaptation

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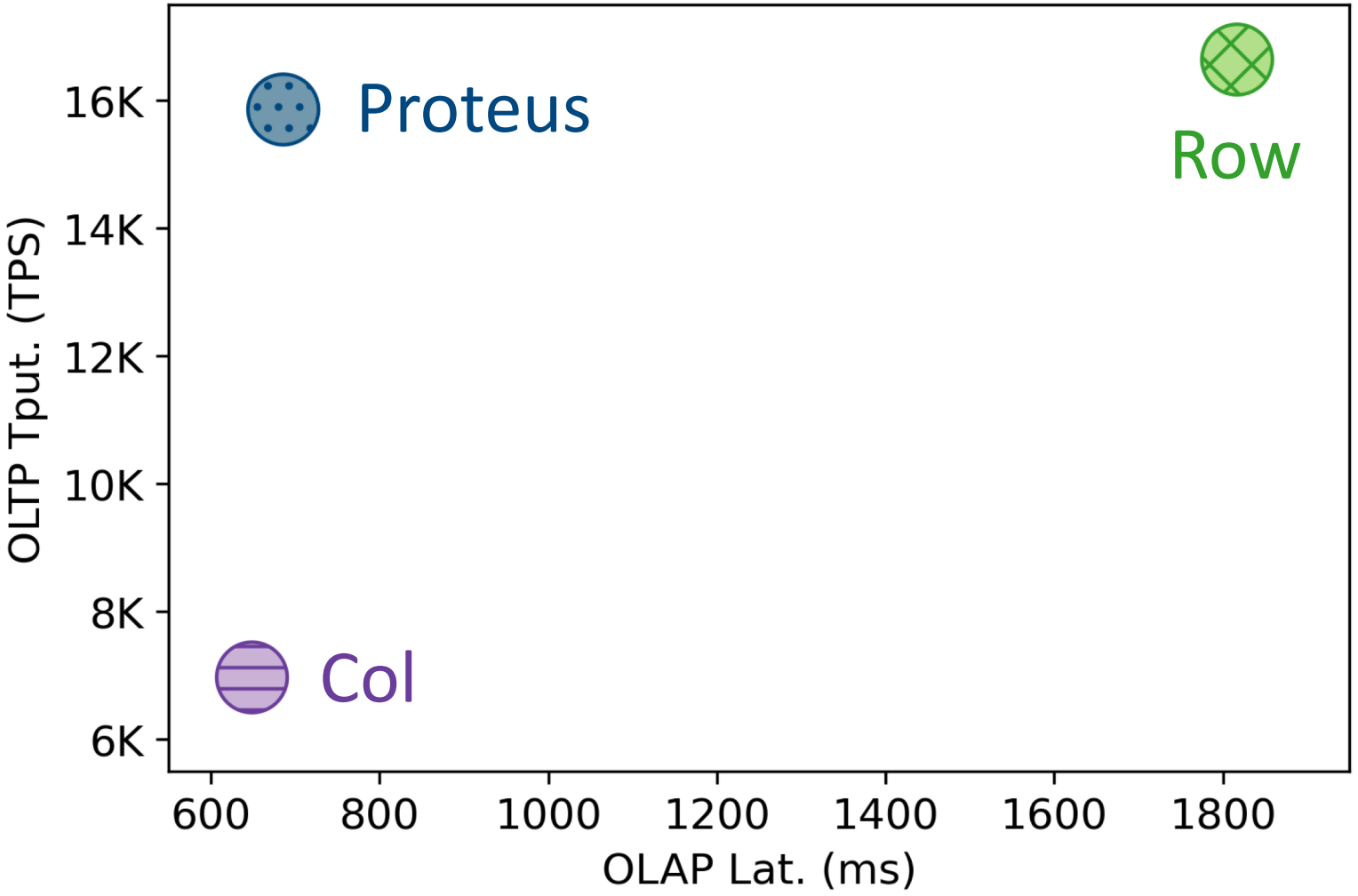
Proteus – Best of Both



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Proteus Goals

Selectively store data in **different** layouts

Leverage layout **specific optimizations**

System makes **decisions** based on **workload**

Scale-Out Distributed System

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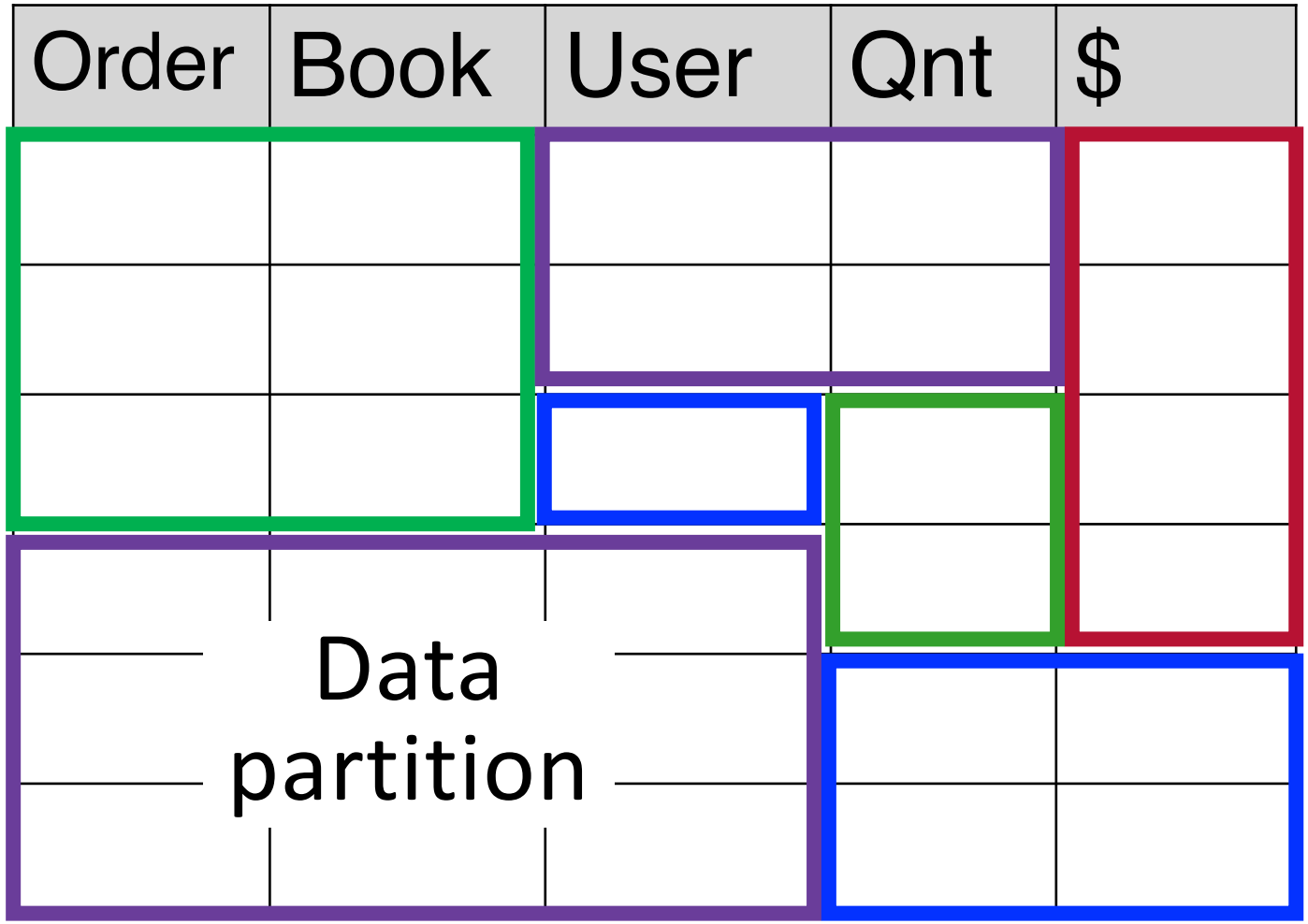
Proteus Decisions



