Column-Stores vs. Row-Stores: How Different Are They Really?

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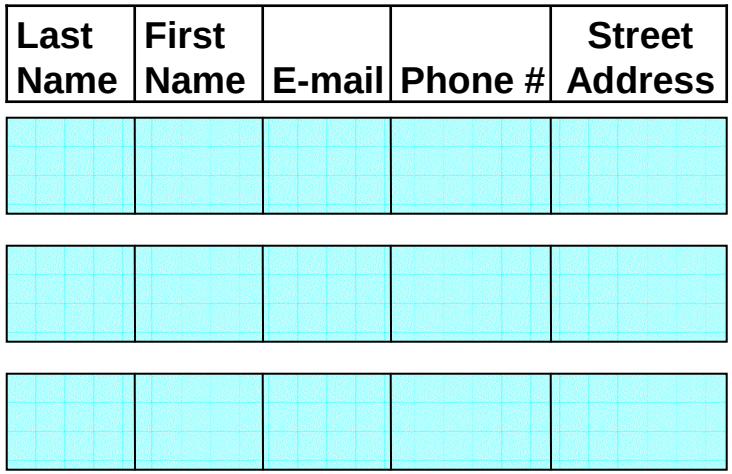
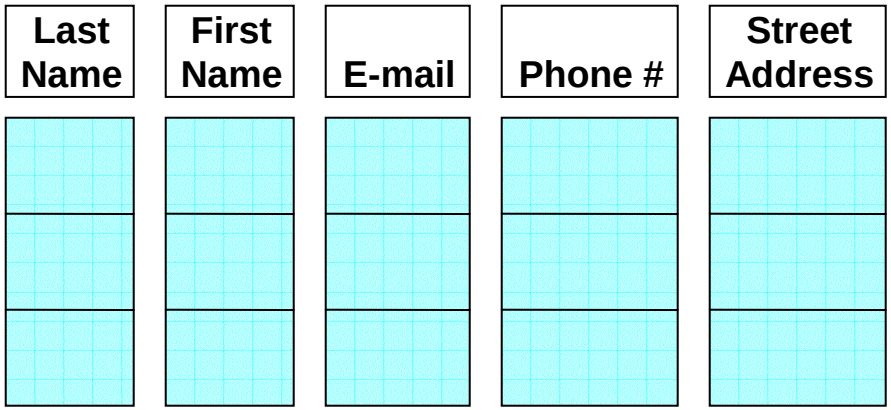
Row vs. Column-Stores

Row-Store



Column-Store



+ Easy to add a new record
– Might read in unnecessary data

+ Only need to read in relevant data
– Tuple writes might require multiple seeks

Column-Stores

- Really good for read-mostly data warehouses
  - Lot's of column scans and aggregations
  - Writes tend to be in batch
  - [CK85], [SAB+05], [ZBN+05], [HLA+06], [SBC+07] all verify this
  - Top 3 in TPC-H rankings (Exasol, ParAccel, and Kickfire) are column-stores
    - Factor of 5 faster on performance
    - Factor of 2 superior on price/performance

Data Warehouse DBMS Software

- $4.5 billion industry (out of total $16 billion DBMS software industry)
- Growing 10% annually

Momentum

- Right solution for growing market → $$$$
- Vertica, ParAccel, Kickfire, Calpont, Infobright, and Exasol new entrants
- Sybase IQ's profits rapidly increasing
- Yahoo's world largest (multi-petabyte) data warehouse is a column-store (from Mahat Technologies acquisition)

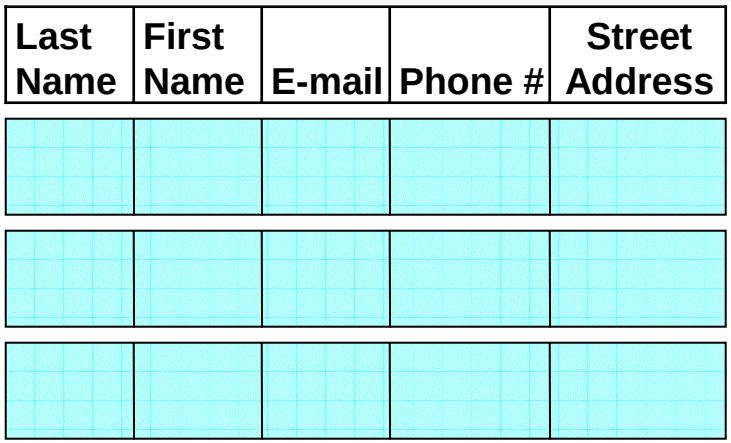
Paper Looks At Key Question

- How much of the buzz around column-stores just marketing hype?
  - Do you really need to buy Sybase IQ or Vertica?
  - How far will your current row-store take you?
    - Can you get column-store performance from a row-store?
    - Can you simulate a column-store in a row-store?

