BIRTE 2011

Real Time Business Intelligence

Blink:
Not Your Father's Database!

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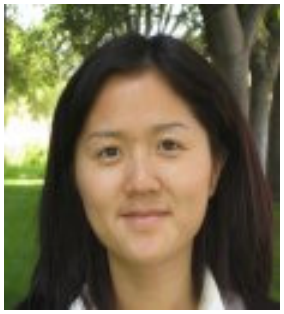
Blink Research Team



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Blink – Agenda

- **Why and What is Blink**
- **Blink Market – Business Intelligence**
- Blink Architecture
- It's All About Performance!
- What's the Big Deal?
- Behind the Curtain – The Query Engine Technology
- References and Related Work
- Next Steps
- Conclusions

Motivation

- **Today, performance of Business Intelligence (BI) queries is too <u>unpredictable</u>**
  - –When an analyst submits a query, s/he doesn't know whether to:
    - •Wait for the response
    - •Go out for coffee
    - •Go out for dinner
    - •Go home for the night!
  - –Response time depends upon "performance layer" of indexes & materializations
  - –Depends critically on predicting the workload
  - –But BI is inherently ***ad hoc!***

- **Goal of Blink:**

  Predictably Fast (i.e., <u>Interactive</u>) Ad Hoc Querying
  - –**Any** query should run in about the same time
  - –Permit an Analyst to interact with the data

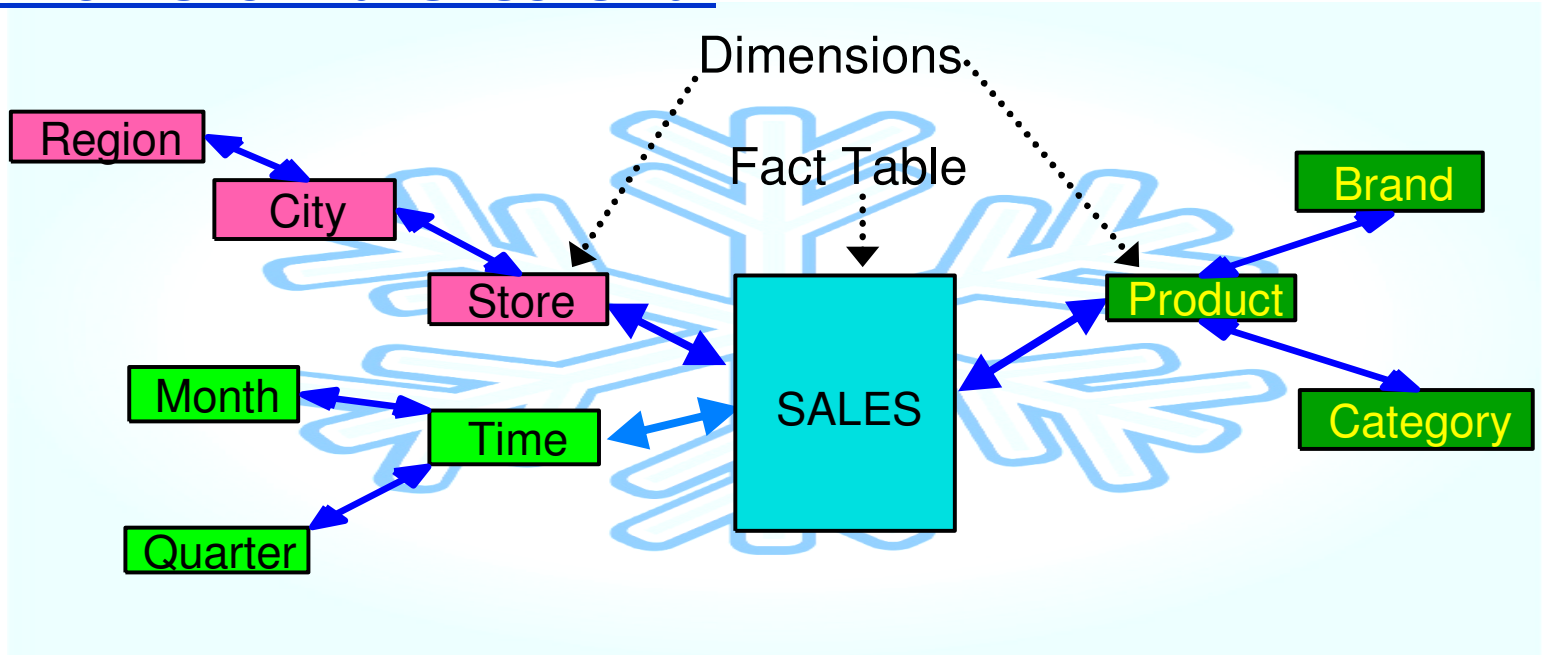
What Is Blink?

- Accelerator technology developed by IBM Almaden Research since 2007
- Contains a compressed copy of a (portion of a) data warehouse
- Exploits:
  - Large main memories
  - Commodity multi-core processors
  - Proprietary compression
- Speeds up typical Business Intelligence SQL queries by **10x to 100x**

- Without requiring tuning of indexes, materialized views, etc.
- **Products offered by IBM based upon Blink:**
  - **IBM Smart Analytics Optimizer for DB2 for z/OS V1.1** – GA'd Nov. 2010
    - Appliance: Runs on zEnterprise Blade eXtension (zBX), network-attached to zEnterprise
  - **Informix Warehouse Accelerator** – GA'd March 2011
    - Virtual Appliance: Runs in same machine as Informix IDS

Target Market: Business Intelligence (BI)

- Characterized by:
  - **"Star" or "snowflake" schema:**



  - **Complex, ad hoc queries that typically**
    - Look for trends, exceptions to make actionable business decisions
    - Touch large subset of the database (unlike OLTP)
    - Involve aggregation functions (e.g., COUNT, SUM, AVG,…)
    - **The "Sweet Spot" for Blink!**

What Blink is Designed For

- **OLAP-style SQL queries:**
  - Relational star schema (large **fact table** joined to multiple **dimensions**)
  - Large subset of data warehouse accessed, reduced significantly by…
  - **Aggregations** (SUM, AVG, COUNT) and optional **grouping** (GROUP BY)
  - **Looking for trends or exceptions**

- **EXAMPLE SQL**:

```
SELECT P.Manufacturer, S.Type, SUM(Revenue)
FROM Fact_Sales F
      INNER JOIN Dim_Product P ON F.FKP = P.PK
      INNER JOIN Dim_Store S ON F.FKS = S.PK
      LEFT OUTER JOIN Dim_Time T ON F.FKT = T.PK
WHERE P.Type = ‚JEANS‘ AND S.Size > 50000 AND
  T.Year = 2007
GROUP BY P.Manufacturer, S.Type
```

