Toward timely, predictable and cost-effective data analytics

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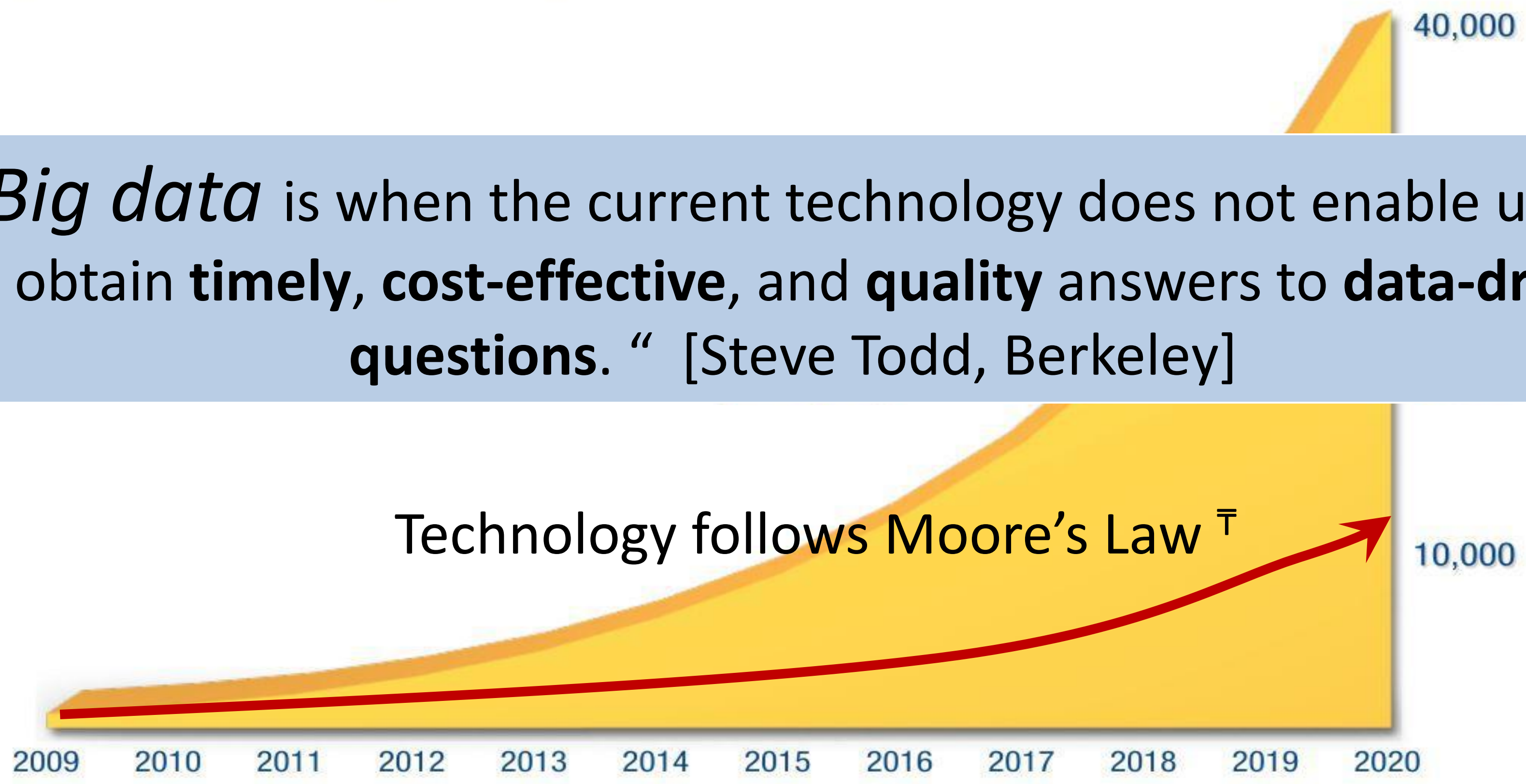
Big data proliferation

The Digital Universe: 50-fold Growth from the Beginning of 2010 to the End of 2020



> “*Big data* is when the current technology does not enable users to obtain **timely**, **cost-effective**, and **quality** answers to **data-driven questions**. “ [Steve Todd, Berkeley]

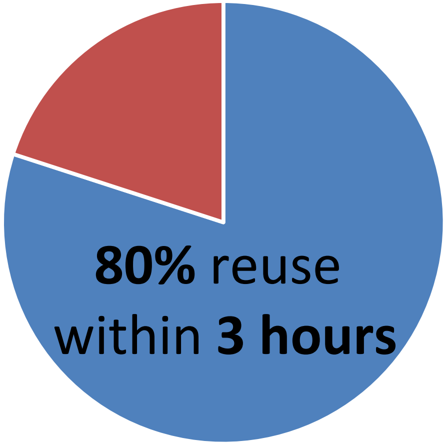
Technology follows Moore’s Law ₸

* “The Digital Universe in 2020: Big Data, Bigger Digital Shadows, and Biggest Growth in the Far East“, 2012, IDC

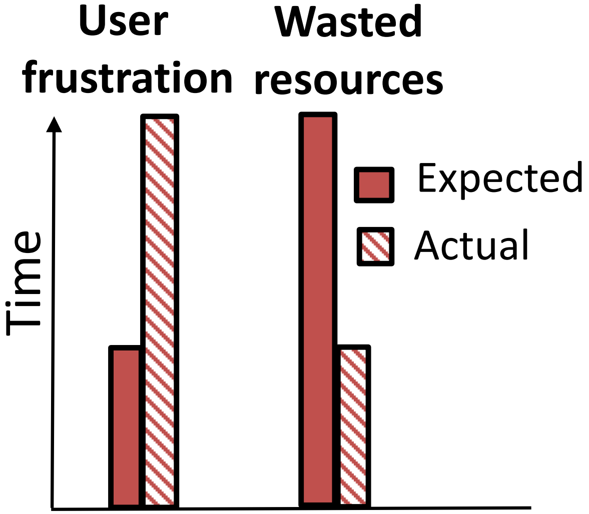
₸ “Trends in big data analytics“, 2014, Kambatla et al

What business analysts want

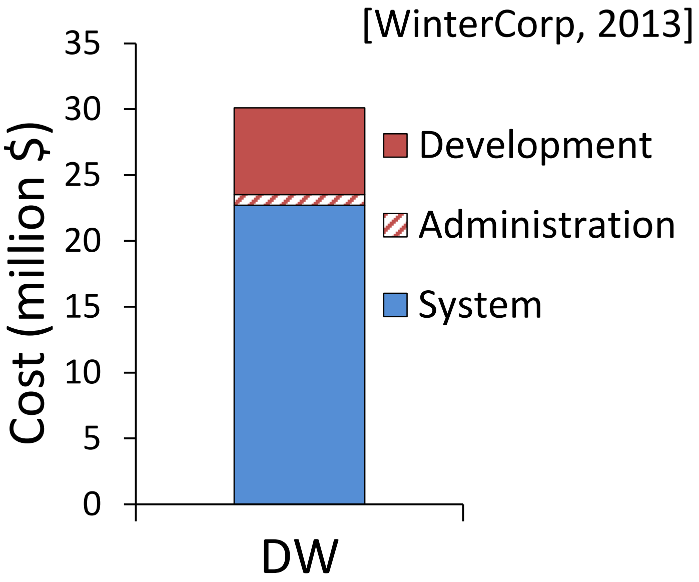
Timely, predictable, cost-effective queries



Minimal data-to-insight time



Predictable response time



Low infrastructure cost

Thesis statement

As traditional DBMS rely on **predefined assumptions** about workload, data and storage, changes cause **loss of performance** and **unpredictability**.

Insight

Query execution must **adapt** at three levels

(to **workload**, **data** and **hardware**) to stabilize and **optimize performance** and **cost**.

Outline

- **Minimize data-to-insight time**
  - Workload-driven adaptation [SIGMOD’12, VLDB’12, CACM’15]
- **Improve predictability of response time**
  - Data-driven adaptation [DBTest’12, ICDE’15]
- **Reduce analytics cost**
  - Cold storage & hardware-driven adaptation [VLDB’16]

Outline

- **Minimize data-to-insight time**
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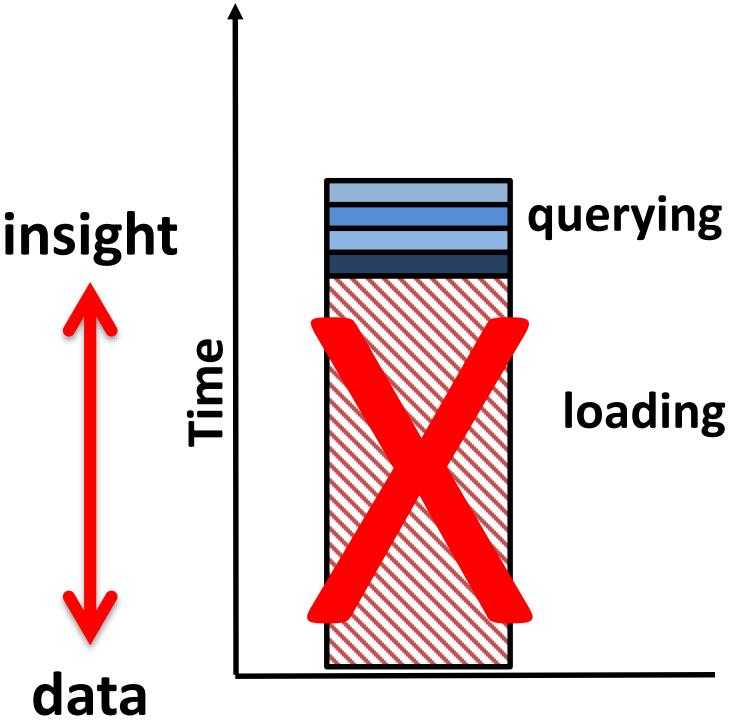
  - Cold storage & hardware-driven adaptation