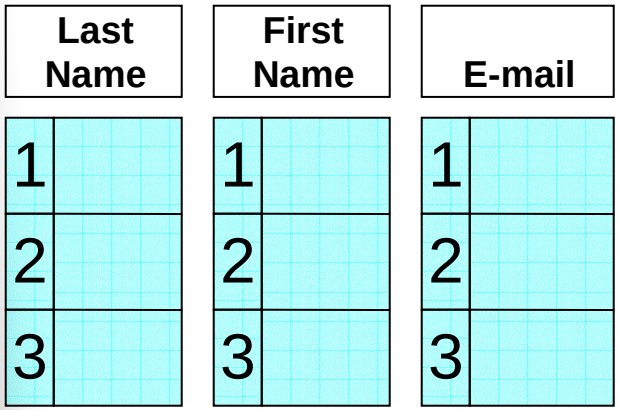
Paper Methodology

- Comparing row-store vs. column-store is dangerous/borderline meaningless
- Instead, compare row-store vs. row-store and column-store vs. column-store
  - Simulate a column-store inside of a row-store
  - Remove column-oriented features from column-store until it behaves like a row-store

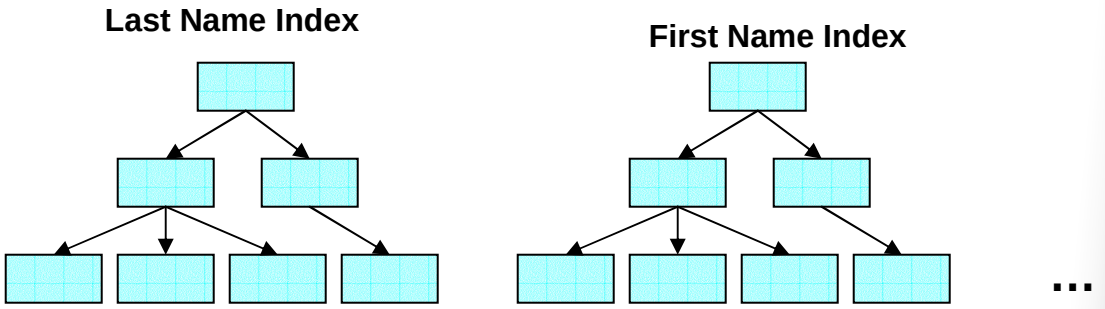
Simulate Column-Store Inside Row-Store



Option A: Vertical Partitioning