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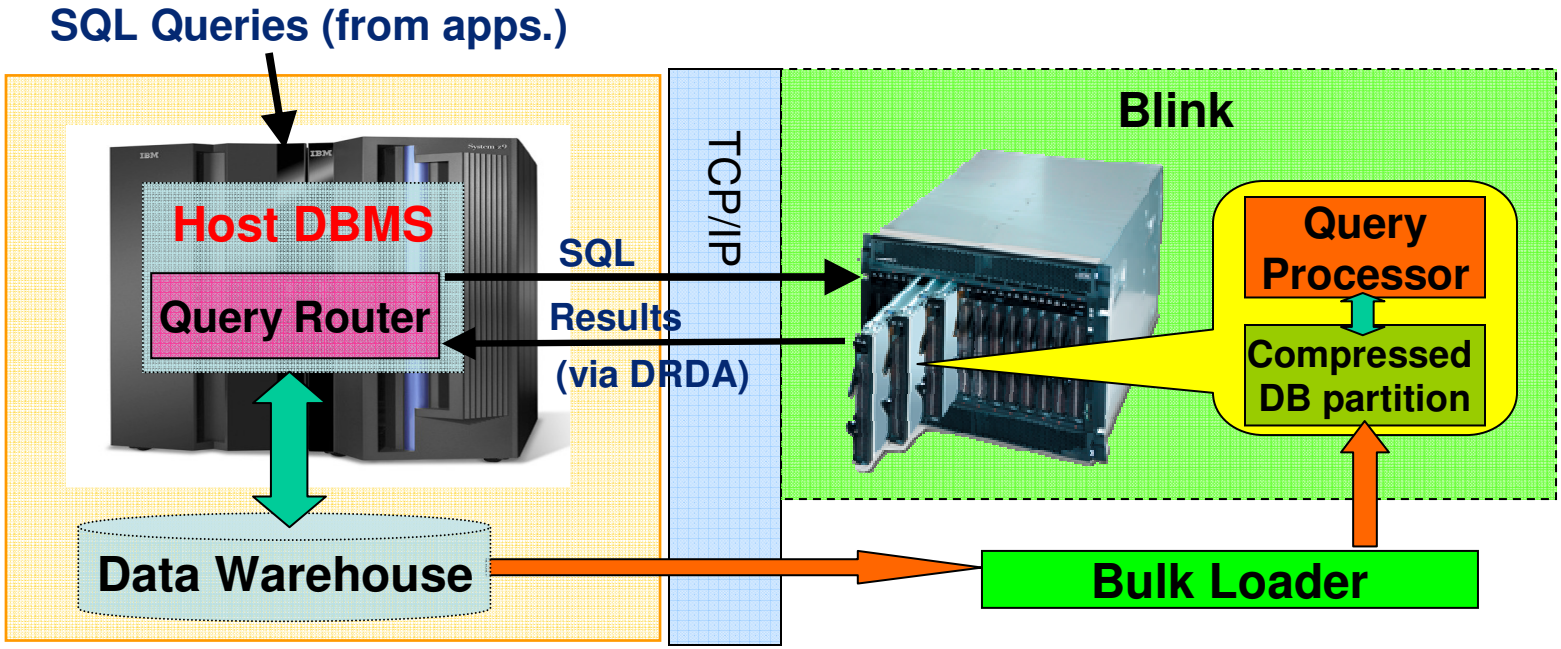
Blink Configuration



Host DBMS (DB2 or IDS):

- **Routes SQL queries to accelerator**
- **User need not change SQL or apps.**
- **No externalized interfaces!**
- **Can always run query in Host DBMS, e.g., if**
  - **too complex SQL, or**
  - **too short an est. execution time**

Blink:

- **Commodity blades**
- **Connects to Host DBMS via TCP/IP & DRDA**
- **Analyzes, compresses, and loads**
  - Copy of (portion of) warehouse
  - Partitioned among nodes
- **Processes routed SQL query and returns answer to Host DBMS**