Data-to-insight time

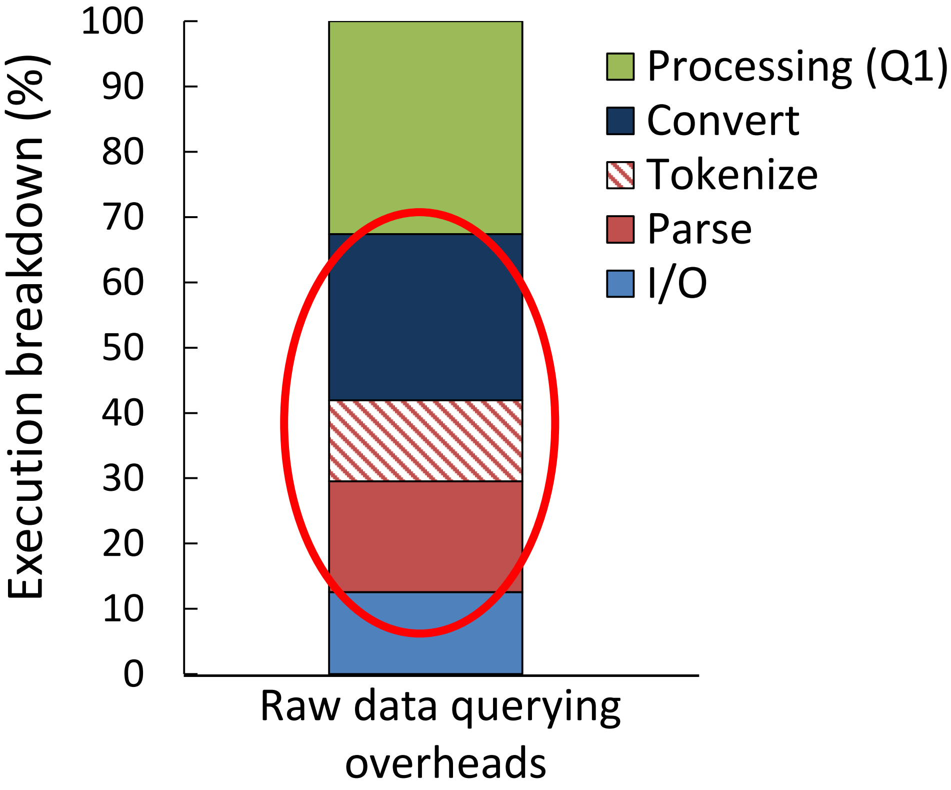
Traditional query stack



Time to first insight too long

Does not scale with data growth

Raw data querying stack

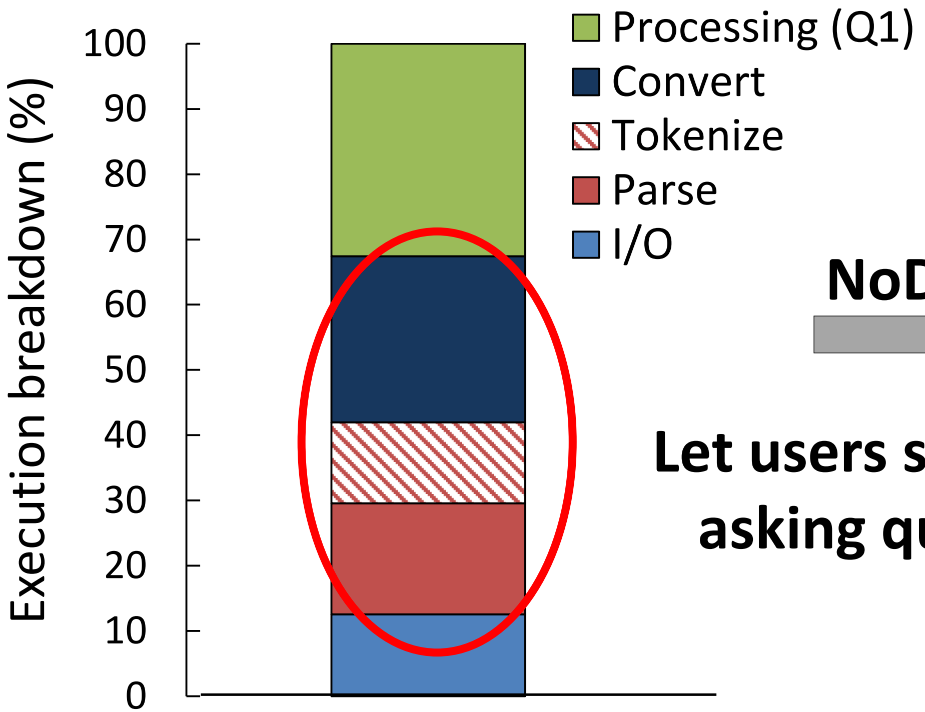


Overheads too high

Current technology ≠ efficient exploration

Optimize raw data querying stack

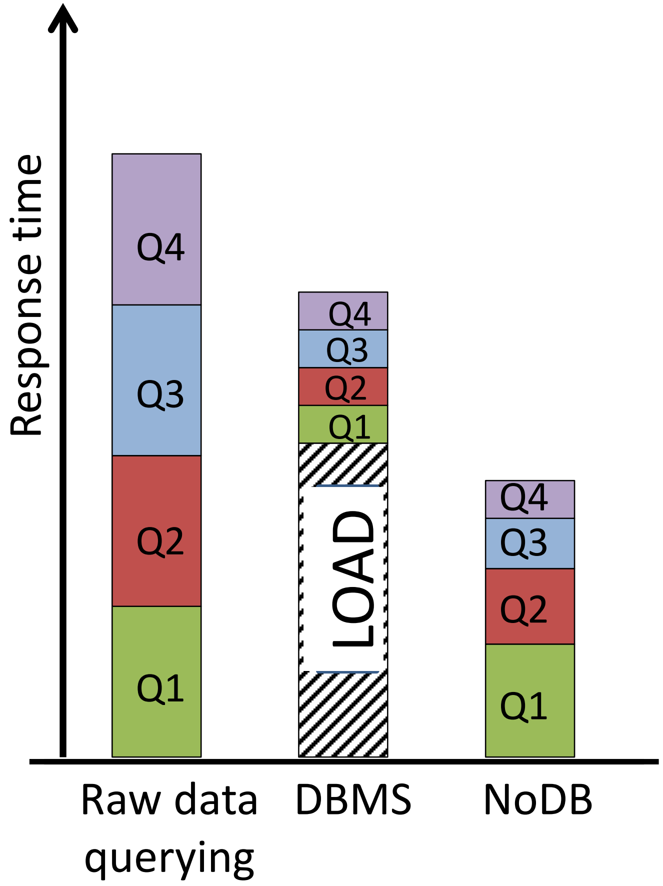
Raw data querying stack



Not everything needed for Q1

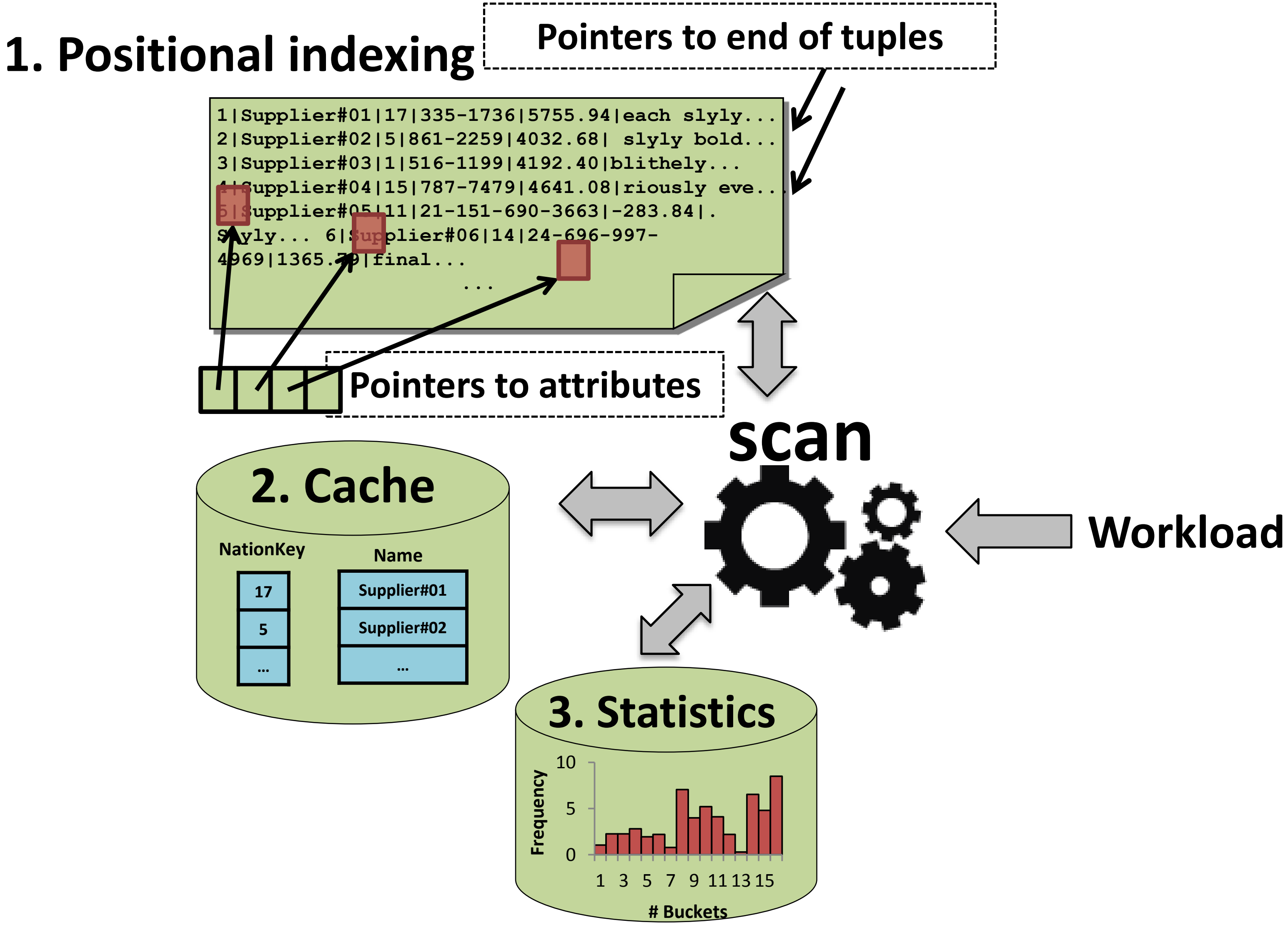
NoDB

Let users show by asking queries



NoDB: Workload-driven data loading & tuning

PostgresRaw: NoDB from idea to practice



1. Positional indexing

Pointers to end of tuples

```
1|Supplier#01|17|335-1736|5755.94|each slyly...
2|Supplier#02|5|861-2259|4032.68| slyly bold...
3|Supplier#03|1|516-1199|4192.40|blithely...
4|Supplier#04|15|787-7479|4641.08|riously eve...
5|Supplier#05|11|21-151-690-3663|-283.84|.
Slyly... 6|Supplier#06|14|24-696-997-
4969|1365.79|final...
                                  ...
```