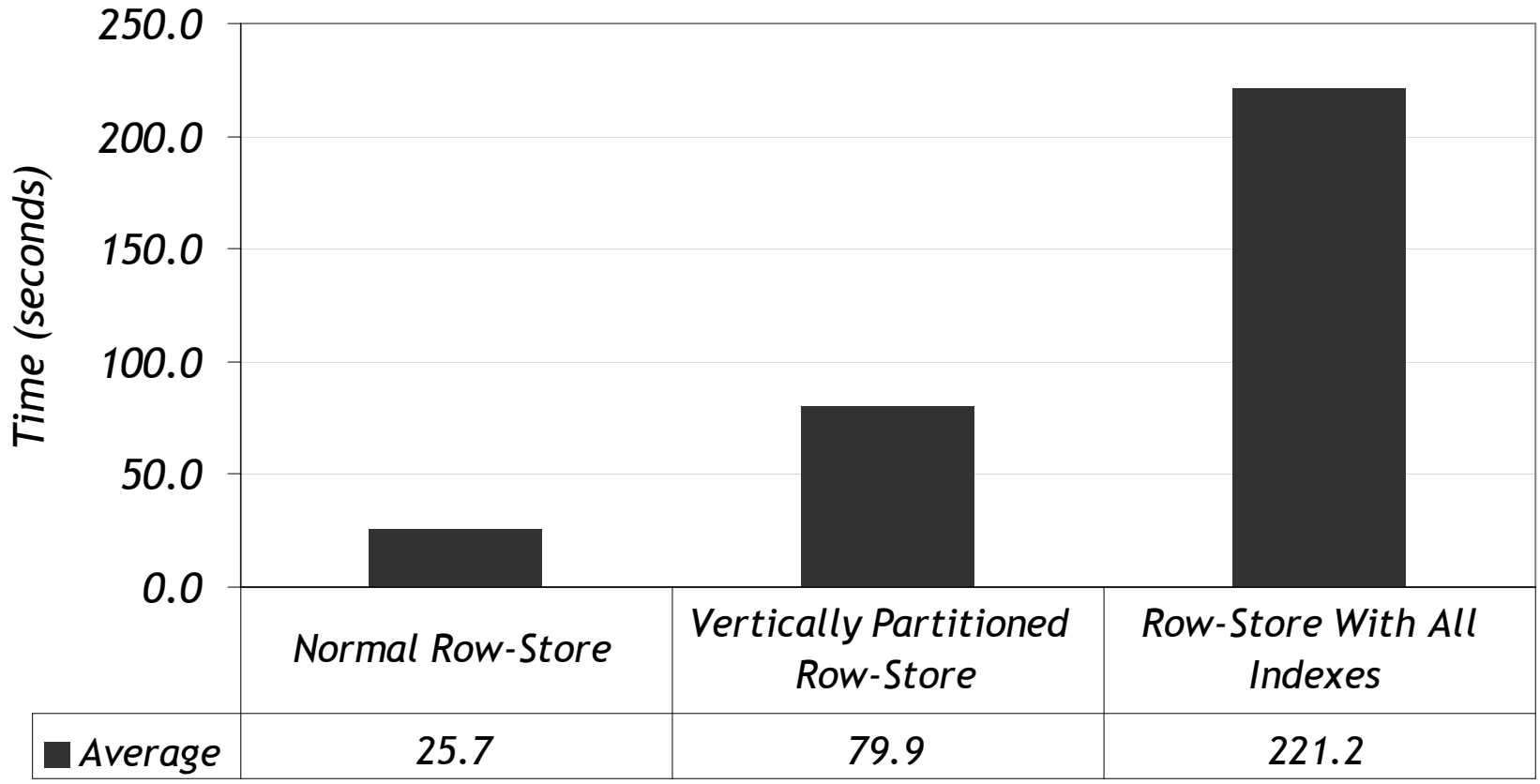
Option B: Index Every Column



Experiments

- Star Schema Benchmark (SSBM)
  - Fact table contains 17 columns and 60,000,000 rows
  - 4 dimension tables, biggest one has 80,000 rows
  - Queries perform 2-4 joins between fact table and dimension tables, aggregate 1-2 columns from fact table
  - [OOC06]
- Implemented by professional DBA
  - Original row-store plus 2 column-store simulations on same row-store product