Storage layout

Master/replica(s)

Txn execution

How to **partition?**

When & **what** to change

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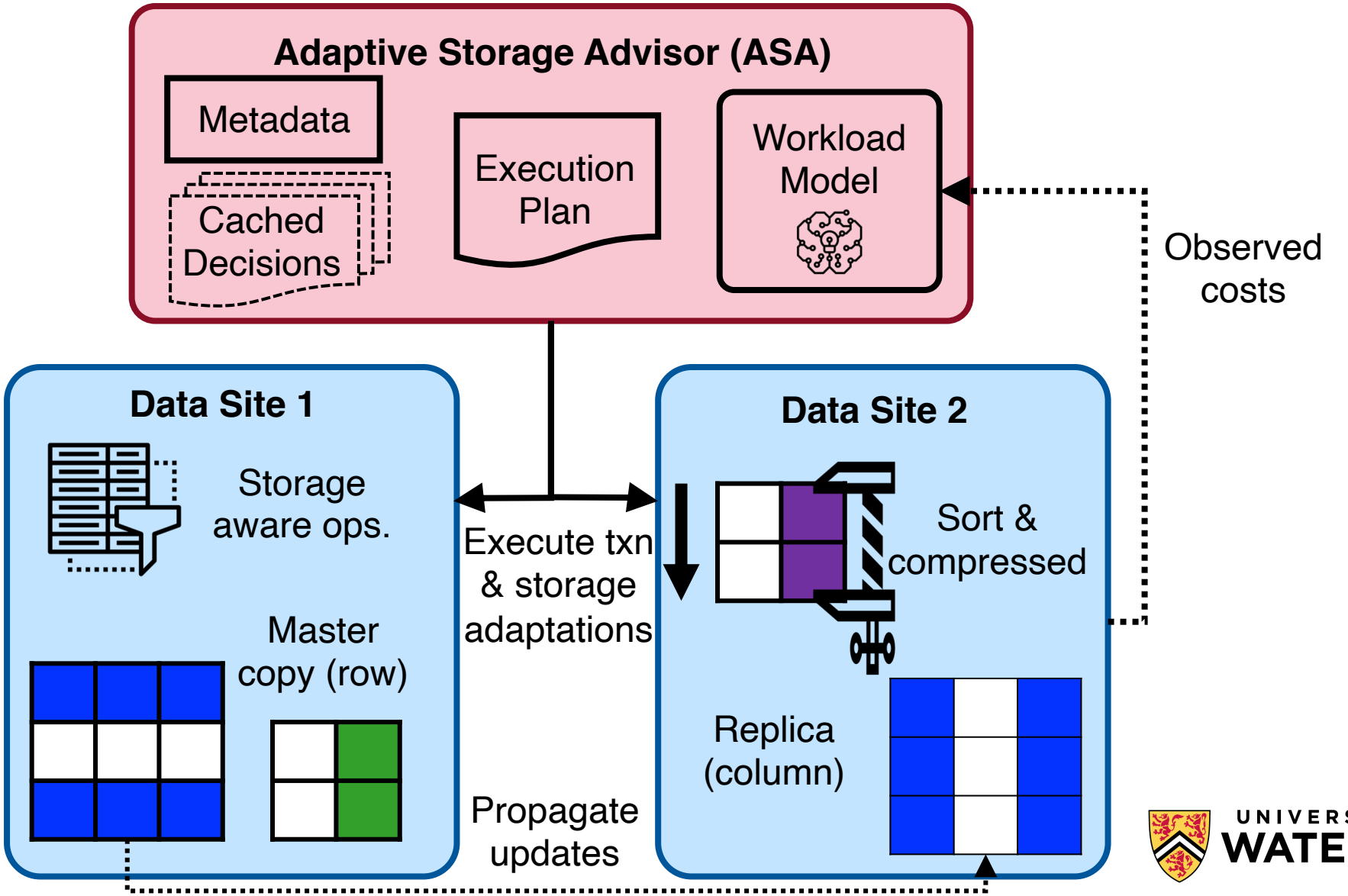
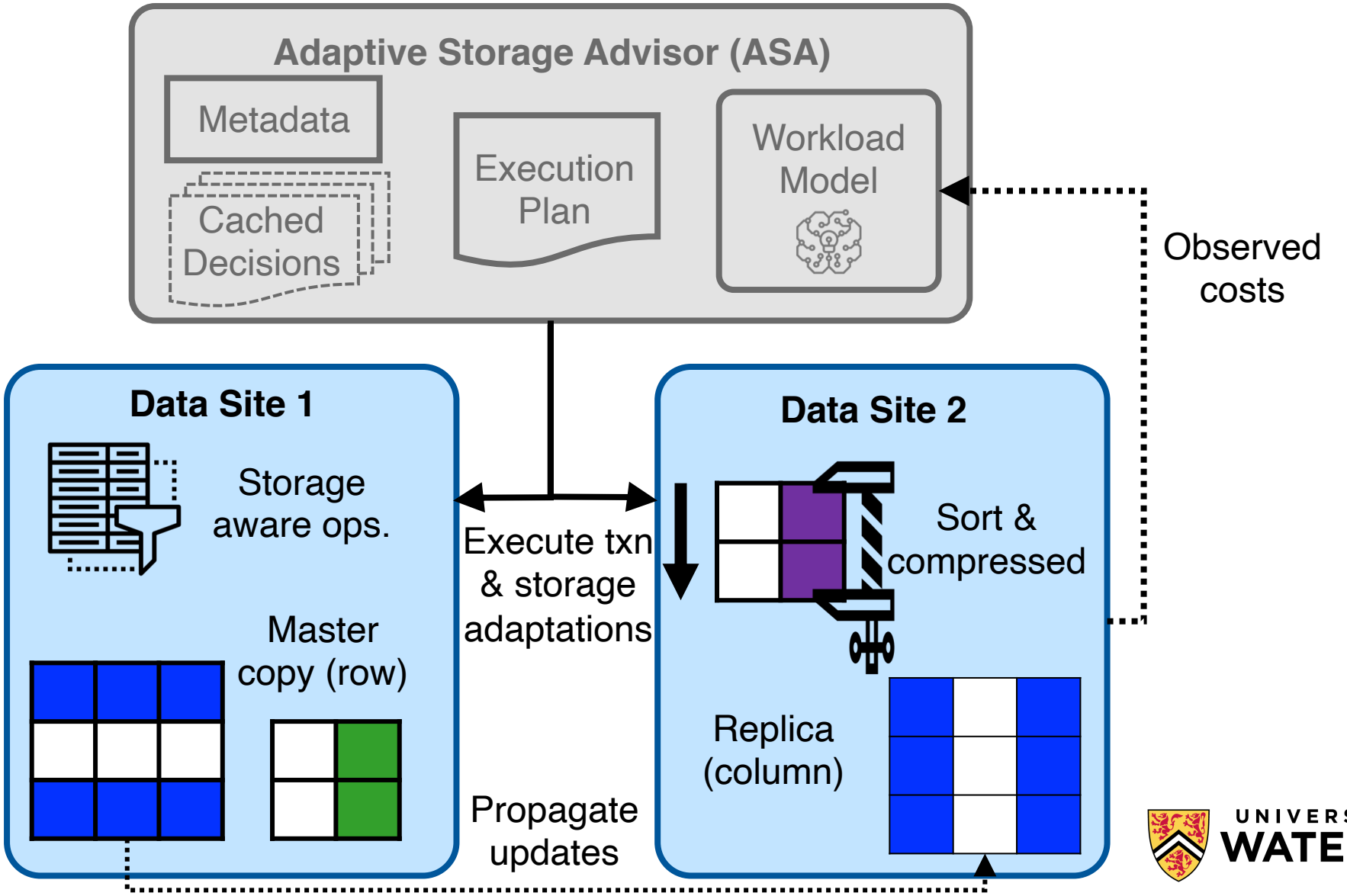
Proteus Architecture