Pointers to attributes

scan

Workload

2. Cache

NationKey	Name
17	Supplier#01
5	Supplier#02
…	…

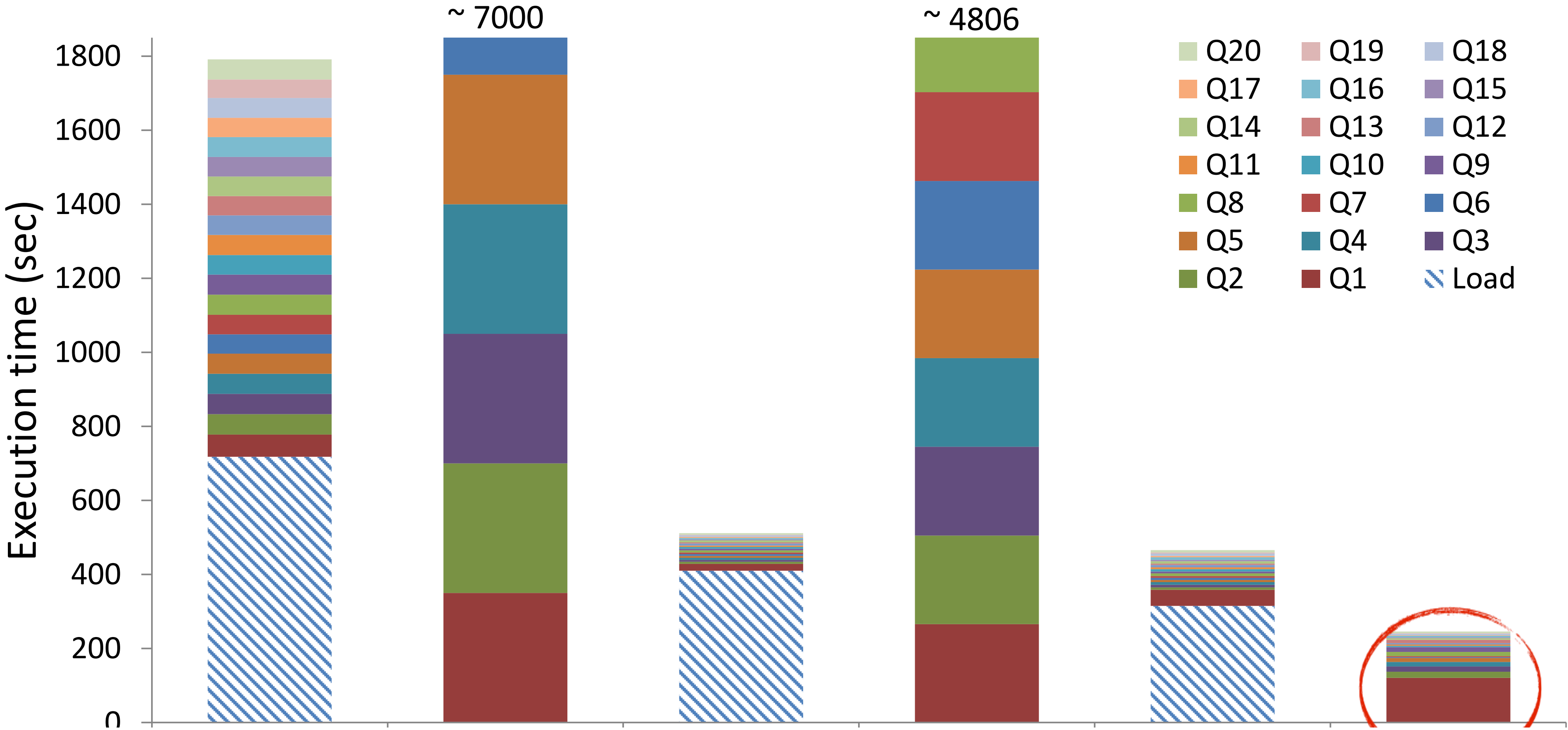
3. Statistics

Adjust to queries = progressively cheaper access

PostgresRaw in action

Setting: 7.5M tuples, 150 attributes, 11GB file

Queries: 10 arbitrary attributes per query, vary selectivity



Data-to-insight time halved with PostgresRaw

Per query performance comparable to traditional DBMS

Summary of PostgresRaw

- **Query processing** engine over **raw data files**
- Uses user **queries** for **partial** data **loading** and **tuning**
- **Comparable performance** to traditional DBMS

IMPACT

- Enables **timely data exploration** with **0 initialization**
- **Decouples** user **interest** from **data growth**

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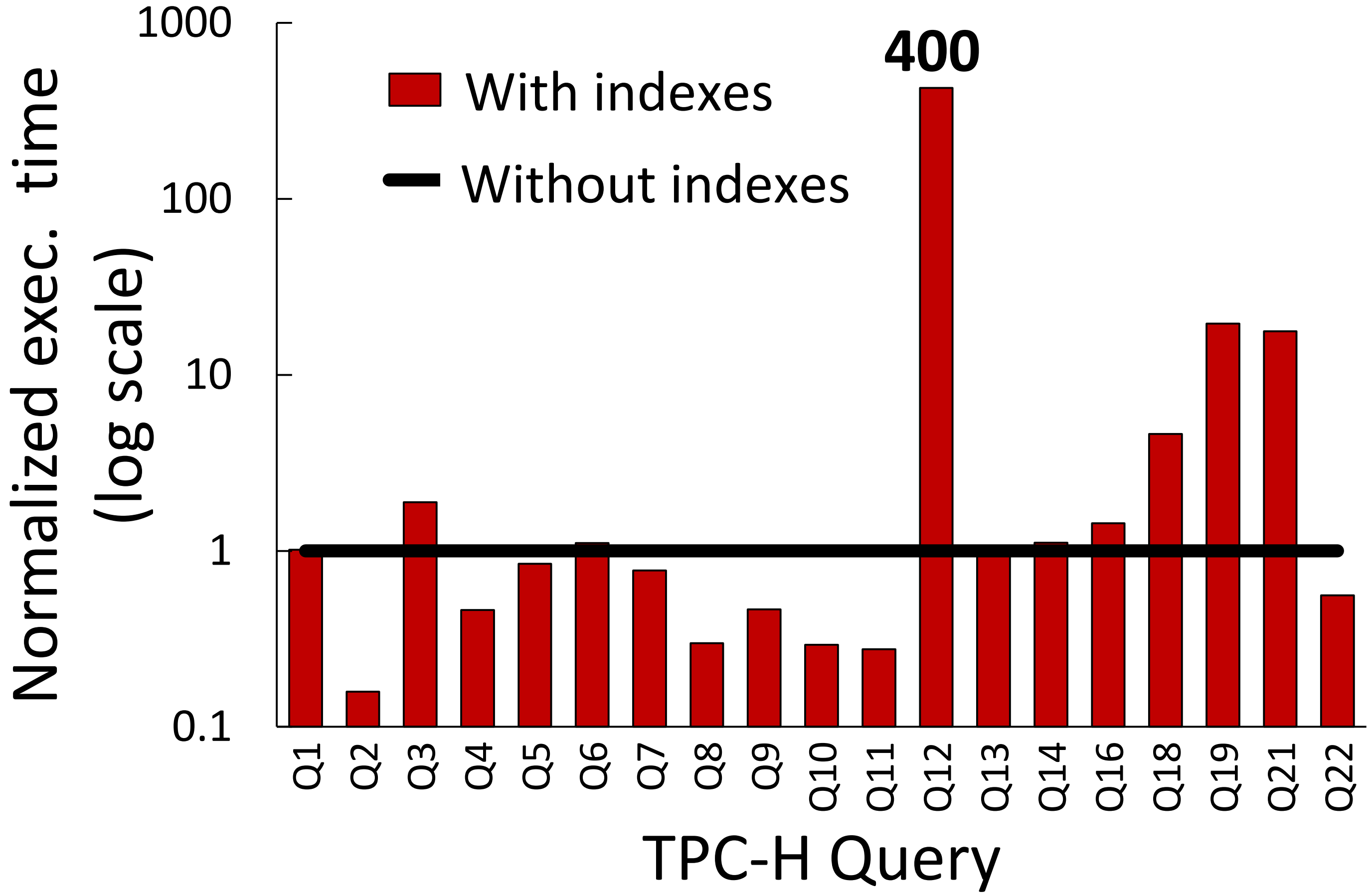
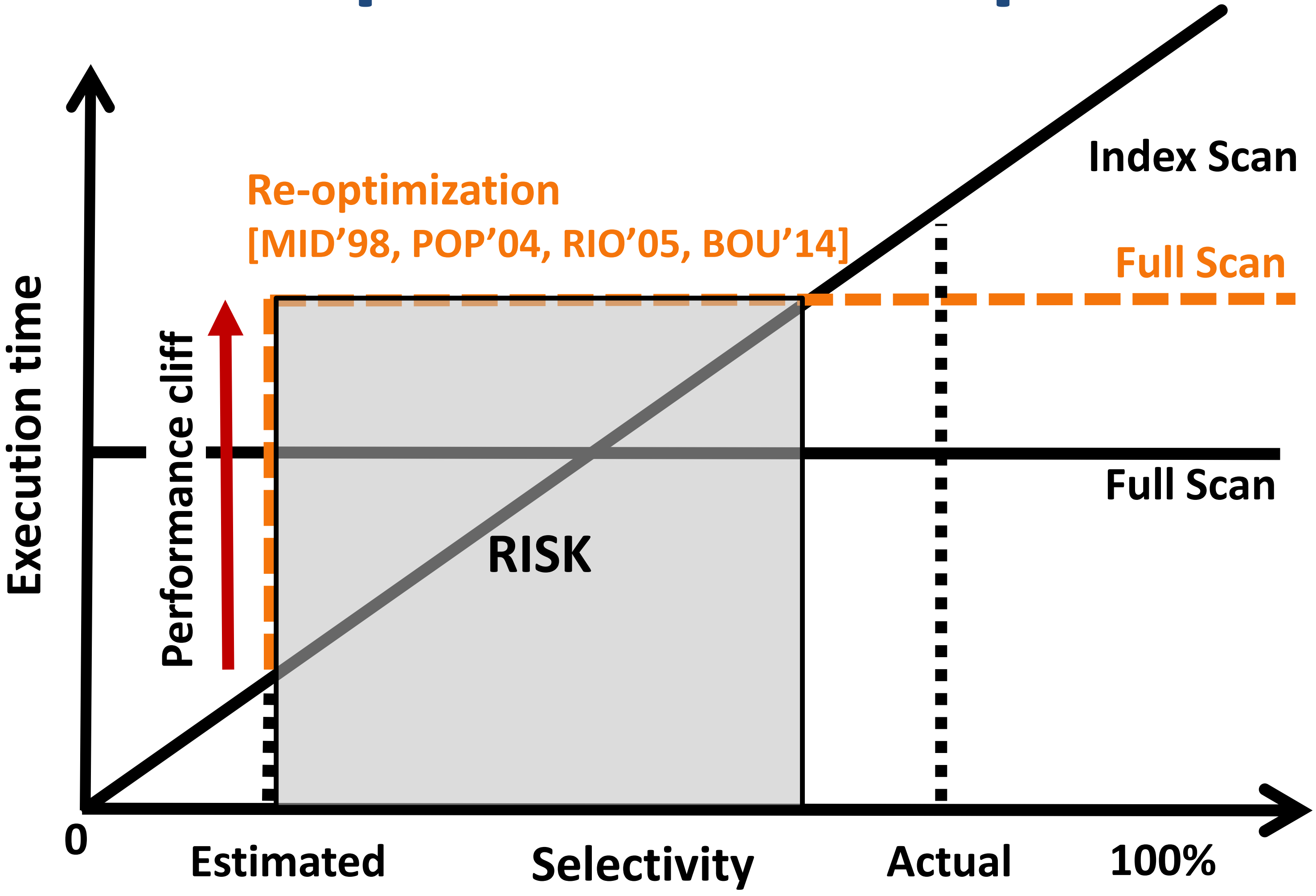
Index: with or without?