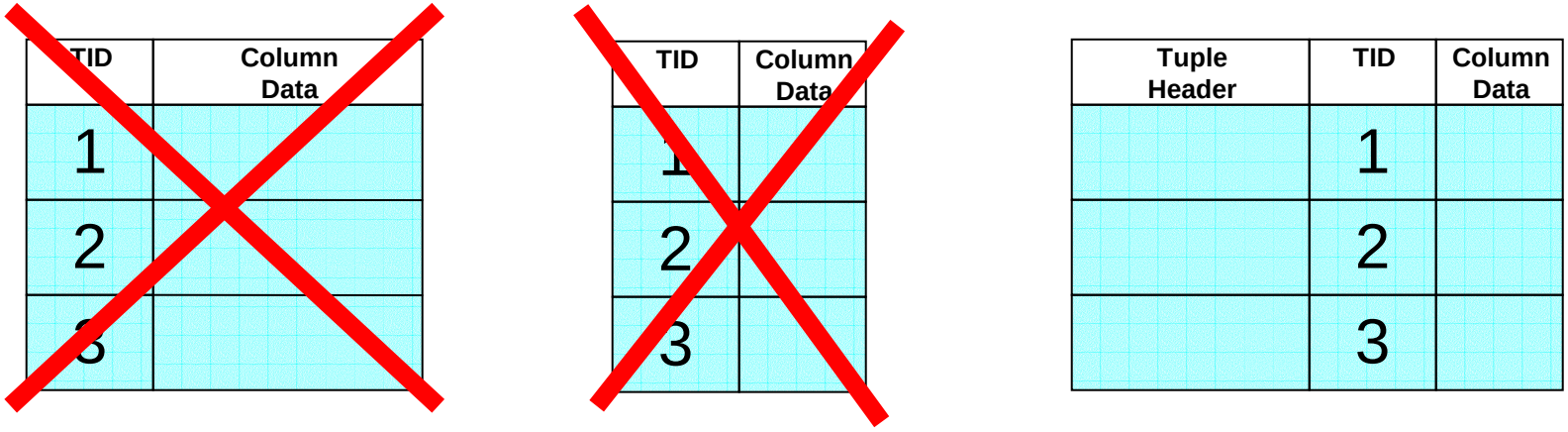
SSBM Averages



What's Going On?

- Vertically Partitioned Case
  - Tuple Sizes
  - Horizontal Partitioning
- All Indexes Case
  - Tuple Reconstruction

Tuple Size



- Queries touch 3-4 foreign keys in fact table, 1-2 numeric columns
- Complete fact table takes up ~4 GB (compressed)
- Vertically partitioned tables take up 0.7-1.1 GB (compressed)

Horizontal Partitioning

- Fact table horizontally partitioned on year
  - Year is an element of the ‘Date’ dimension table
  - Most queries in SSBM have a predicate on year
  - Since vertically partitioned tables do not contain the ‘Date’ foreign key, row-store could not similarly partition them

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Tuple Construction

- Common type of query:
  - SELECT store_name, SUM(revenue)
    FROM Facts, Stores
    WHERE fact.store_id = stores.store_id
    AND stores.country = “Canada”
    GROUP BY store_name