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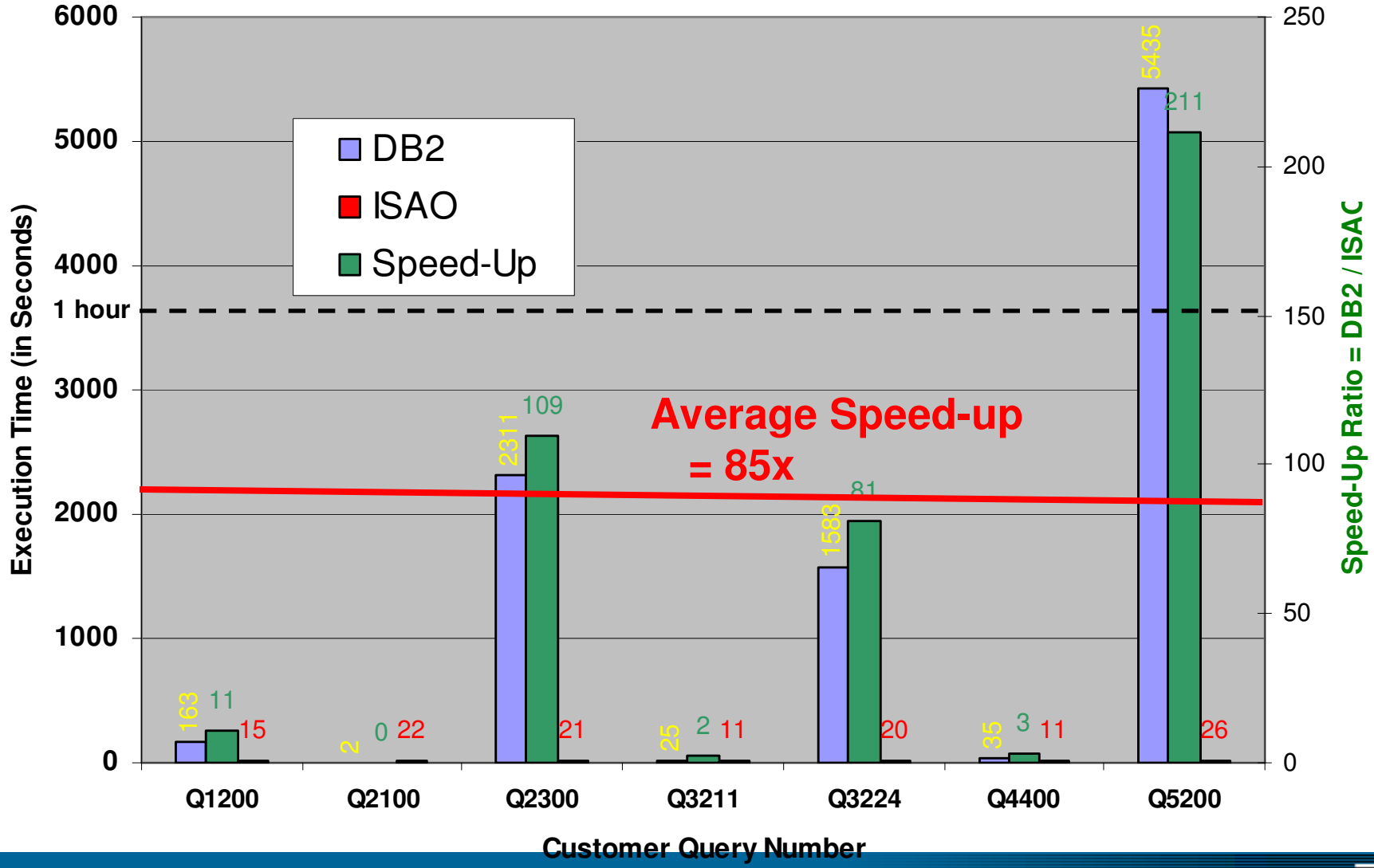
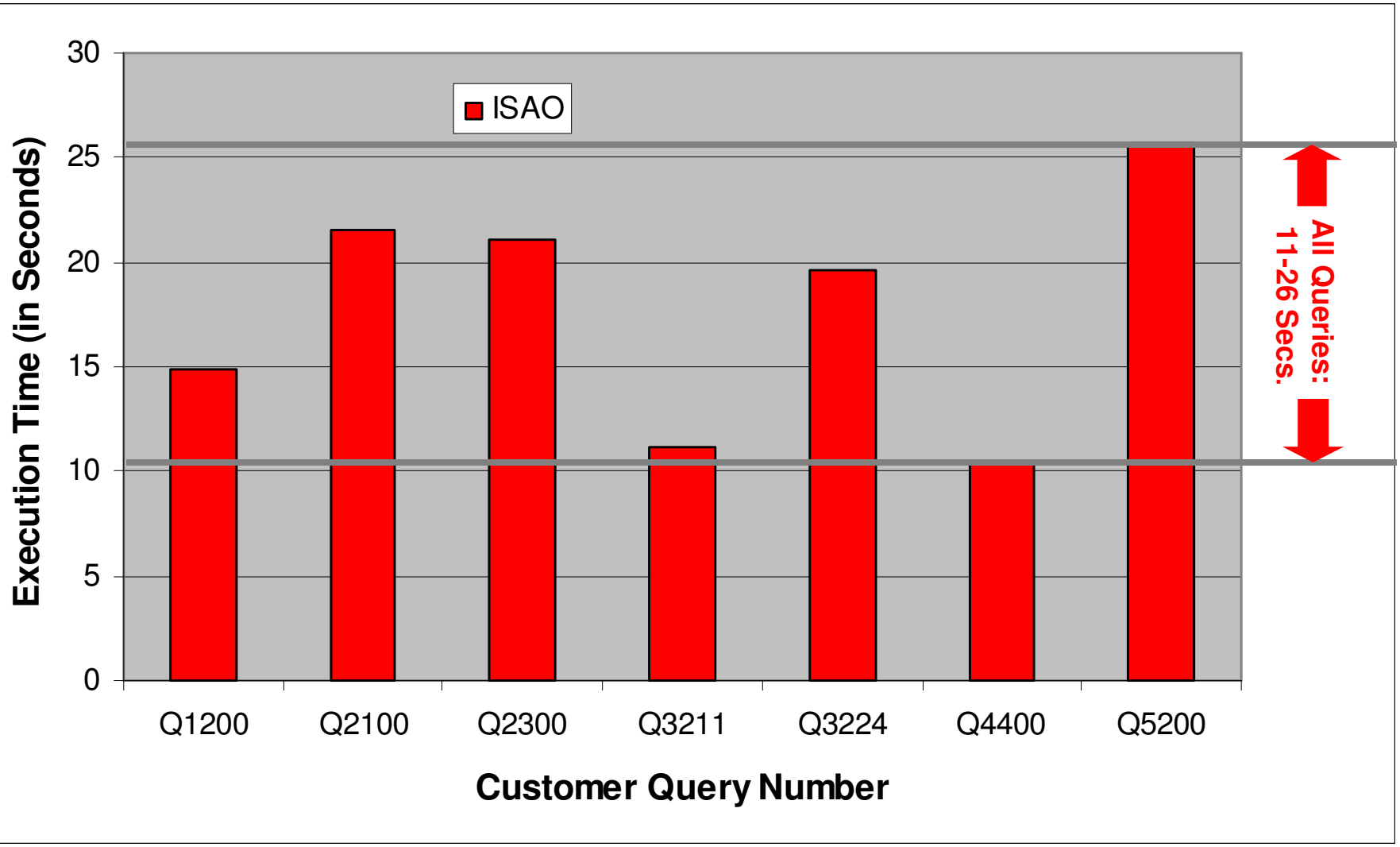
Blink Accelerates Most the Longest-Running Queries



Blink Query Execution times (magnified)