Setting: TPC-H, SF10, DBMS-X, Tuning tool 5GB space for indexes



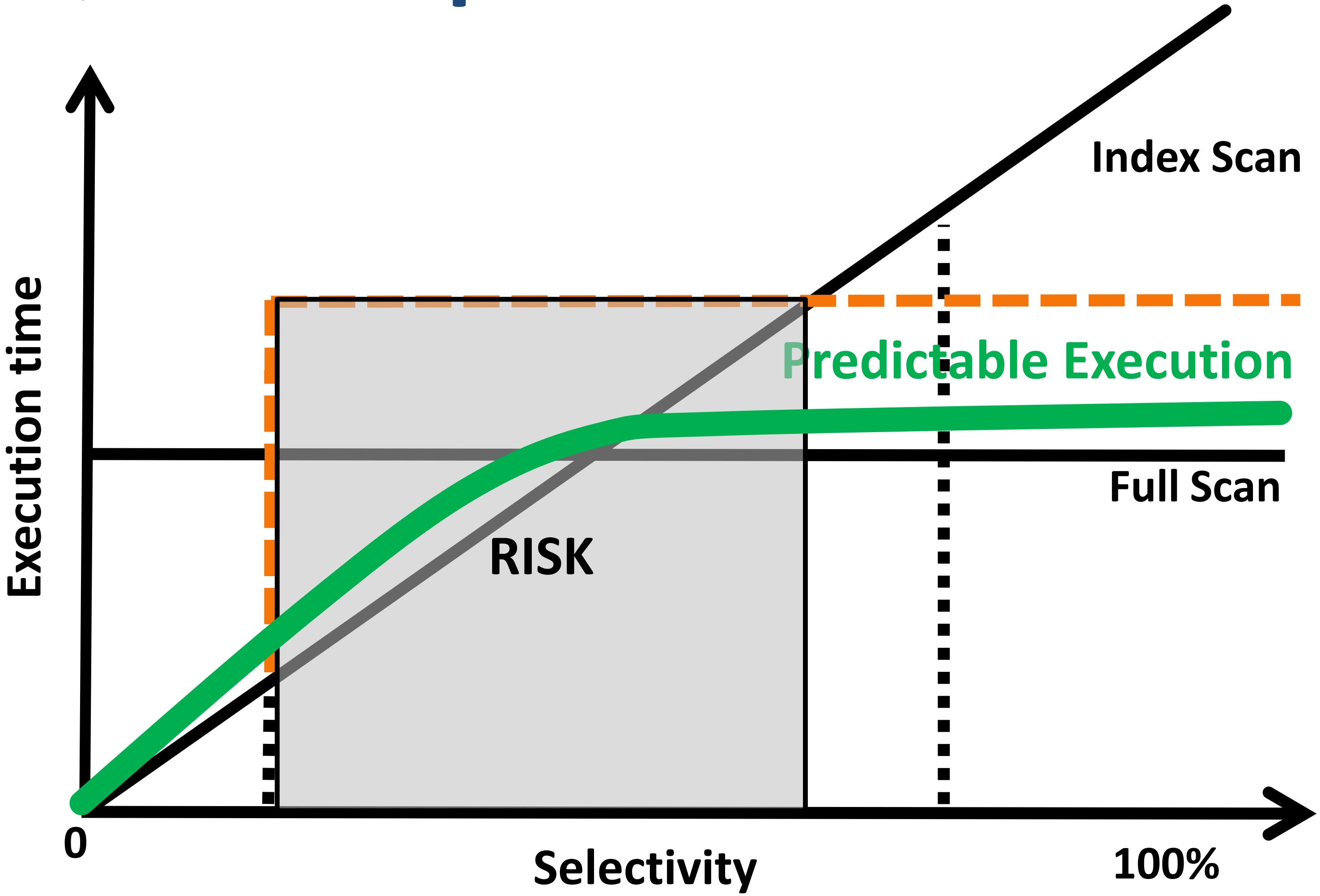
Performance hurt after tuning

Access path selection problem



Statistics: unreliable advisor
Re-optimization: risky

Quest for predictable execution



Removing variability due to (sub-optimal) choices

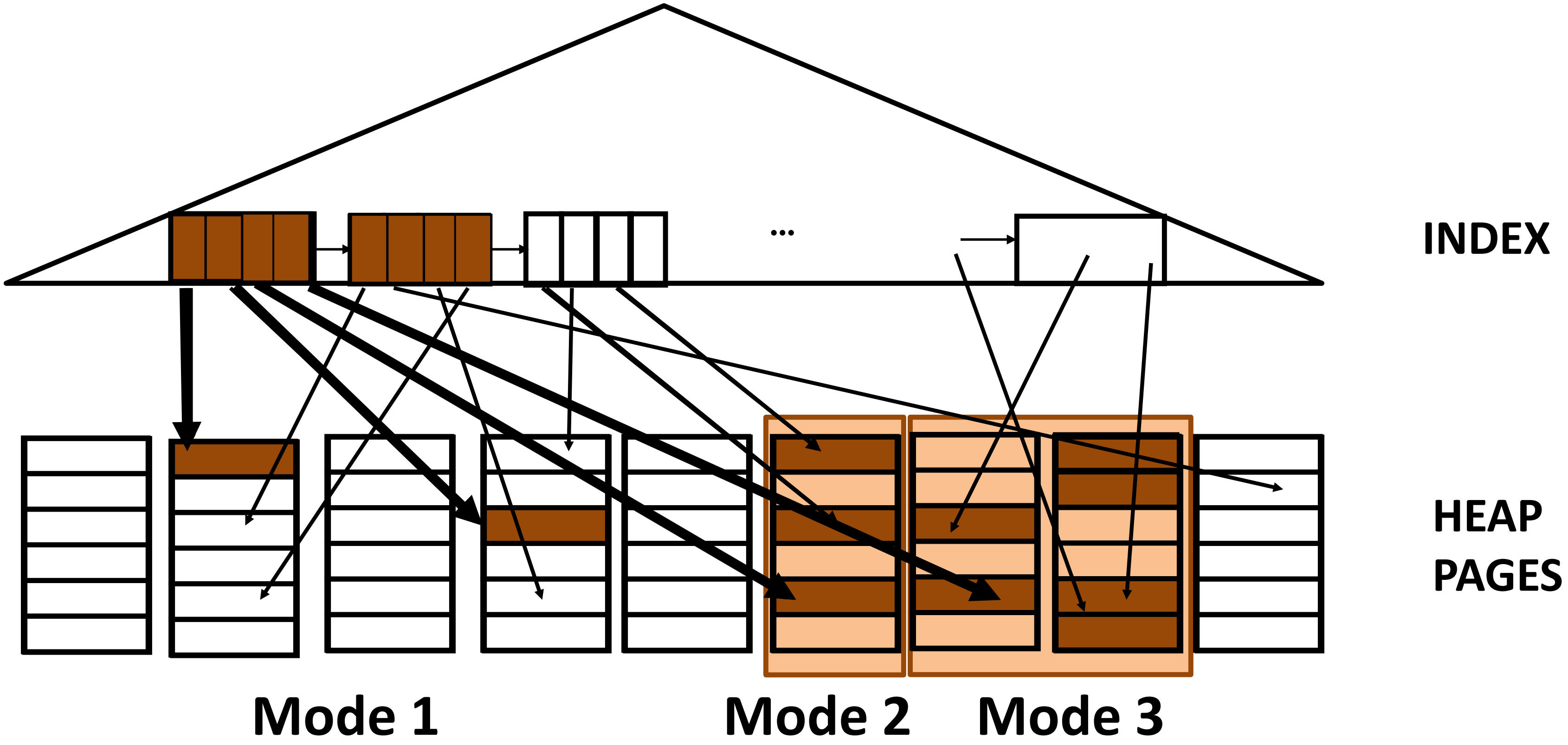
Smooth Scan

Morph between Index and Sequential Scan based on **observed result** distribution