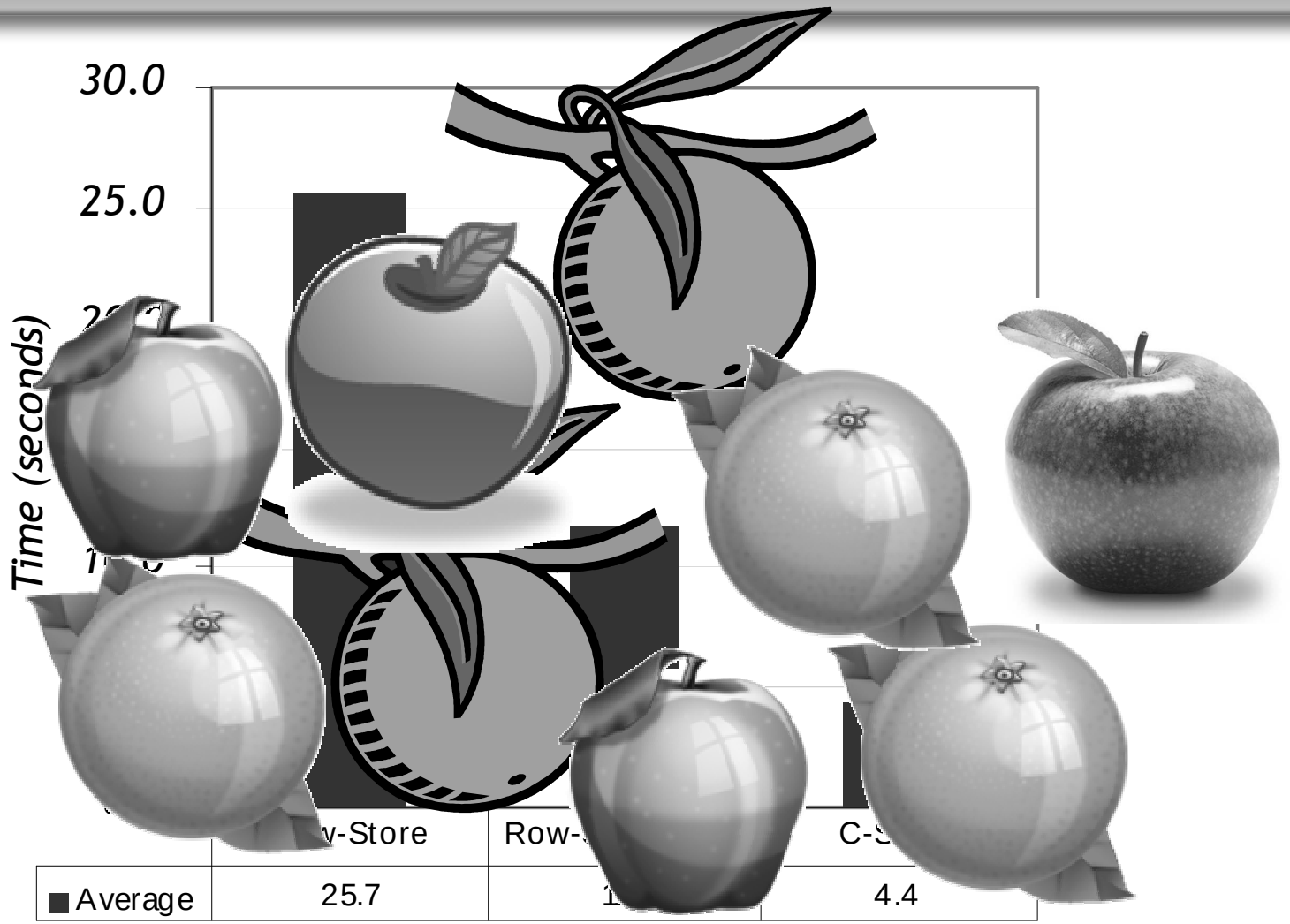
Tuple Construction

- Result of lower part of query plan is a set of TIDs that passed all predicates
- Need to extract SELECT attributes at these TIDs