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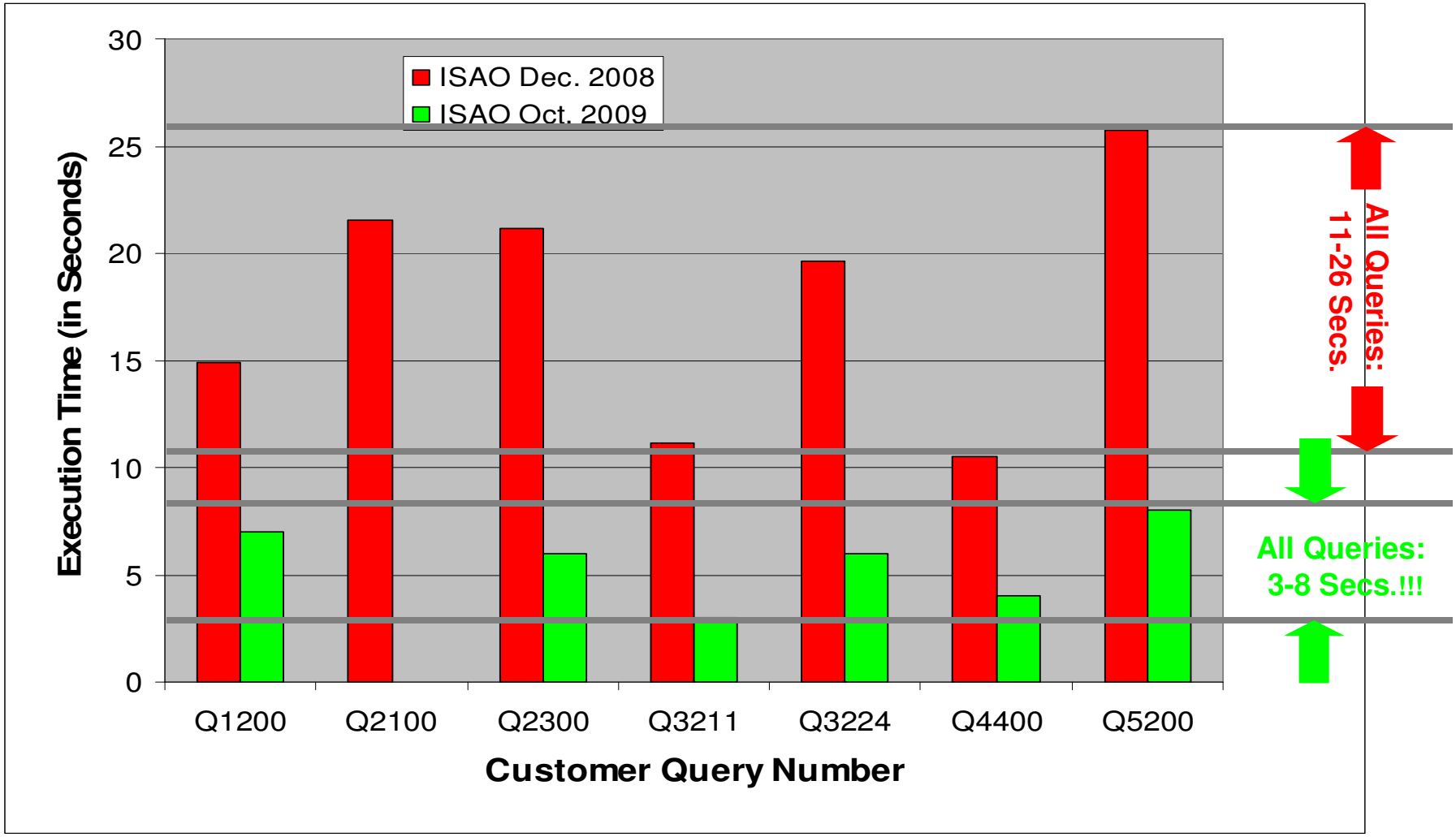
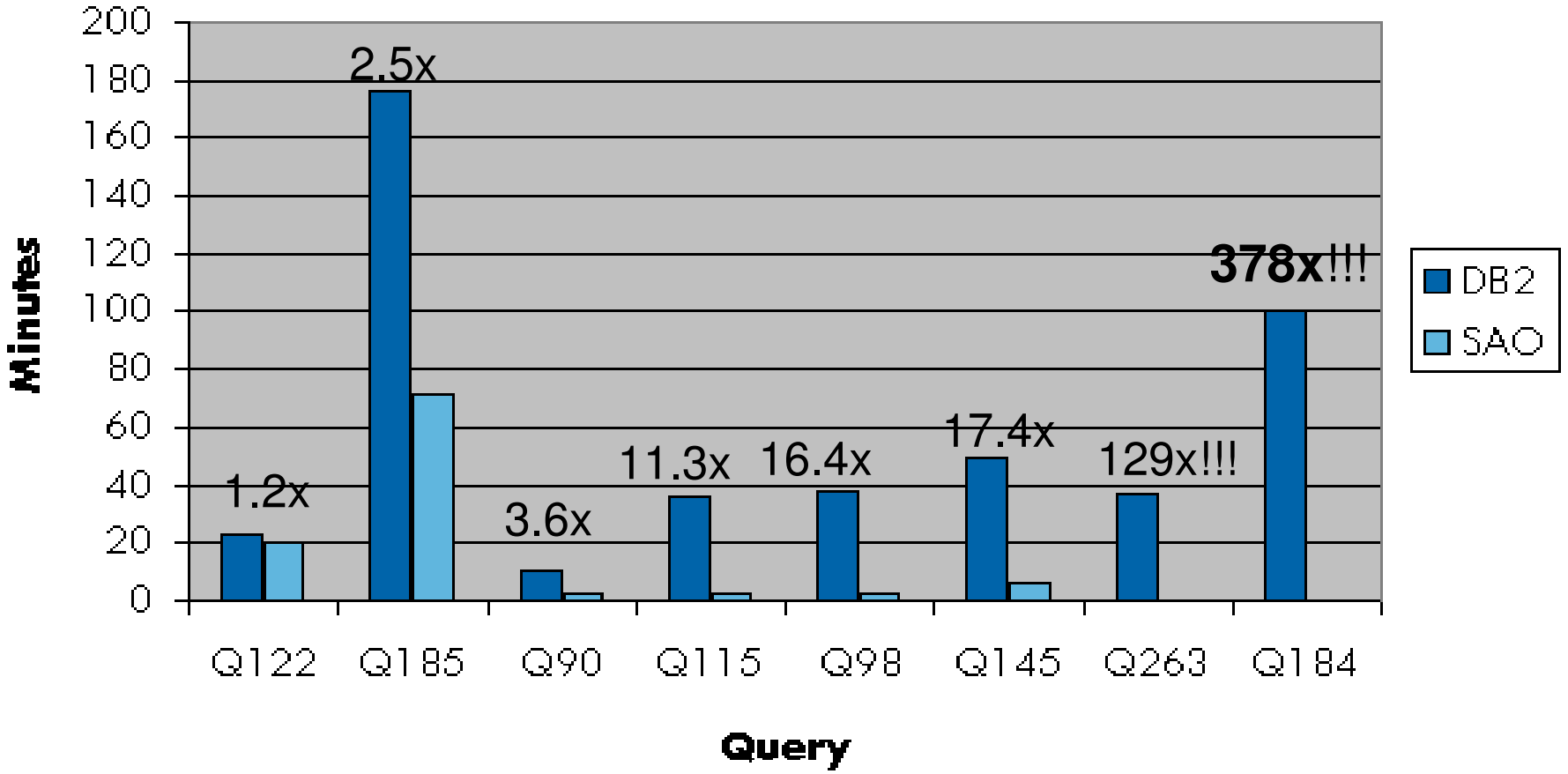


Beta Test – Blink Elapsed Time & Speedup



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What's the Big Deal? What's so Disruptive?

- **Blink rides the wave of hardware technology trends:**
  - –Multi-core processors
  - –Large main memories
  - –Fast interconnects
  - –Increasing latency gap between DRAM and disk

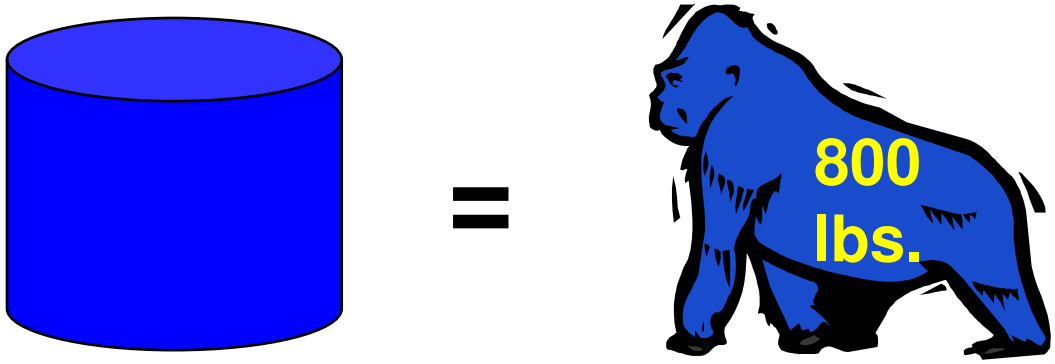
- **Blink disrupts at least 4 major tenets that have been held sacrosanct for over 4 decades!**