Efficient Execution



Storage-Aware Operators

Order	Book	User	Qnt	$
100	HP	Alice	7	$15
101	Drac	Ted	90	$3
102	SQL	Geoff	1	$100
103	HP	Jean	3	$15

```
SELECT $
WHERE
  book == 'HP'
  or  QNT > 50
```

Storage-Aware Operators

Use **column-specific** operators

Merge bitmaps for predicates, extract data

Book	Qnt	Book == HP	Qnt > 50	Merged
Drac	90	0	1	1
HP	7	1	0	1
HP	3	1	0	1
SQL	1	0	0	0

```
SELECT $
WHERE
  book == 'HP'
  or  QNT > 50
```

Storage-Aware Operators

Order	Book	User	Qnt	$
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Book	Qnt

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Storage-Aware Operators

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SELECT
book, **SUM**(qnt)
GROUP BY book

Book	Qnt
HP	7

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Storage-Aware Operators

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100	HP	Alice	7	$15
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103	HP	Jean	3	$15

SELECT
book, **SUM**(qnt)
GROUP BY book

Book	Qnt
HP	7
Drac	90

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Storage-Aware Operators

Order	Book	User	Qnt	$
100	HP	Alice	7	$15
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SELECT
book, **SUM**(qnt)
GROUP BY book