  - BUT: index maps value to TID
  - You really want to map TID to value (i.e., a vertical partition)
  - → Tuple construction is SLOW

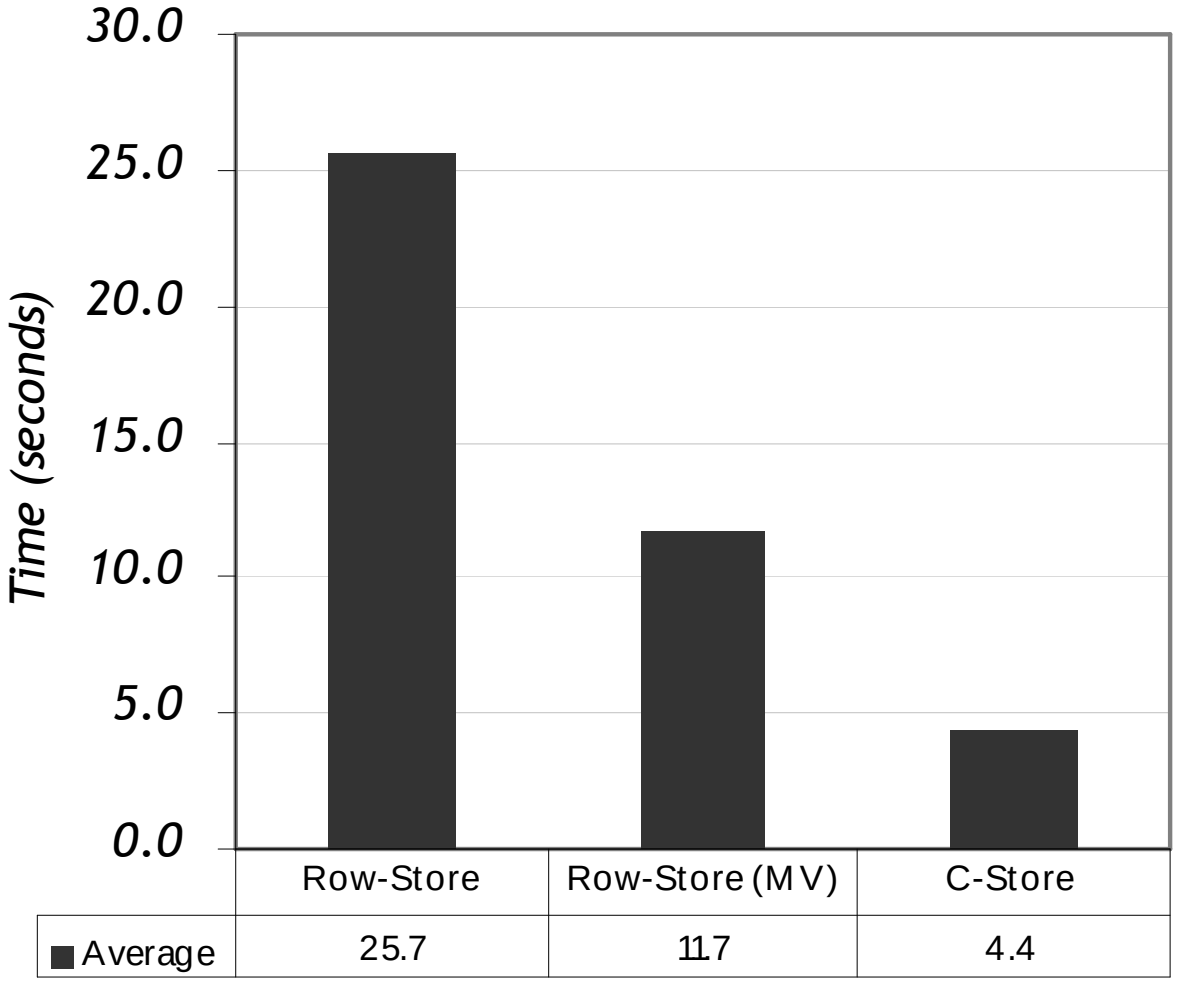
So….