Morphing mechanism

Modes:

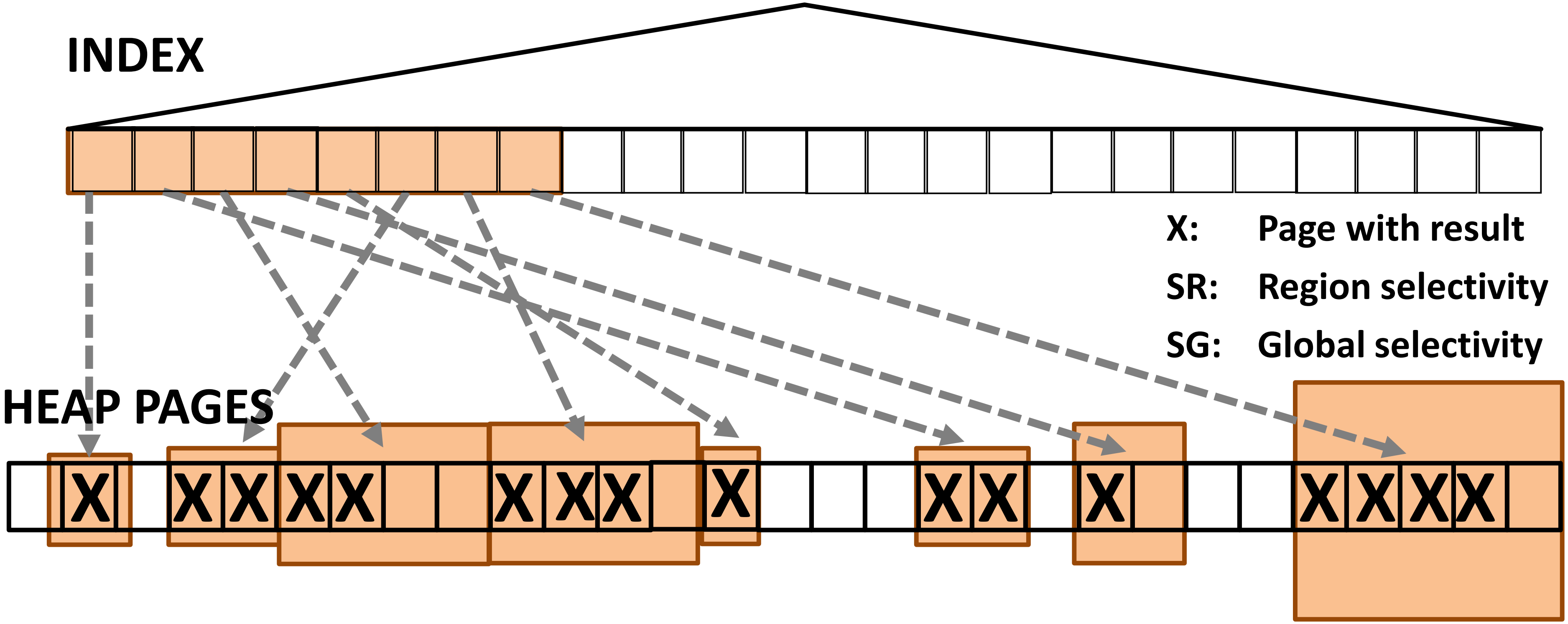
1. **Index Access:** Traditional index access
2. **Entire Page Probe:** Index access probes entire page
3. **Gradual Flattening Access:** Probe adjacent region(s)



Morphing policy

- Selectivity Increase -> Mode Increase
- Selectivity Decrease -> Mode Decrease

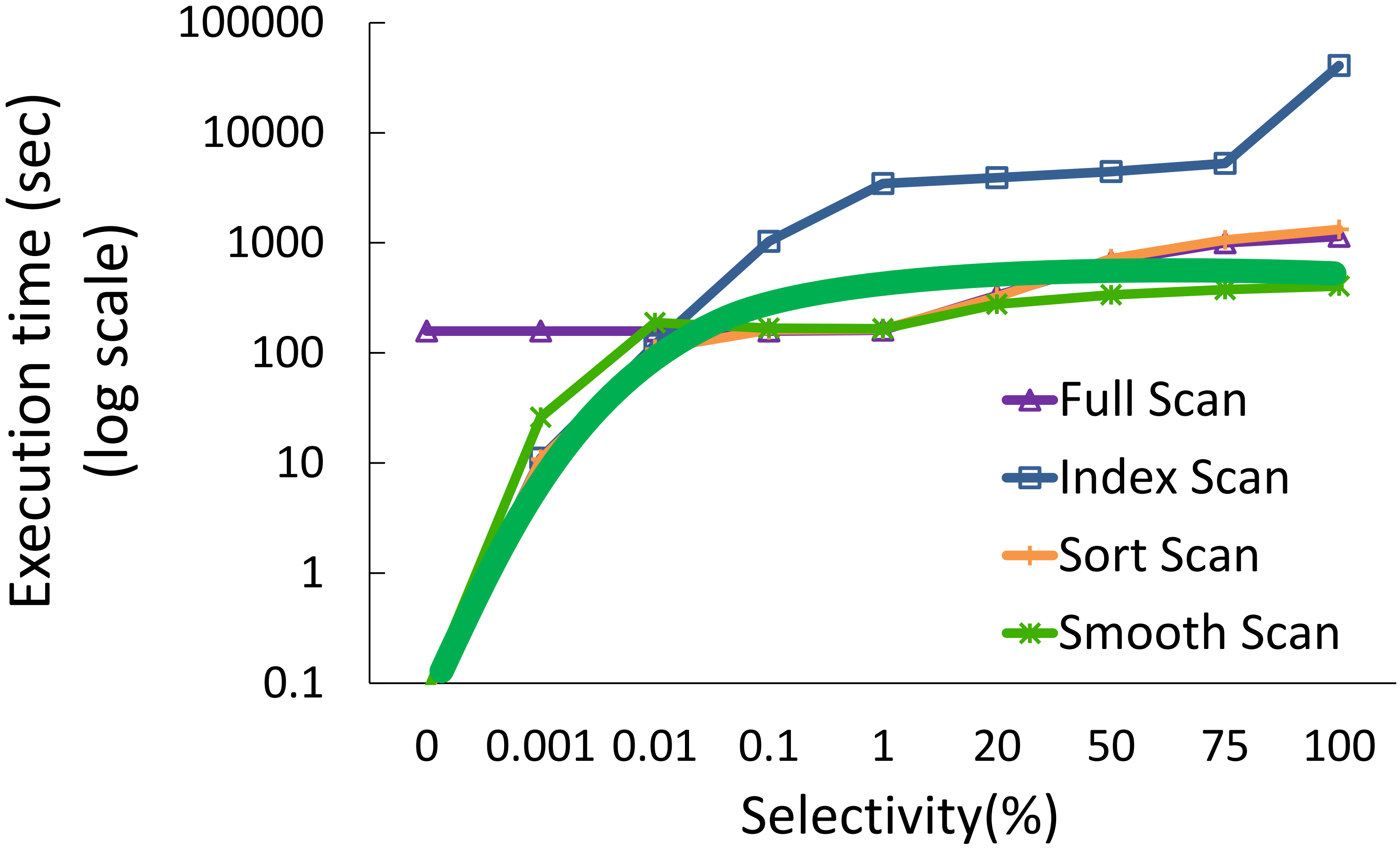
SEL_region >= SEL_global
SEL_region < SEL_global



Region snooping = Data-driven adaptation

Smooth Scan in action

Setting: Micro-benchmark, 25GB table, Order by, Selectivity 0-100%



Near-optimal over entire selectivity range

Summary of Smooth Scan

- **Statistics-oblivious** access path
- Uses region snooping to **morph** between alternatives
- **Near-optimal performance** for all selectivities

IMPACT

- **Removes** access path selection **decision**
- Improves **predictability** by **reducing variability** in query execution