Disruption 1 of 4

- **Tenet #1**: General-purpose DBMSs are most cost-effective
- **Consequence of Tenet #1**: BI pays for OLTP overheads
  - Locking
  - Logging

- **Disruption #1**: Specialized DBMSs for BI now commonplace in market!
- **Consequences of Disruption #2**:
  - BI uses snapshot semantics (typically roll-in or roll-out in batches of rows)
  - Can simplify and eliminate OLTP overheads
  - Can still embed specialty engines in general-purpose DBMS!
    - "Workload-optimized systems"

Disruption 2 of 4



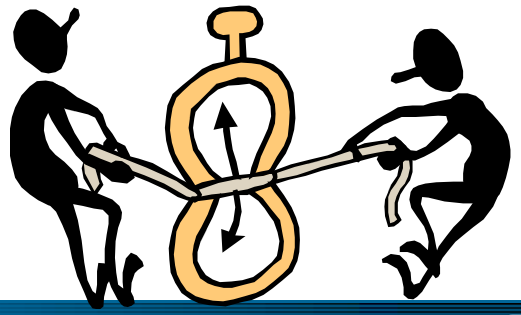
- **Tenet #2:** Data warehouses are too big for memory
- **Consequence of Tenet #2:** Disk I/O concerns dominate DBMS…
  - Costs
  - Performance
  - Administration efforts
- **Disruption #2:** Huge, cheap main memories (RAM) and flash memories
- **Consequences of Disruption #2:**
  - Portions of warehouse can fit, if partitioned among multiple machines
  - Compression helps!
  - New bottleneck is memory bandwidth (RAM ←→ L2 cache) and CPU
  - No preferred access path

Disruption 3 of 4

- **Tenet #3:** Need many Indexes & MQTs for scalable OLAP performance
- **Consequences of Tenet #3:**
  - Need an optimizer to choose among access paths
  - Need a ★★★★ wizard to design "performance layer" (expensive!)
  - Must anticipate queries
  - Large time to update performance layer when new data added
- **Disruption #3:** Massive parallelism achieves DB scan in seconds!
  - Arbitrarily partition database among nodes (32–64 GB RAM / node)
  - Exploit multi-core architectures within nodes (1 user or DB cell / core)
- **Consequences of Disruption #3:**
  - Only need to define 1 view in DB2 to satisfy many queries on the accelerator
  - Always scan tables!!
  - Accelerator automatically does equivalent of partition elimination
    - If literal is not in dictionary of that partition
  - Accelerator itself doesn't need
    - Performance layer (indexes or materialized views)!
    - Optimizer!
  - **Simpler! (no need for 4-star wizard)**
  - **Lower TCO!**
  - Consistent response times

Disruption 4 of 4

- **Tenet #4:** Main-memory DBMSs are the same as a big buffer pool
- **Consequence of Tenet #4:** Don't need a special main-memory DBMS
- **Disruption #4:** Clever engineering can save lots more!
- **Examples of Disruption #4:**
  - Specialized order-preserving & fixed-length compression within partitions permits:
    - Faster access
    - Performing most operations **on encoded values**
      - **Saves CPU for most processing and decoding**
      - **More efficient use of cache and memory bandwidth**
    - **Simultaneous application of predicate conjuncts (1 compare!)**
  - Cache-conscious algorithms make max. use of L2 cache and large registers
  - Exploit multi-core processors
  - Hash-based grouping avoids sorting



IBM

Blink's "Secret Sauce"

1

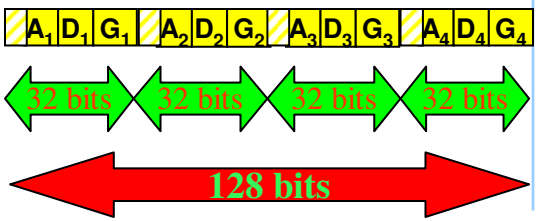
Operate on <u>encoded</u> data

- Dictionary compression with approximate Huffman encoding (fixed length within each part.)
- **Most SQL operations on compressed data!**
- Enables SIMD operations on multiple values in a register
- Dramatically improves efficiency in utilization of RAM, cache, and memory bandwidth

2

Register Store

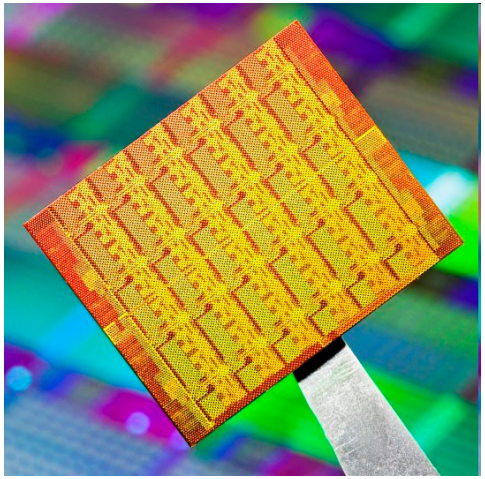
- Pack several column values into a register
- Access only columns referenced in query
- Favors scan-based processing
- L2 / L3 efficiency



3

Parallelism

- KIWI: Kill It With Iron!
- Multiple nodes (blades)
- Designed and built for multi-core, from the ground up

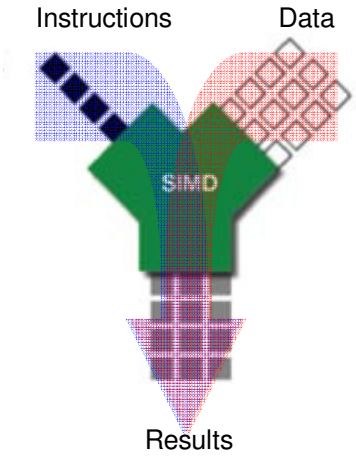


Blink's "Secret Sauce"

4

Single Instruction, Multiple Data (SIMD)

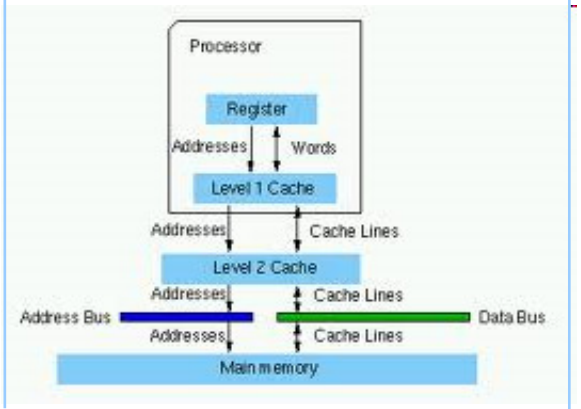
- Enabled by encoded data and register store
- CPU vector processing
- Large gains in CPU efficiency
- 3rd level of parallelism!