Book	Qnt
HP	7
SQL	1
Drac	90

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Storage-Aware Operators

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100	HP	Alice	7	$15
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```
SELECT
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GROUP BY book
```

Book	Qnt
HP	10
SQL	1
Drac	90

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Storage-Aware Operators

Use **column-specific** operators

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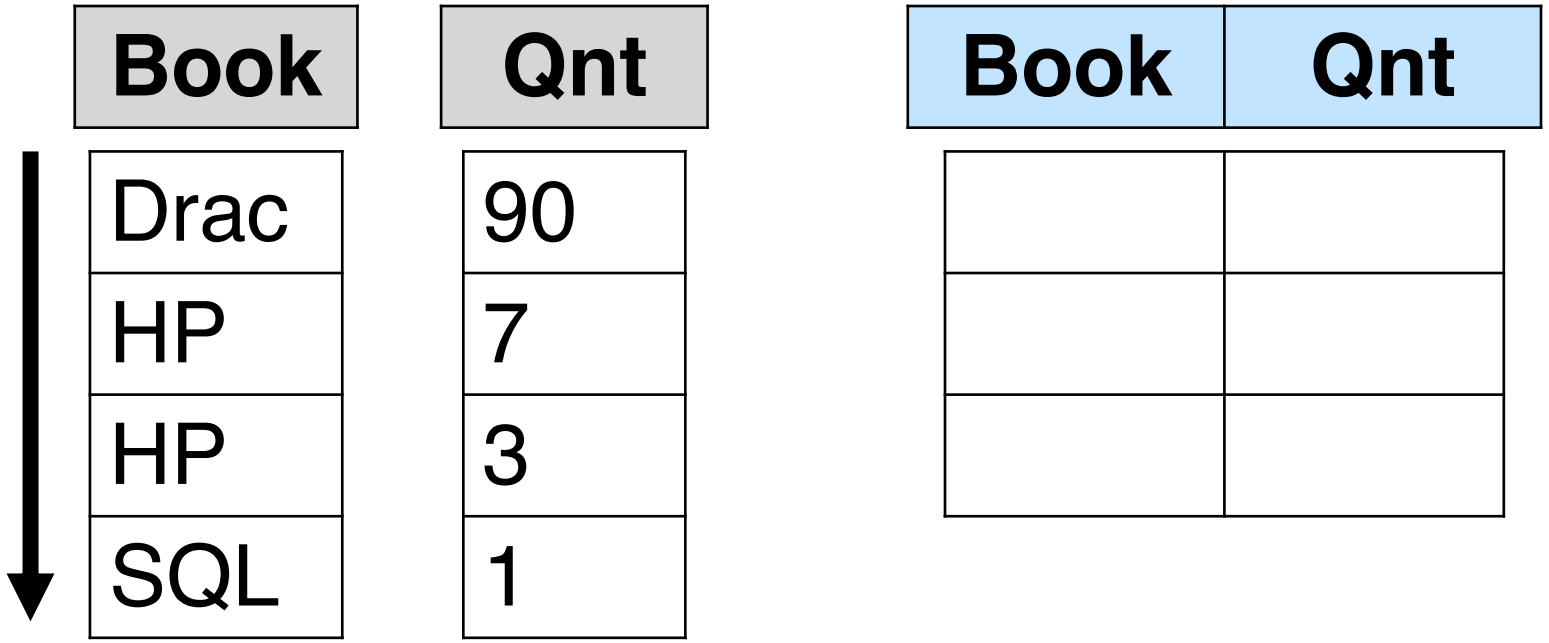

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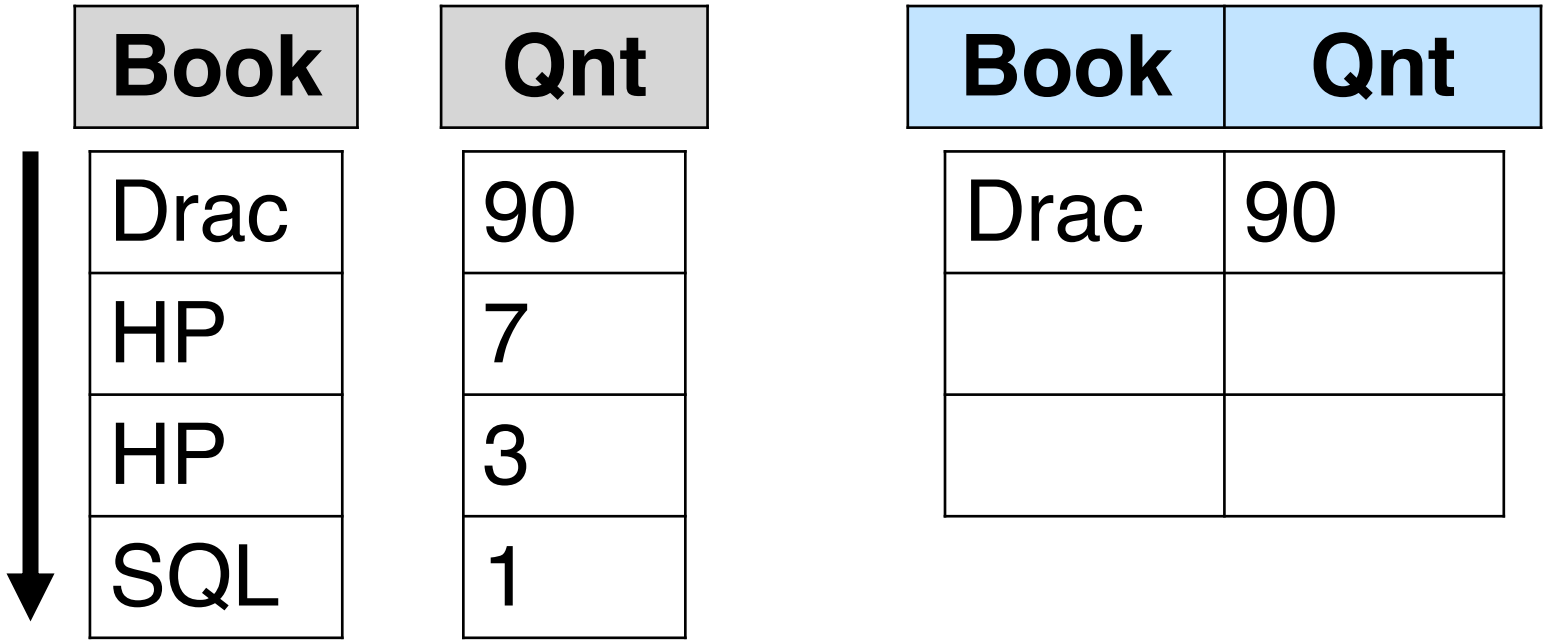

Book	Qnt
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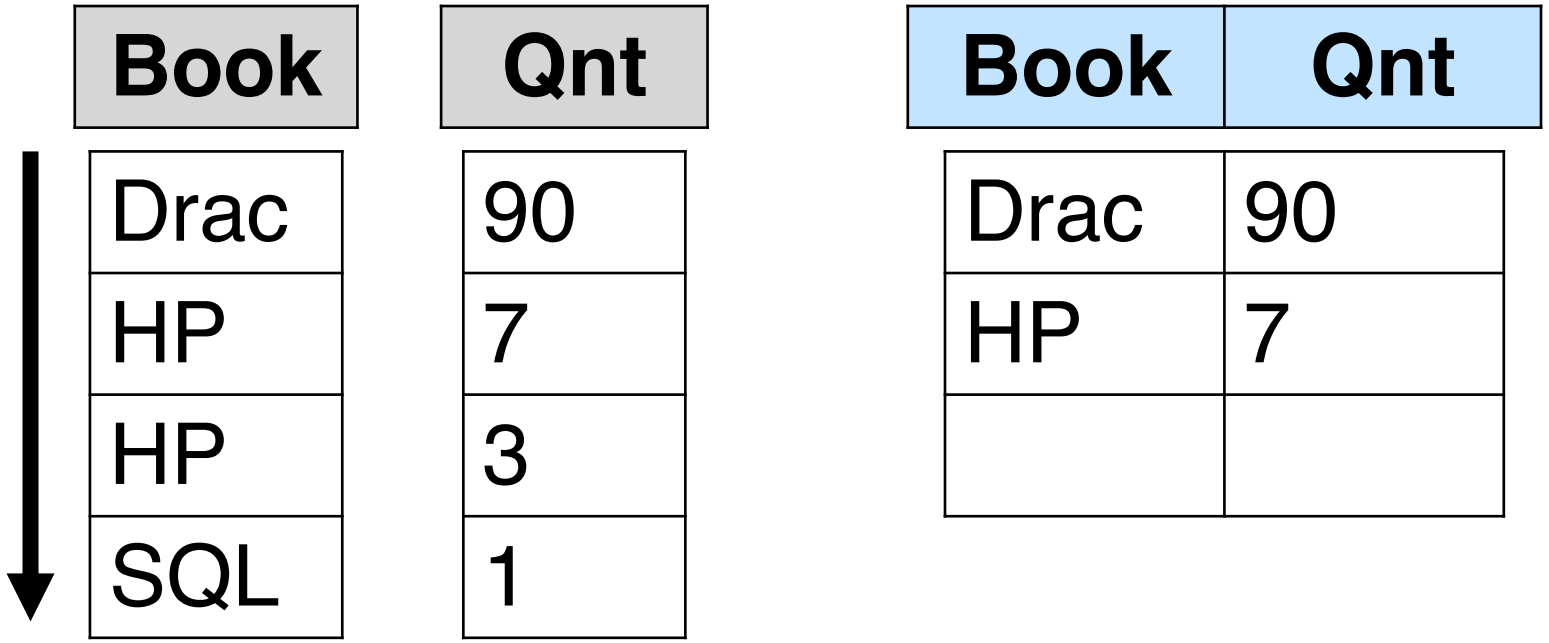

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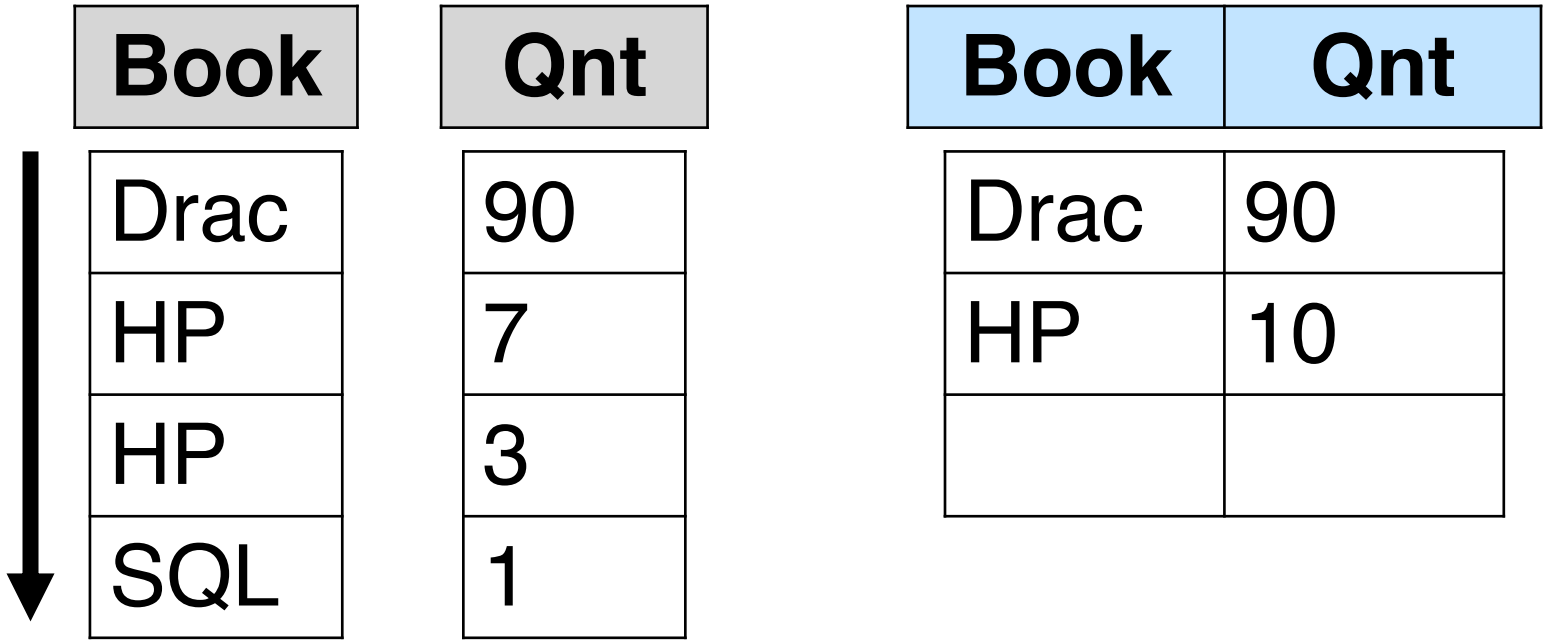

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Storage-Aware Operators

Use **column-specific** operators

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SELECT
   book, SUM( qnt )
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```

Operate **directly** over **sorted** and **compressed** data

Book	Qnt
Drac	90
HP	7
HP	3
SQL	1

Book	Qnt
Drac	90
HP	10
SQL	1

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Storage-Aware Operators