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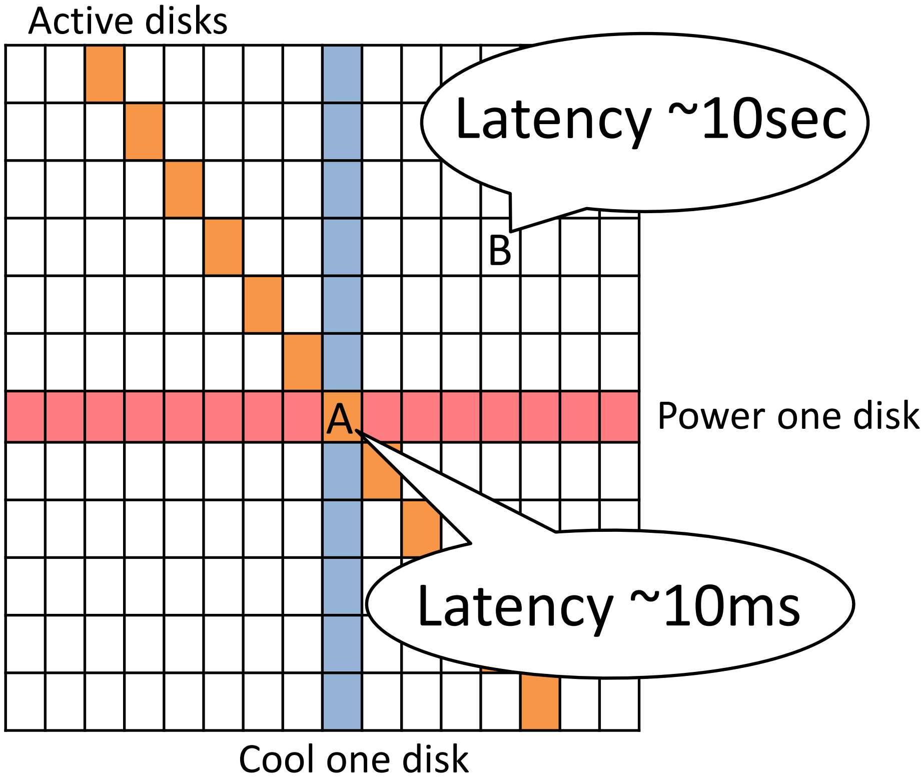
Proliferation of cold data

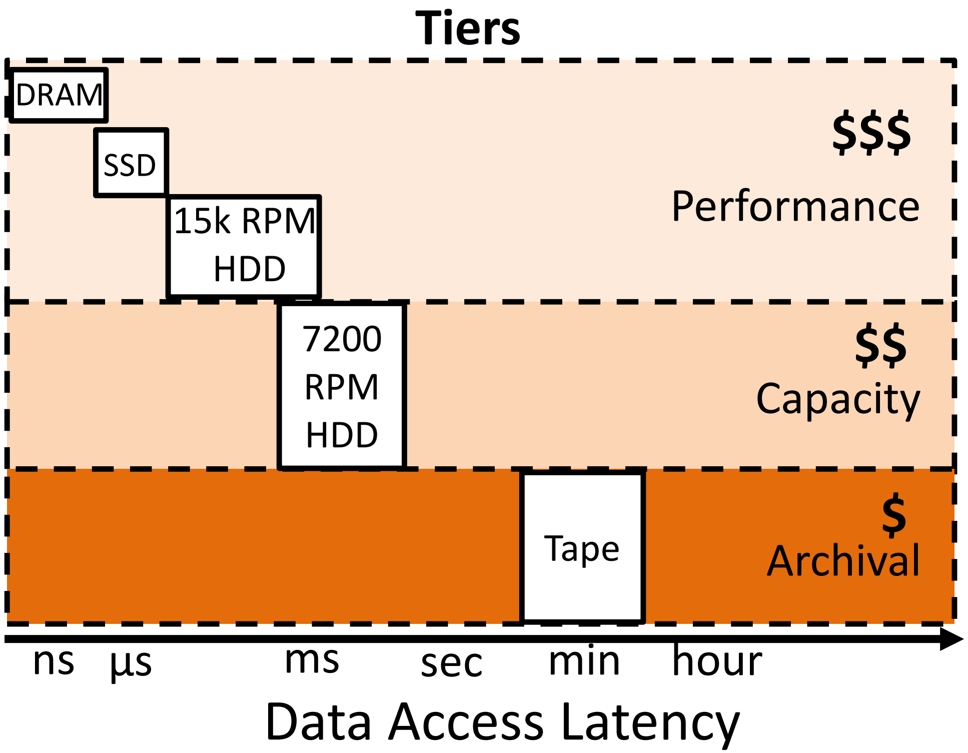
"80% enterprise data is ***cold*** *with 60% CAGR" [Horison, 2015]*
"cold data: incredibly valuable for analysis" [Intel, 2013]