5

Architecture-conscious

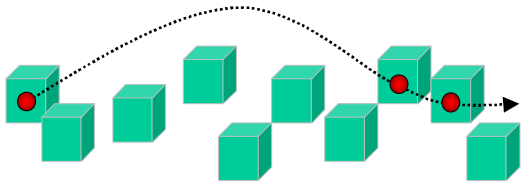
- Cache-conscious query evaluation
- Operate on groups of rows
- Scan-friendly



6

Selection via Synopses

- Skip entire blocks based upon meta-data
- No DBA action to define or use – truly invisible.
- Similar to Netezza's "zonal maps"



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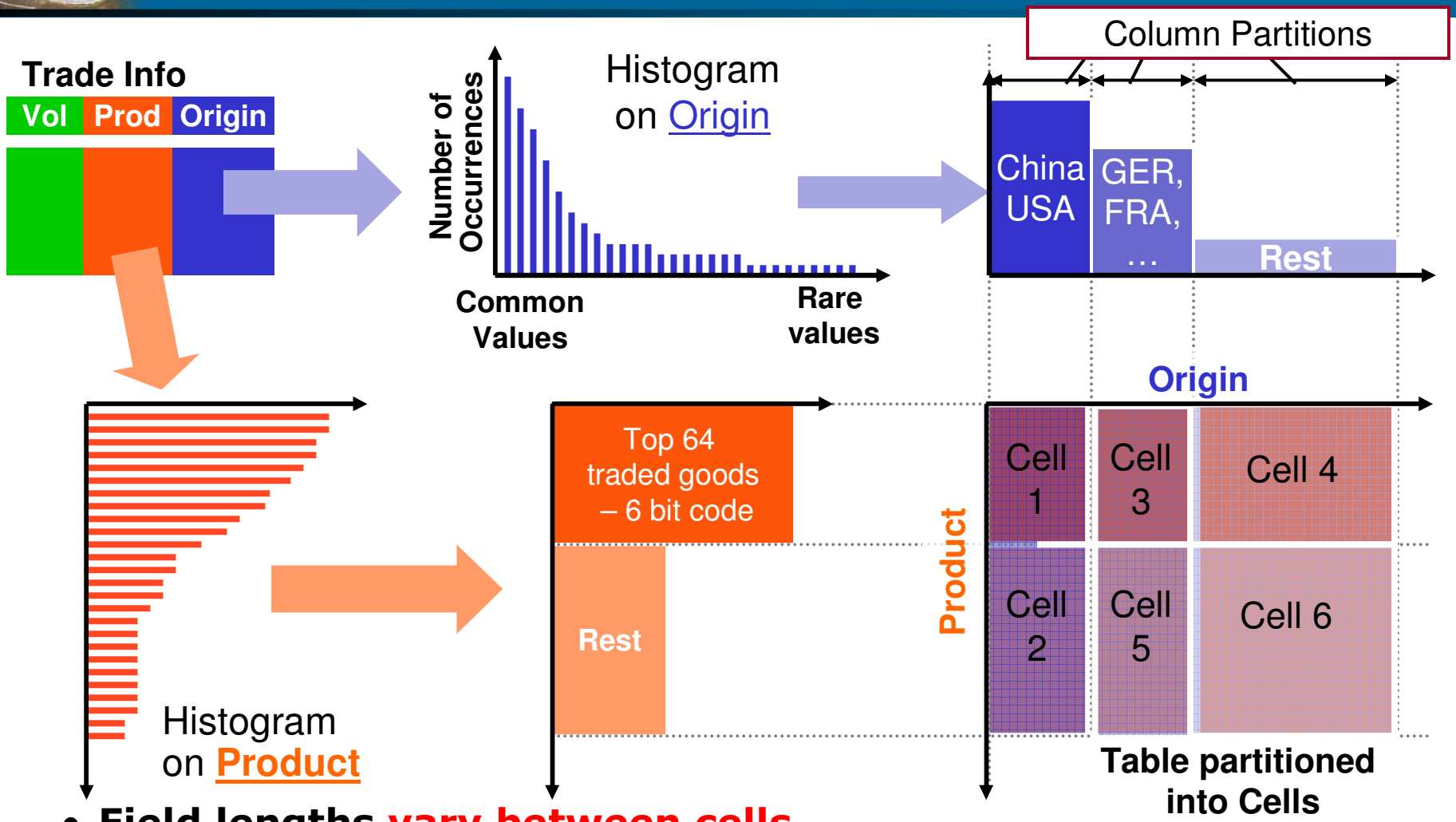
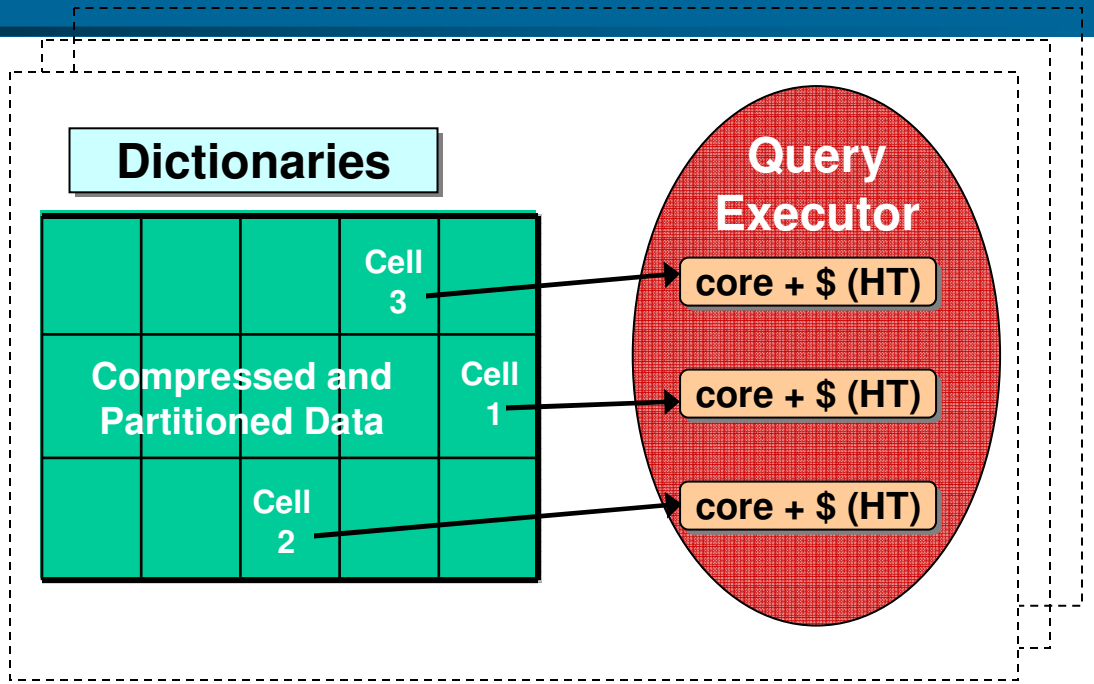
Compression: Frequency Partitioning