- All indexes approach is a poor way to simulate a column-store
- Problems with vertical partitioning are NOT fundamental
  - Store tuple header in a separate partition
  - Allow virtual TIDs
  - Allow HP using a foreign key on a different VP
- So can row-stores simulate column-stores?

Row-Store vs. Column-Store



Row-Store vs. Column-Store

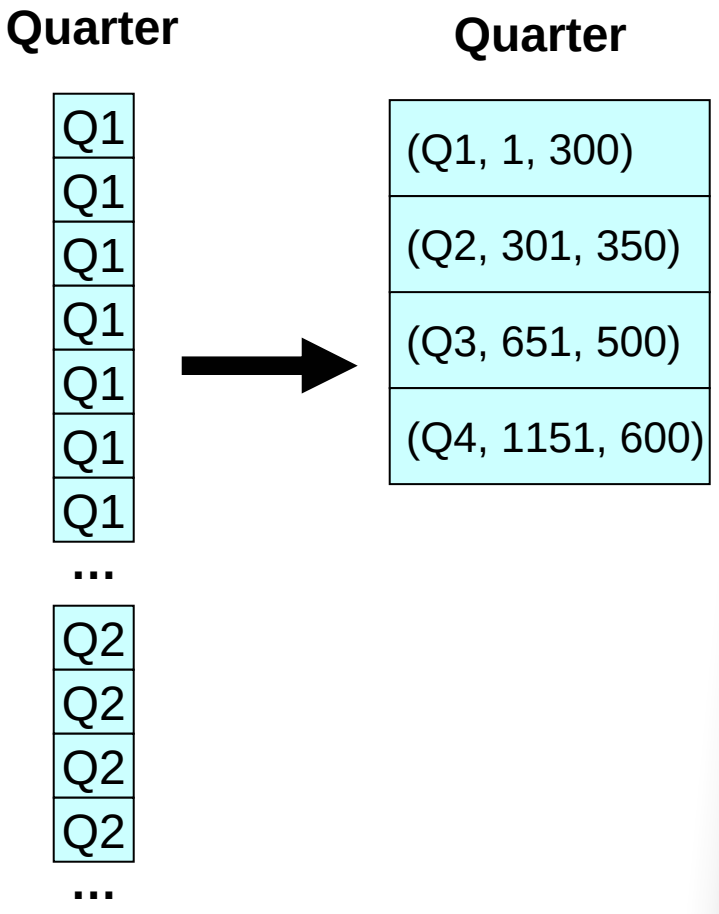


Column-Store Experiments

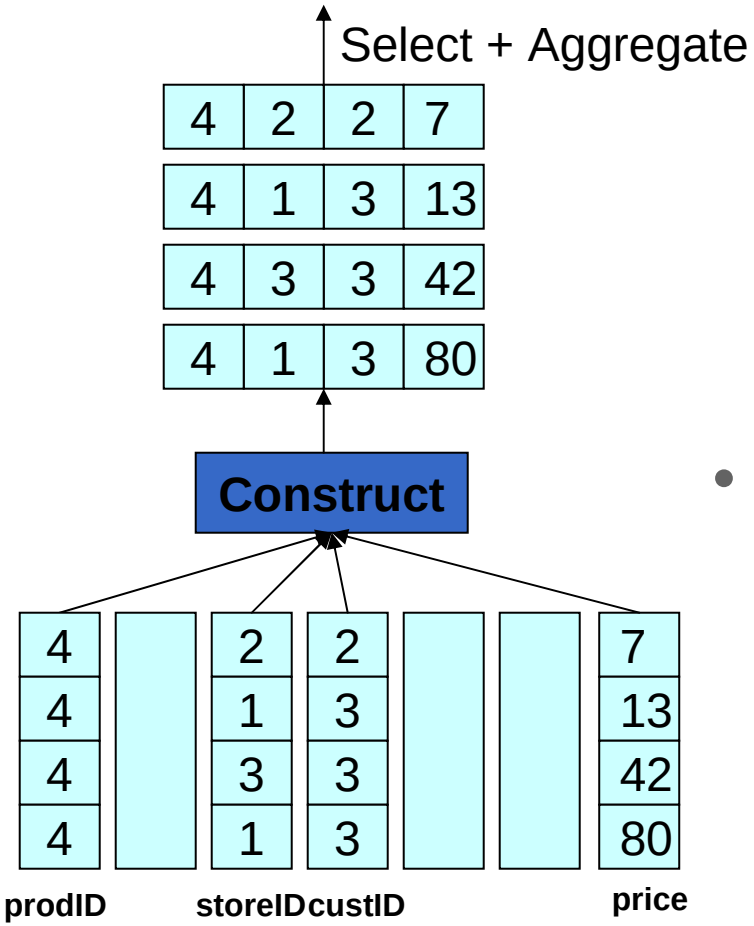
- Start with column-store (C-Store)
- Remove column-store-specific performance optimizations
- End with column-store with a row-oriented query executer

Compression

- Higher data value locality in column-stores
  - Better ratio → reduced I/O
- Can use schemes like run-length encoding
  - Easy to operate on directly for improved performance ([AMF06])



Early vs. Late Materialization



QUERY:

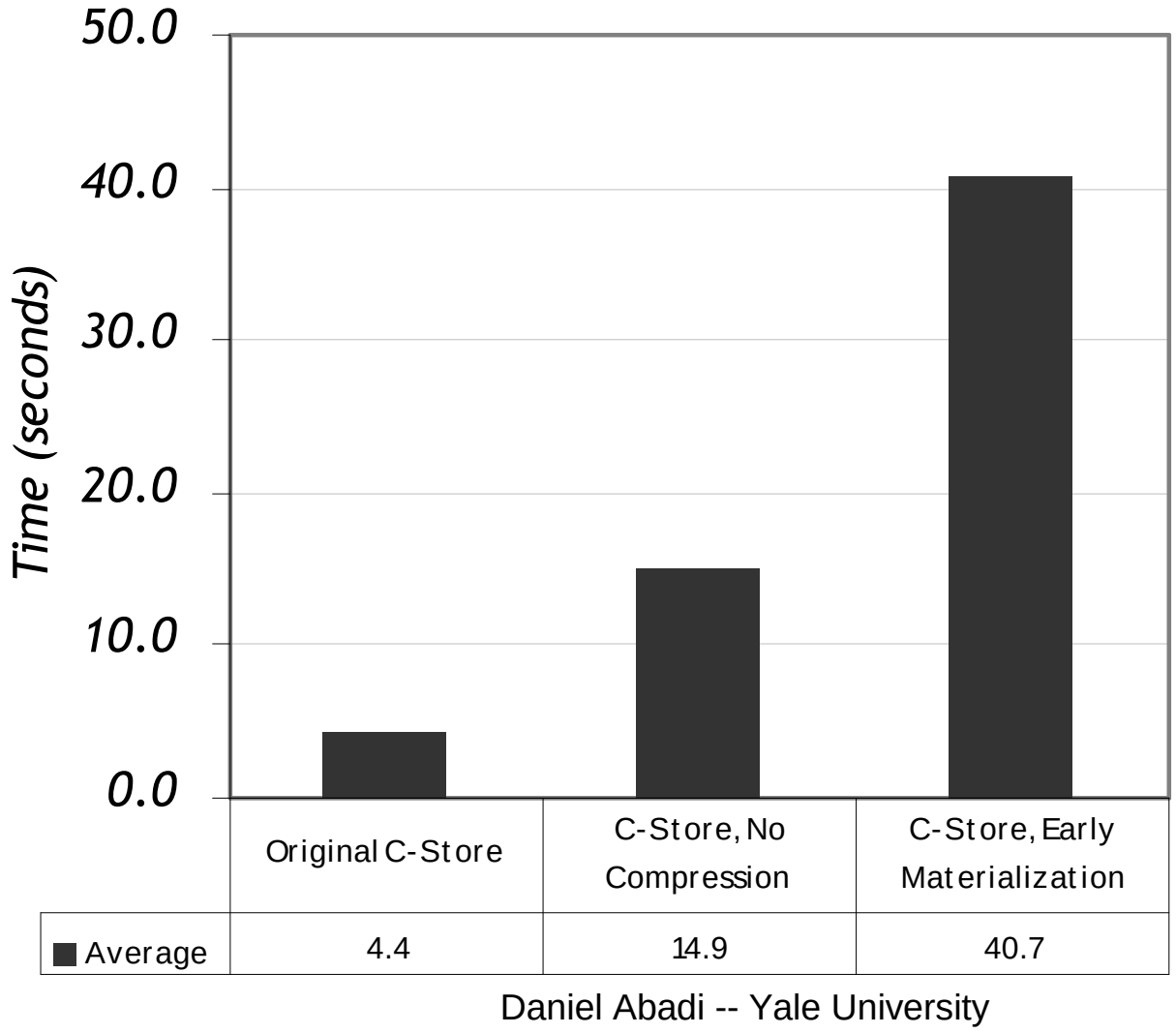
```
SELECT custID,SUM(price)
FROM table
WHERE (prodID = 4) AND
      (storeID = 1) AND
GROUP BY custID
```

- **Early Materialization: create rows first. But:**
  - **Poor memory bandwidth utilization**
  - **Lose opportunity for vectorized operation**

Other Column-Store Optimizations

- Invisible join
  - Column-store specific join
  - Optimizations for star schemas
  - Similar to a semi-join
- Block Processing

Simplified Version of Results



Conclusion

- Might be possible to simulate a row-store in a column-store, BUT:
  - Need better support for vertical partitioning at the storage layer
  - Need support for column-specific optimizations at the executer level
- Working with HP Labs to find out

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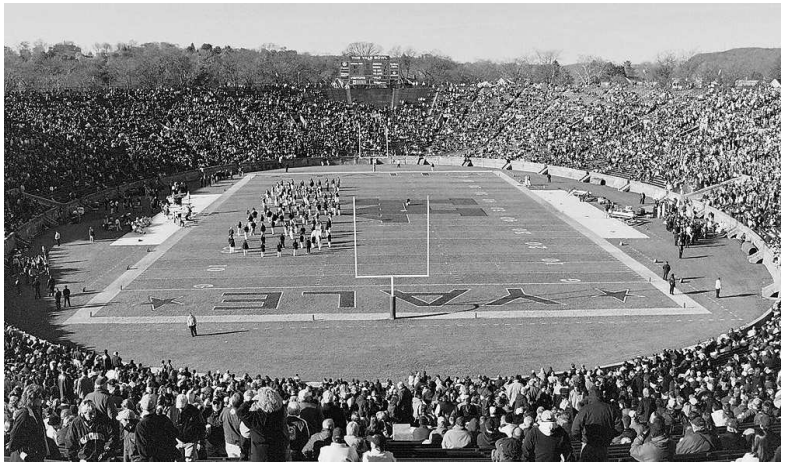

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