Cold Storage Devices (CSD) to the rescue

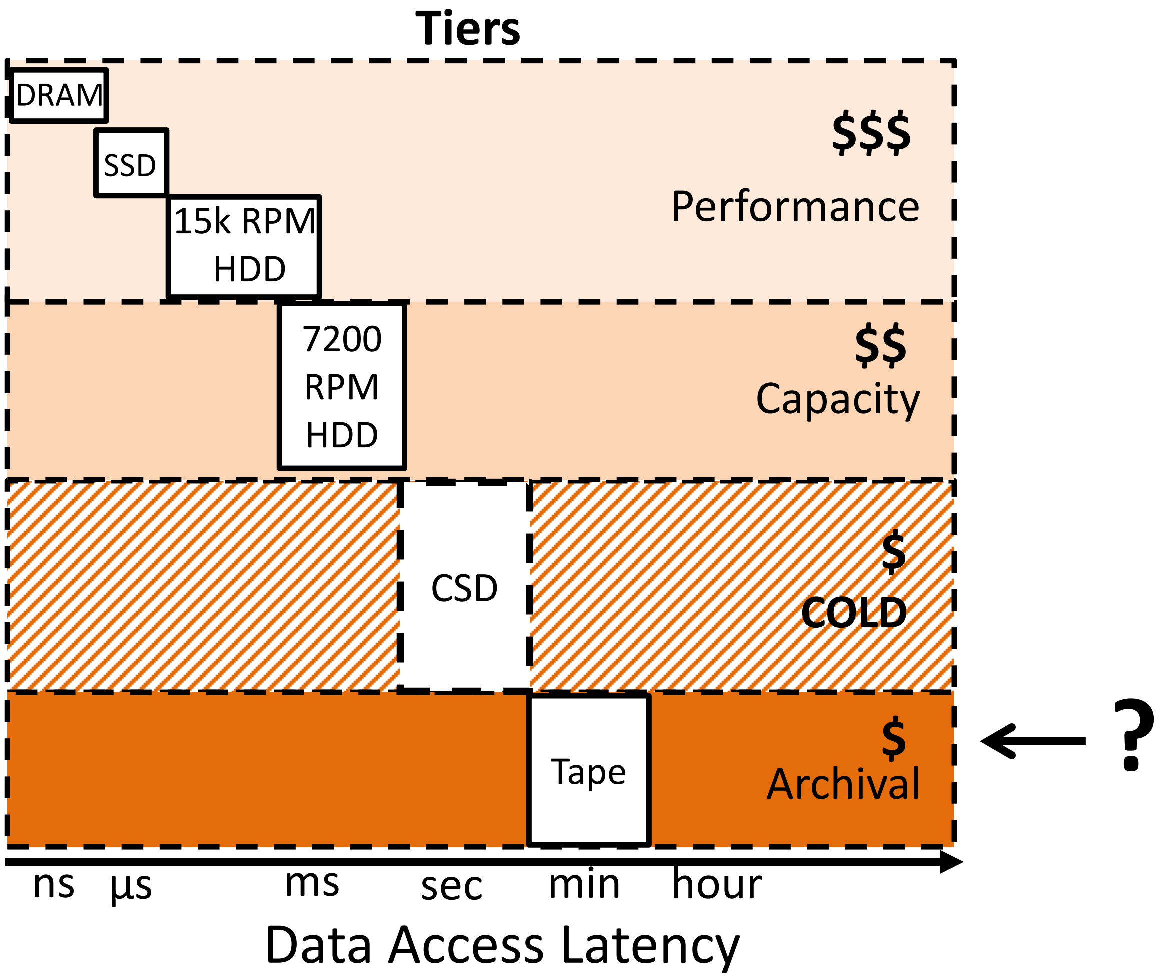


PB-size storage at cost ~ tape and latency ~ disks

CSD in the storage tiering hierarchy

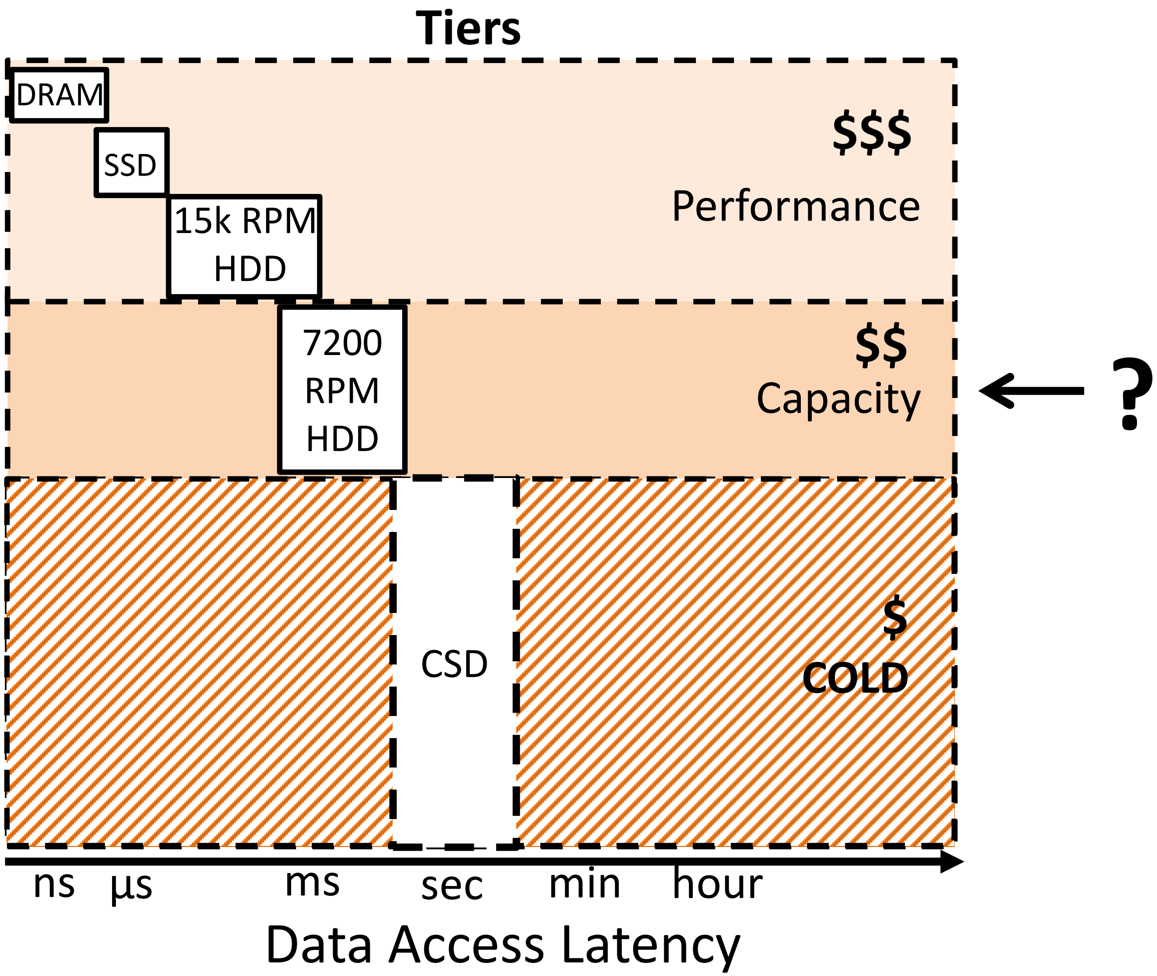


CSD in the storage tiering hierarchy



Can we shrink tiers to reduce cost?

CSD in the storage tiering hierarchy



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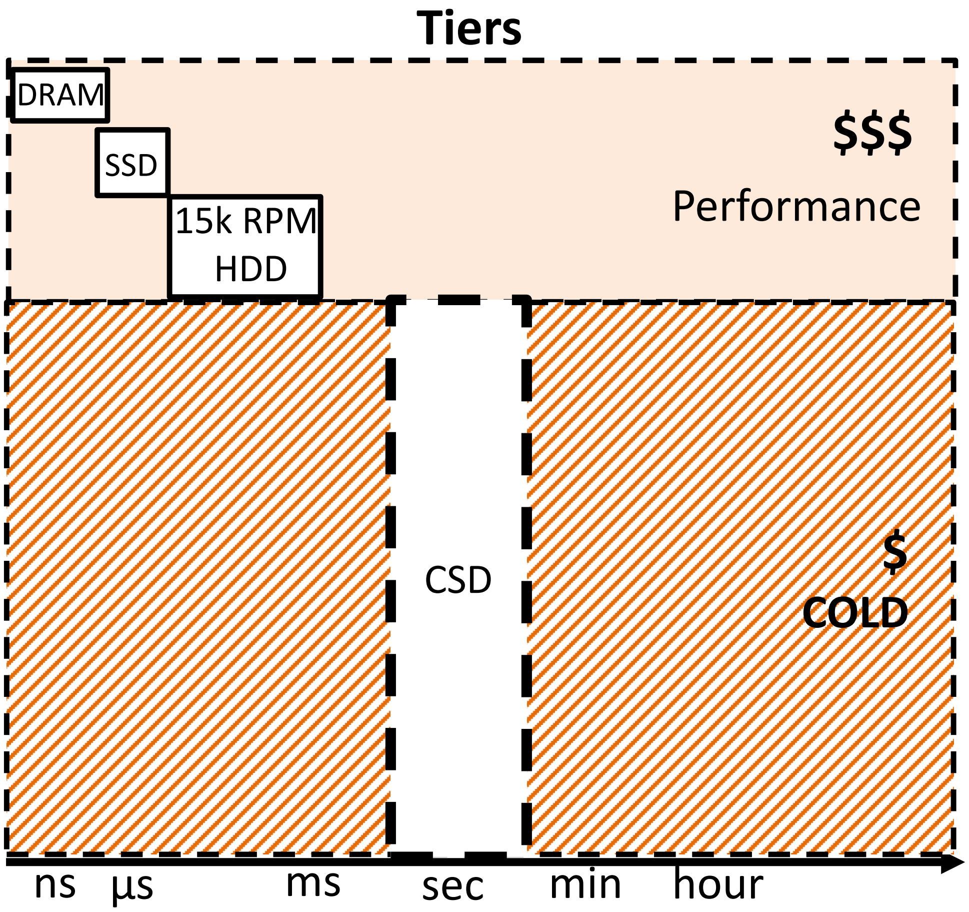
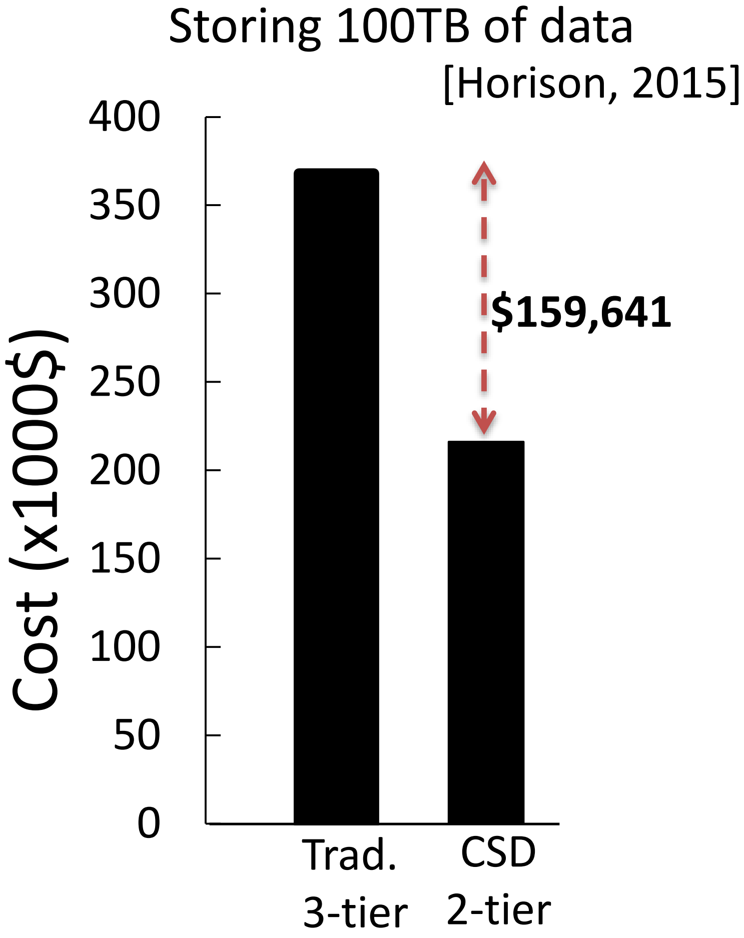
CSD in the storage tiering hierarchy



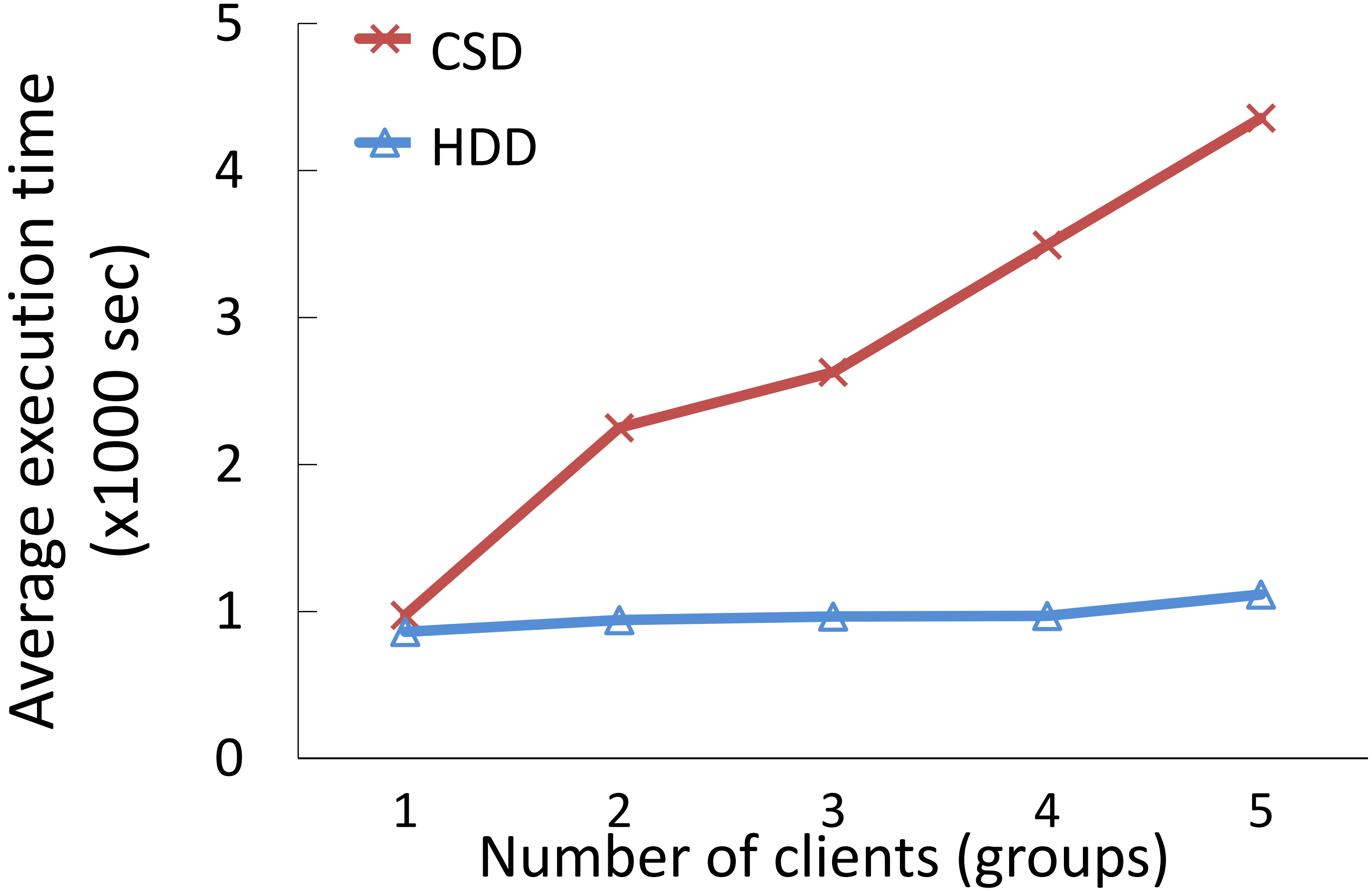


CSD offer significant cost savings (40%)

But … can we run queries over CSD?