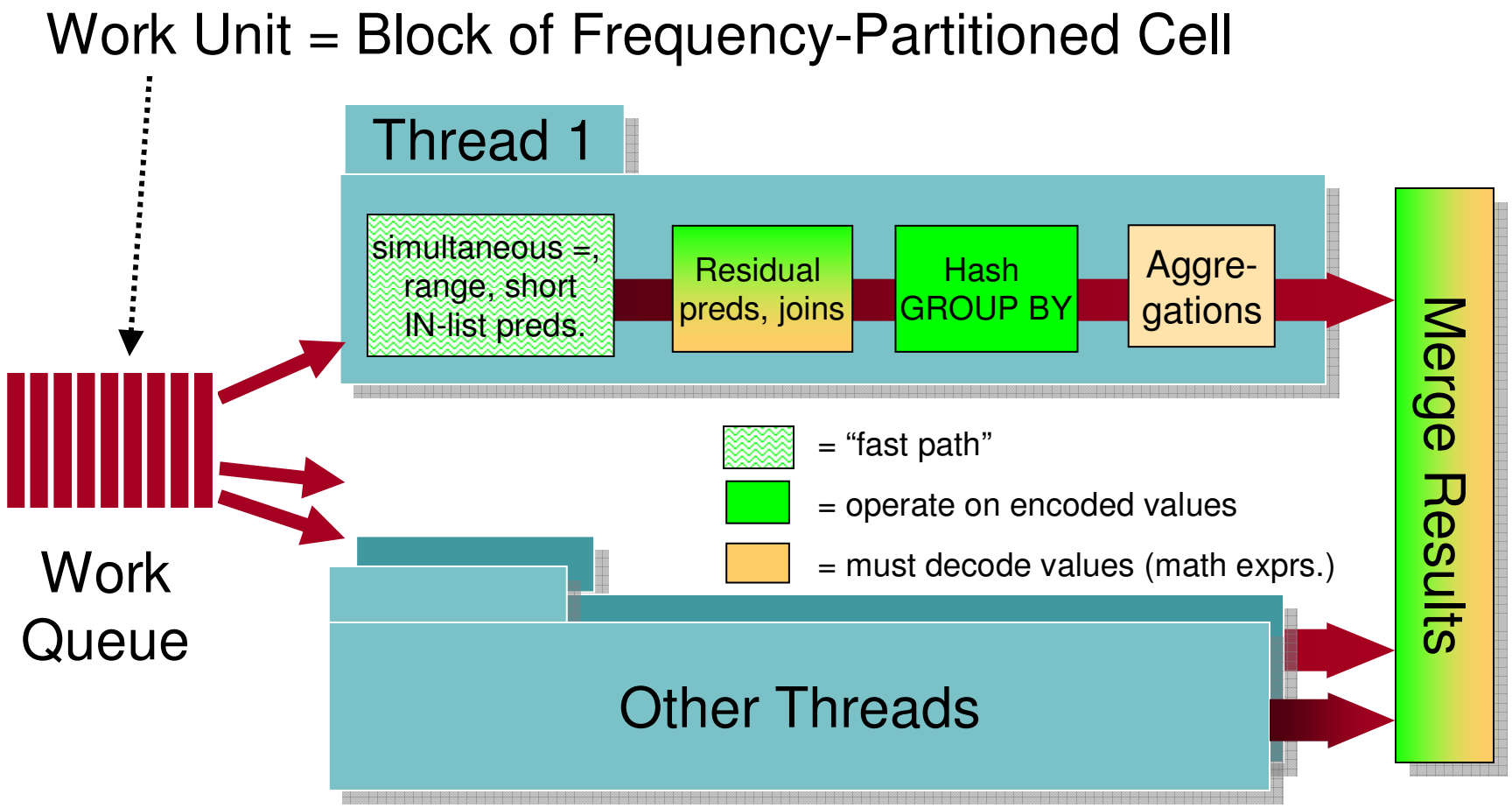
- **Field lengths vary between cells**
  - –Higher Frequencies ➔ Shorter Codes (Approximate Huffman)
- **Field lengths fixed within cells**