Use **column-specific** operators

Operate **directly** over **sorted** and **compressed** data

Per layout implementations of operators

- Update
- Read
- Scan
- Join
- Aggregate

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Zone Maps

Order	Book	User	Qnt	$
100	HP	Alice	7	$15
101	Drac	Ted	90	$3
102	SQL	Geoff	1	$100
103	HP	Jean	3	$15
Min	100	Drac	Alice	1	$3
Max	103	SQL	Ted	90	$100

SELECT Book
WHERE
QNT > 100

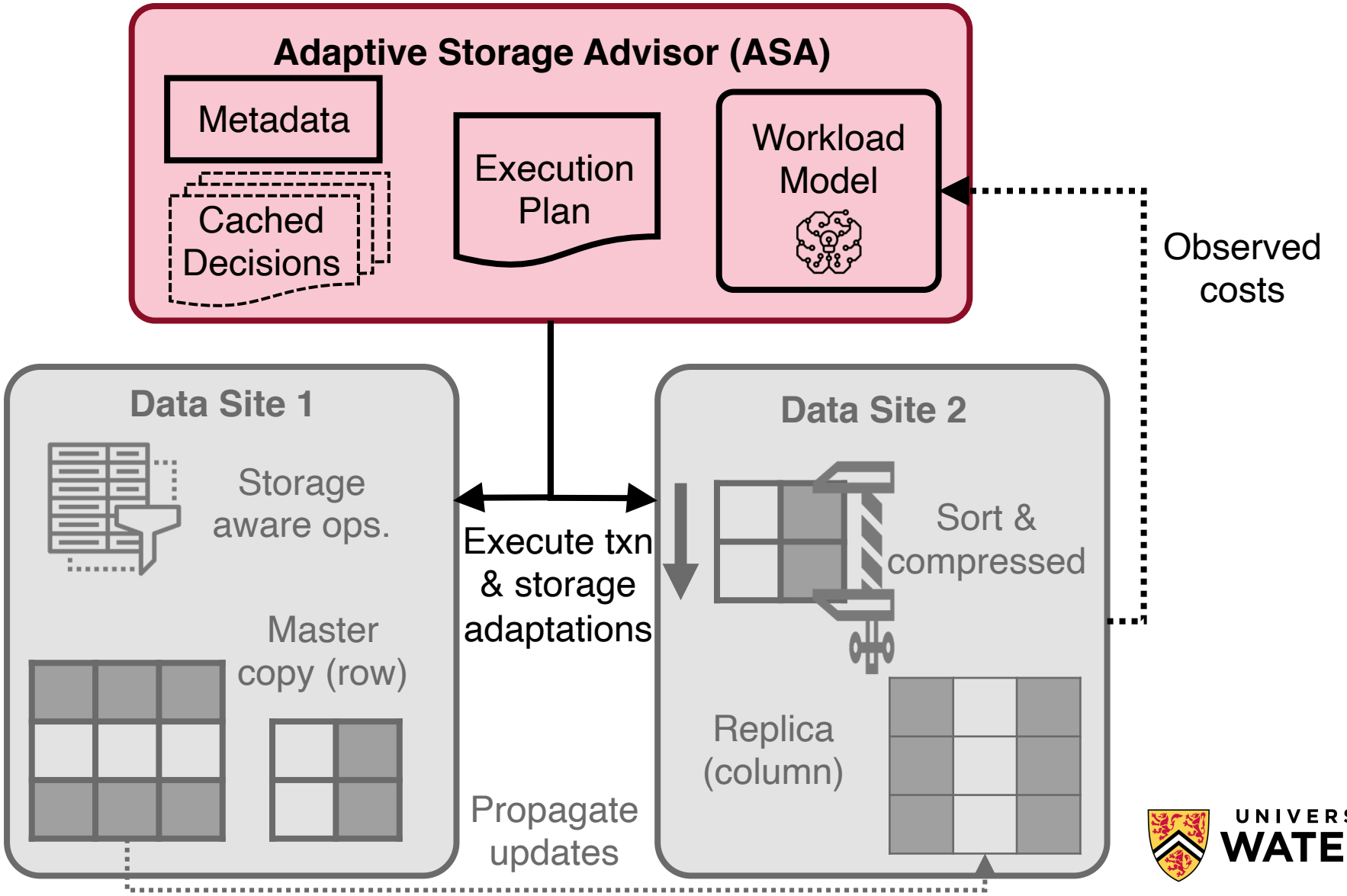
Zone Maps

Kept in memory and on a per partition basis

Allows data skipping, minimizing I/O

Min	100	Drac	Alice	1	$3
Max	103	SQL	Ted	90	$100

Storage Adaptation Decisions



Adaptive Storage Advisor

Should we **execute** a proposed change?

What **changes** should we propose?

Adaptive Storage Advisor

Should we **execute** a proposed change?

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Making Layout Decisions

Quantify if a layout change is **beneficial**

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SELECT book, **SUM**(qnt)
GROUP BY book

Should Proteus use **column** storage **sorted** by **book**?

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Quantifying Layout Decisions

Quantify if a layout change is **beneficial**

Txn **latency** with **current** vs **proposed** layouts

Current	**Proposed**