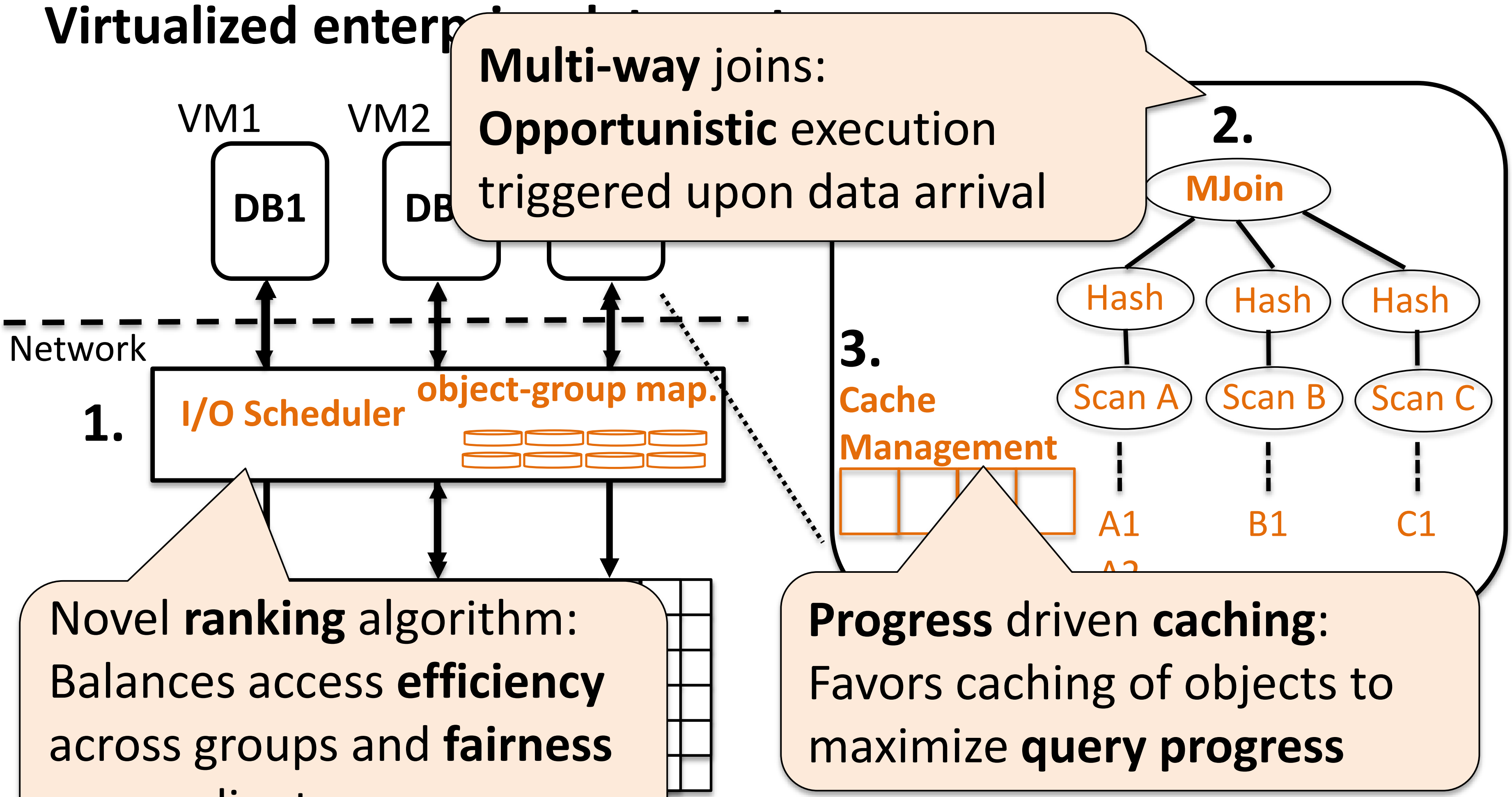
Query execution over CSD

Setting: virtualized enterprise datacenter, clients: PostgreSQL , TPCH 50, Q12, CSD: shared, layout: one client per group



Lost opportunity: CSD relegated to archival storage

Skipper to the rescue



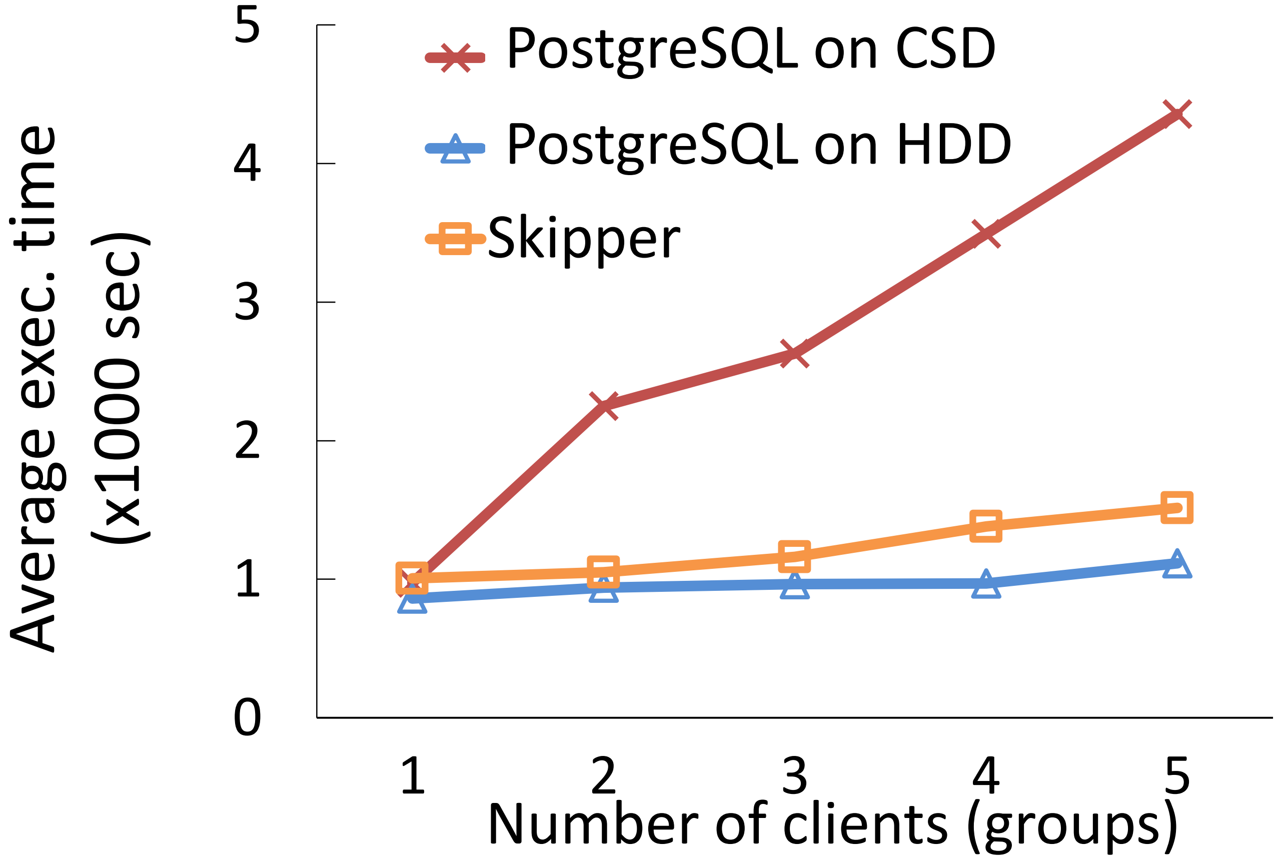
Multi-way joins:
Opportunistic execution triggered upon data arrival

Novel **ranking** algorithm:
Balances access **efficiency** across groups and **fairness** across clients

Progress driven **caching**:
Favors caching of objects to maximize **query progress**

Skipper in action

Setting: multitenant enterprise datacenter, clients: TPCH 50, Q12, CSD: shared, layout: one client per group



Approximates HDD-based capacity tier by 20% avg.

Summary of Skipper

- Efficient query execution over CSD with:
  1. **Rank-based** I/O **scheduling**
  2. Out-of-order execution based on **multi-way joins**
  3. **Progress based caching** policy
- Approximates **performance** of **HDD-based storage** tier

IMPACT

- Cold storage **can reduce TCO** by **shrinking** storage hierarchy
- Skipper enables data analytics-over-CSD-as-a-service

Thesis contributions

- **Minimize data-to-insight time**
  - Workload-driven adaptation
  - **Skip loading, tune as a byproduct of query execution**
- **Improve predictability of response time**
  - Data-driven adaptation
  - **Remove access decisions a priori, transform gradually**
- **Reduce analytics cost**
  - Cold storage & hardware-driven adaptation
  - **From plan pull-based to hardware push-based execution**
- **Uncertainty cured with adaptivity**

Thank you!