(row)	(Sorted col)
52 ms	15 ms

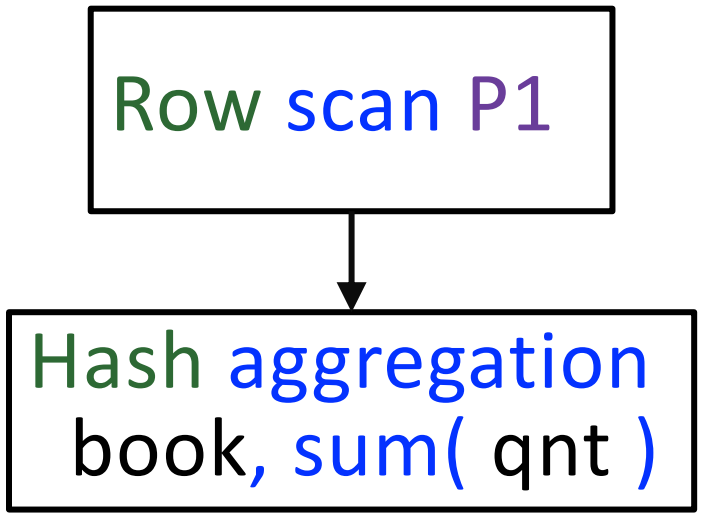
SELECT book, **SUM**(qnt)
GROUP BY book

Latency of a Transaction

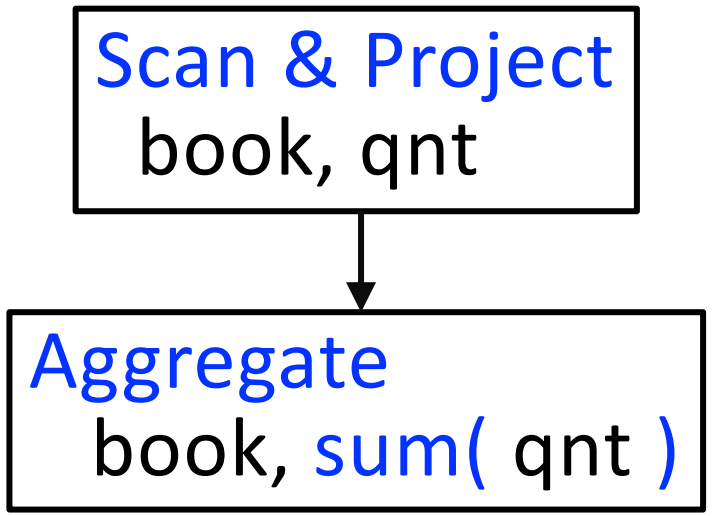
Breakdown transaction into **physical** operators

SELECT book, **SUM**(qnt) **GROUP BY** book

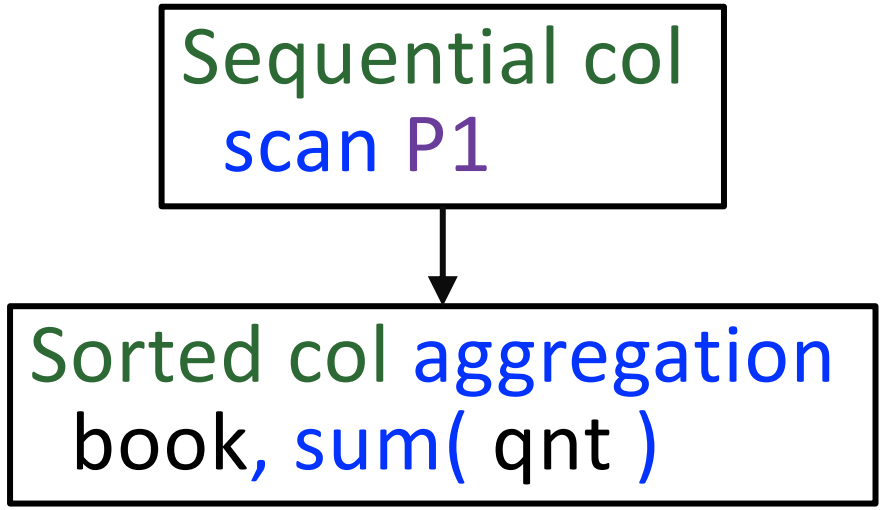
Row layout



Logical Plan



Sorted column layout



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Latency of a Transaction

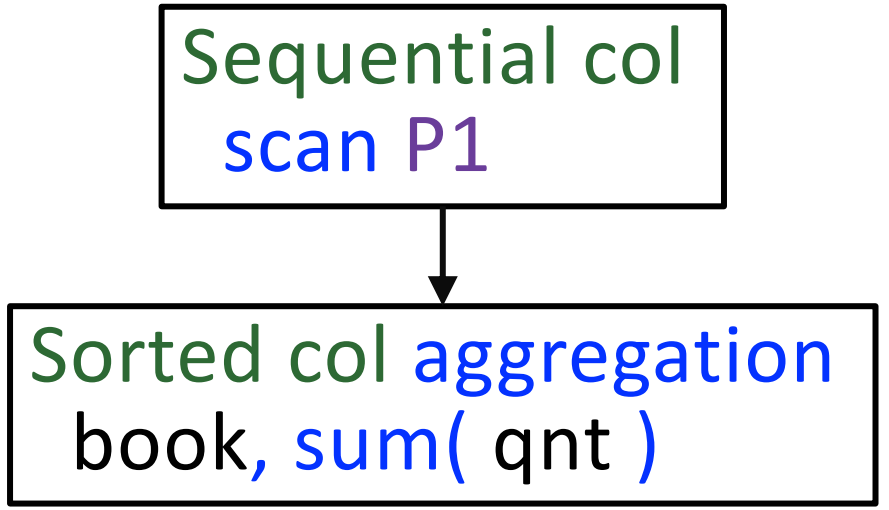
Breakdown transaction into **physical** operators

SELECT book, **SUM**(qnt) **GROUP BY** book

	Predictions
Sequential col scan P1	14 ms
Sorted col aggregation book, sum(qnt)	1 ms

Total predicted latency: 15 ms

Sorted column layout



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Predicting Latency of a Transaction

Breakdown transaction into **physical** operators

Predict physical operator latency

Per layout with workload stats as parameters

Cardinality
Data Width
Est Selectivity

Predicted Latency

Seq col scan

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Predicting Latency of a Transaction

Breakdown transaction into **physical** operators

Predict physical operator latency

Per layout with workload stats as parameters

Cardinality
Data Width
Est Selectivity

Row scan

Predicted Latency

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Quantifying Layout Decisions

Quantify if a layout change is **beneficial**

Txn **latency** with **current** vs **proposed** layouts

Current (row)	**Proposed** (Sorted col)	
52 ms	15 ms	**SELECT** book, **SUM**(qnt) **GROUP BY** book
14 ms	28 ms	**INSERT** (104, LoTR, John, 2, $21)

Weight by **likelihood** of transaction

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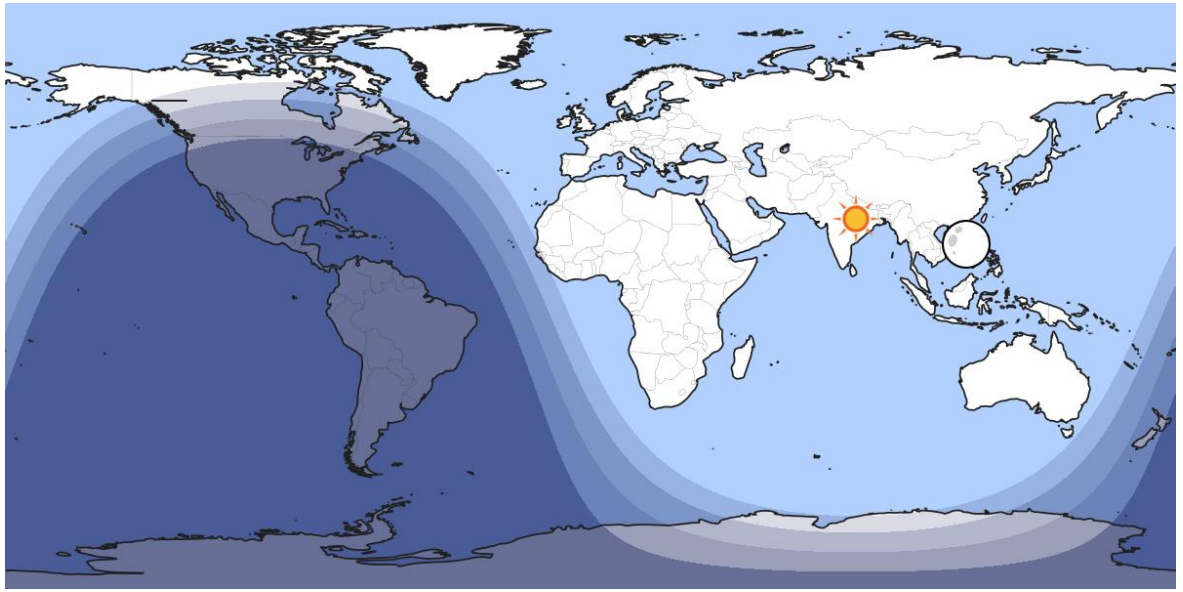
Likelihood of a Transaction

Data **accesses** to **storage**
often follow **predictable** pattern



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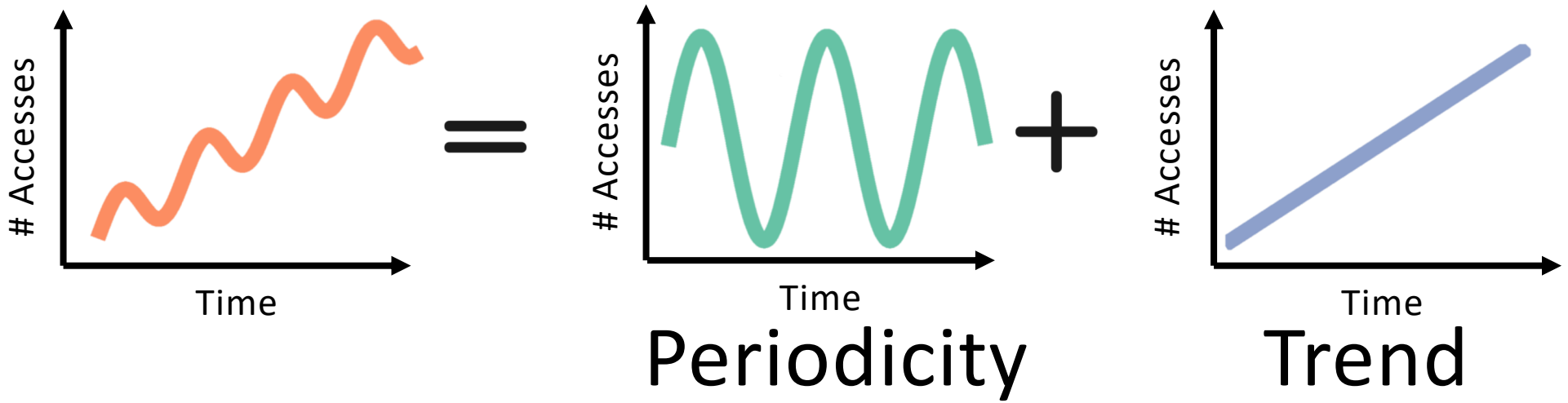


Quantifying Layout Decisions

Expected Benefit of Change

Txn **latency** with **current** vs **proposed** layouts

Weight by likelihood of txn

Cost incurred to perform change

Adaptive Storage Advisor

Should we **execute** a proposed change?

What **changes** should we propose?

Selecting What to Change

Based on **ongoing transaction**

Change high cost plan operators

Storage Layout	Decisions	
Format	row	column
Tier	memory	disk
Optimization	sort	compress
Replication	split or merge	horizontal or vertical
Mastership	Which site?	

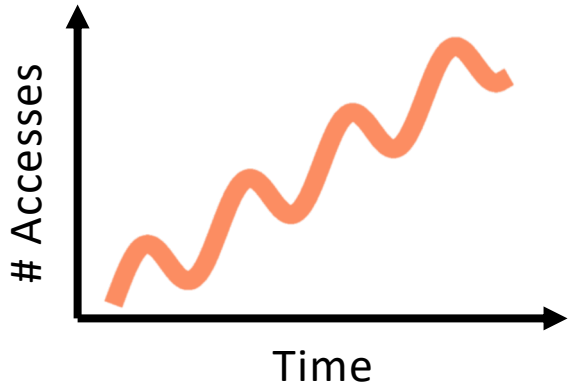
Selecting What to Change

Based on **ongoing transaction**

Change high cost plan operators

Predictively based on upcoming accesses

Simulate transactions



Based on **storage constraints**

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How well does Proteus work?

CH BenCHmark (TPC-C & TPC-H)

Comparisons

Row Store (RS)
Column Store (CS)
} *Single Copy*

Janus
TiDB
} *Maintain row & column*

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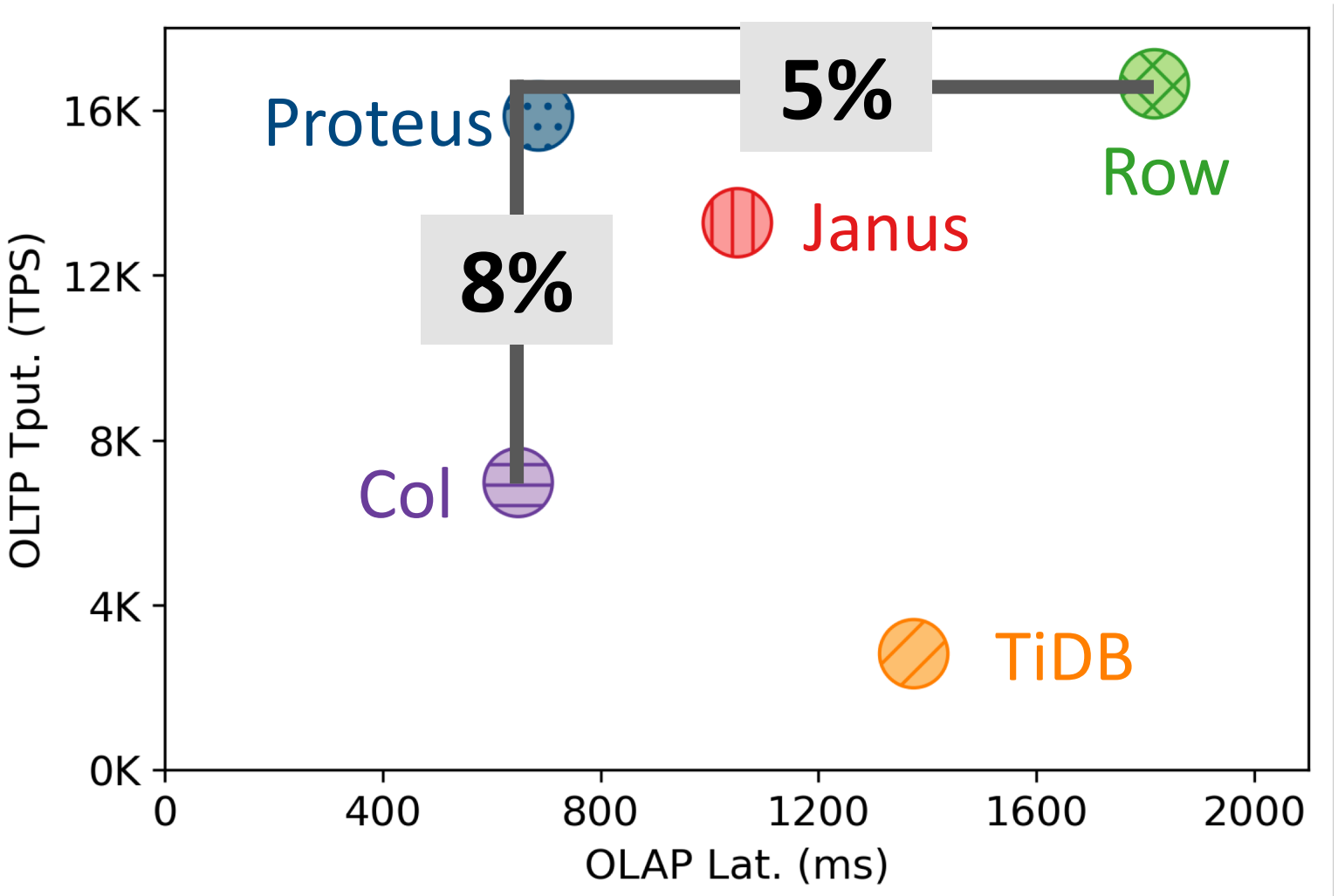
CH BenCHmark



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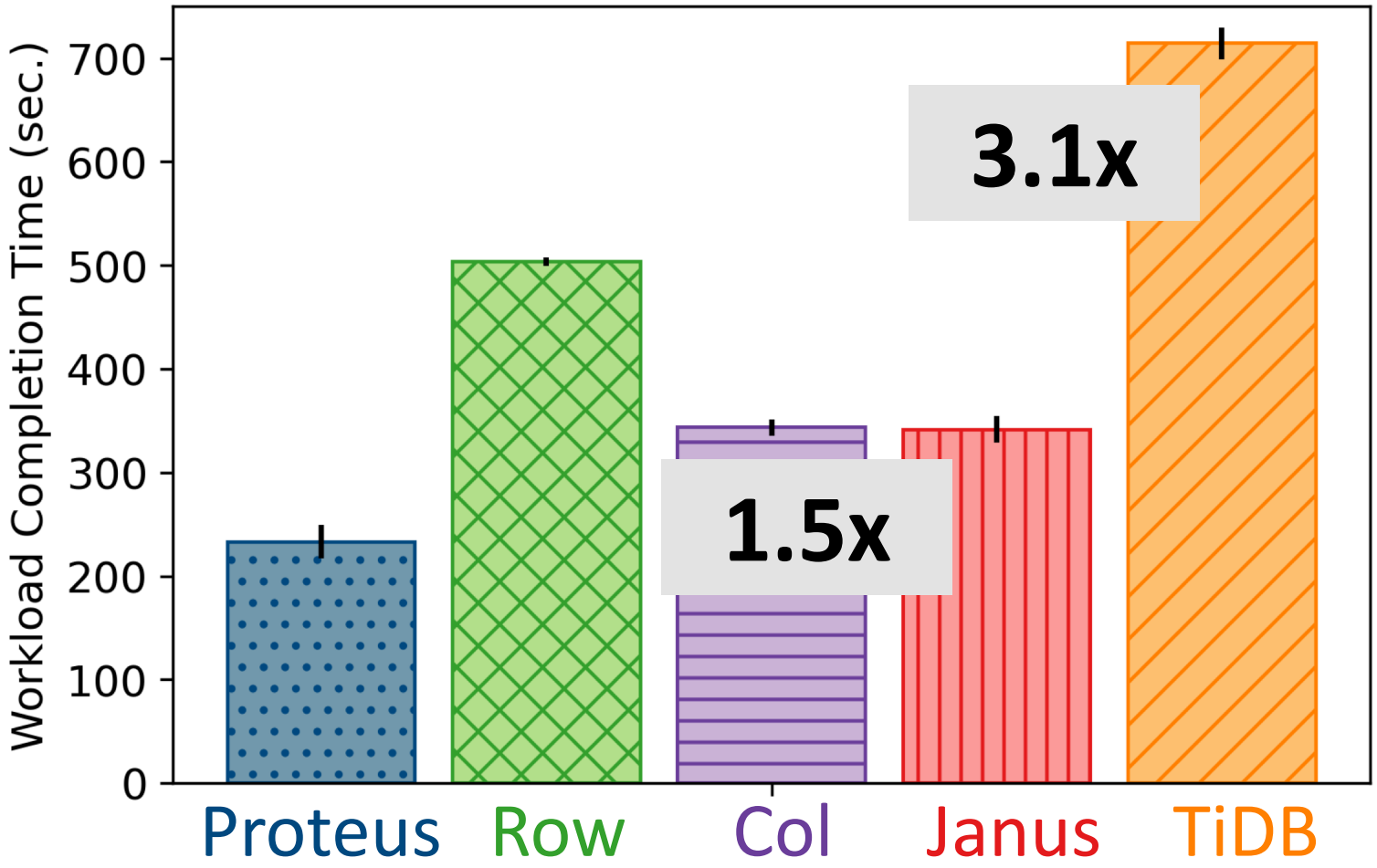

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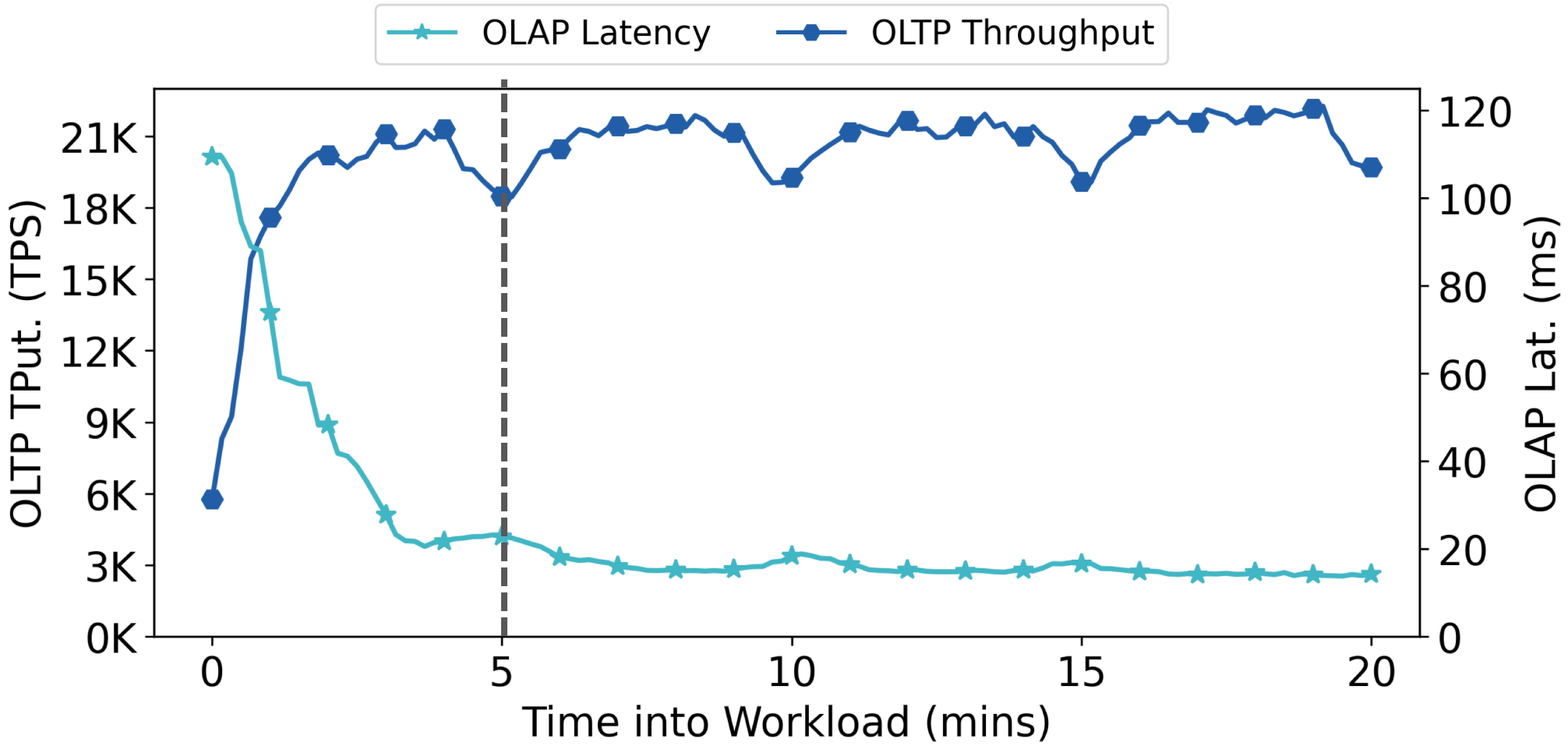
Predictive Adaptation



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More Details

tiny.cc/proteus

More experimental workloads: Twitter, YCSB

Shifting workloads, Ablation studies

ML models (cost & access arrival)

Storage format and layout change execution

Efficient replication and concurrency control

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Proteus Takeaways tiny.cc/proteus

Adaptive Scale-Out Distributed DBMS

Selectively stores data in different formats

Proteus makes **decisions** based on **workload**

Superior performance on **mixed** workloads

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