Query Processing

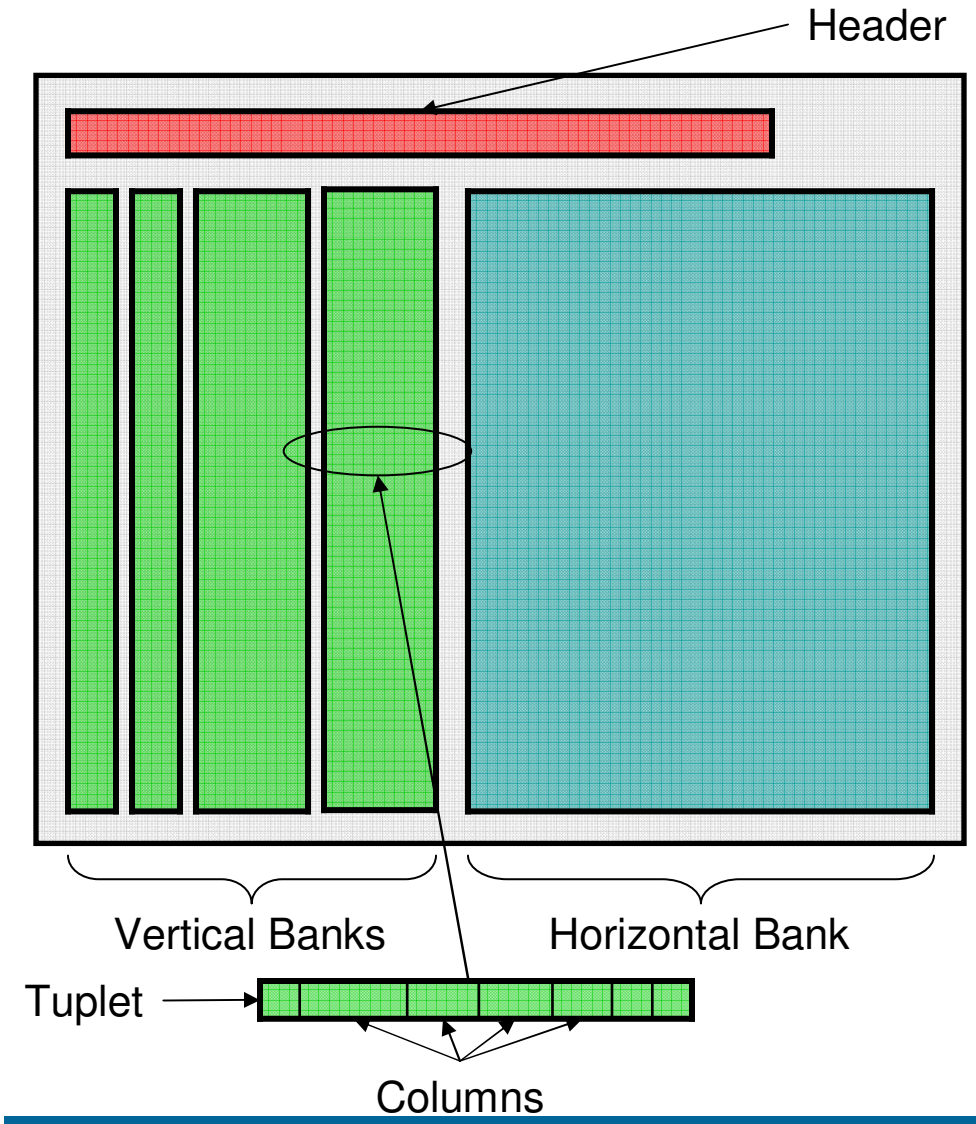


- **Cell is also the unit of processing, each cell…**
  - Assigned to one core
  - Has its own hash table in cache (so no shared object that needs latching!)
- **Main operator: SCAN over compressed, main-memory table**
  - Do selections, GROUP BY, and aggregation as part of this SCAN
  - Only need de-compress for arithmetic operations
- **Response time ∝ (database size) / (# cores x # nodes)**
  - Embarrassing Parallelism – little data exchange across nodes

Fine-Grained Data Parallelism



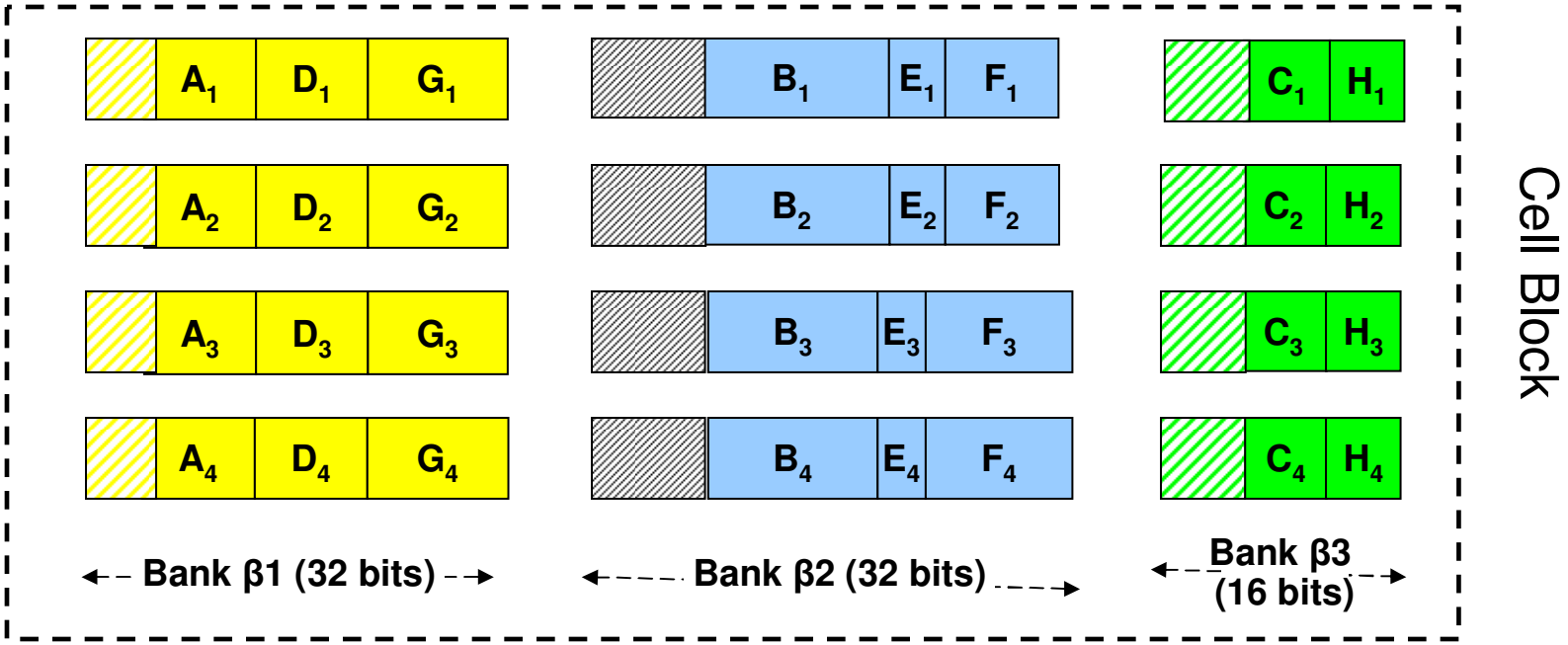
Blink PAX Data Storage Format – Overview



- **Frequency Partitioning into Cells**
  - Column-wise compression
  - Each col. dictionary partitioned by value frequency
  - Cross-product of col. partitions ➔Cells
  - Encoded columns are fixed-length (bits) in a cell
- **Cell data are stored in fixed-sized (1MB) Blocks**
- **Rows are partitioned vertically within blocks, into Banks**
  - Encoded columns are bin-packed into word-sized (8,16,32,64 bit) banks
  - **Vertical Banks**: contain columns typically used in predicates and grouping
  - **Horizontal Bank**: contains measure columns
  - **Access Pattern**:
    - Scan V-banks to apply predicates.
    - RID access to V-banks for residual predicates, grouping columns.
    - RID access to H-bank for aggregation.

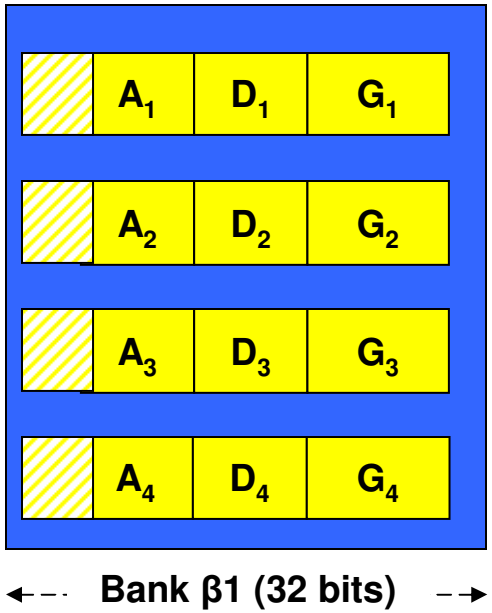
Banks and Tuplets in Blink

- **A *bank* is a vertical partition of a table, containing a subset of its columns**
  - Assignment of columns to banks is cell-specific, since column's length
    - Varies from cell to cell, but
    - Is fixed within a cell
  - Banks contain
    - Concatenations of the fixed-length column codes
    - Padded to the nearest fraction of a word length (8 / 16 / 32 / 64 bits).
    - We call these word-sized units ***tuplets*.**
- **Blink's bank-major layouts are a <u>hybrid</u> of row-major and column-major**



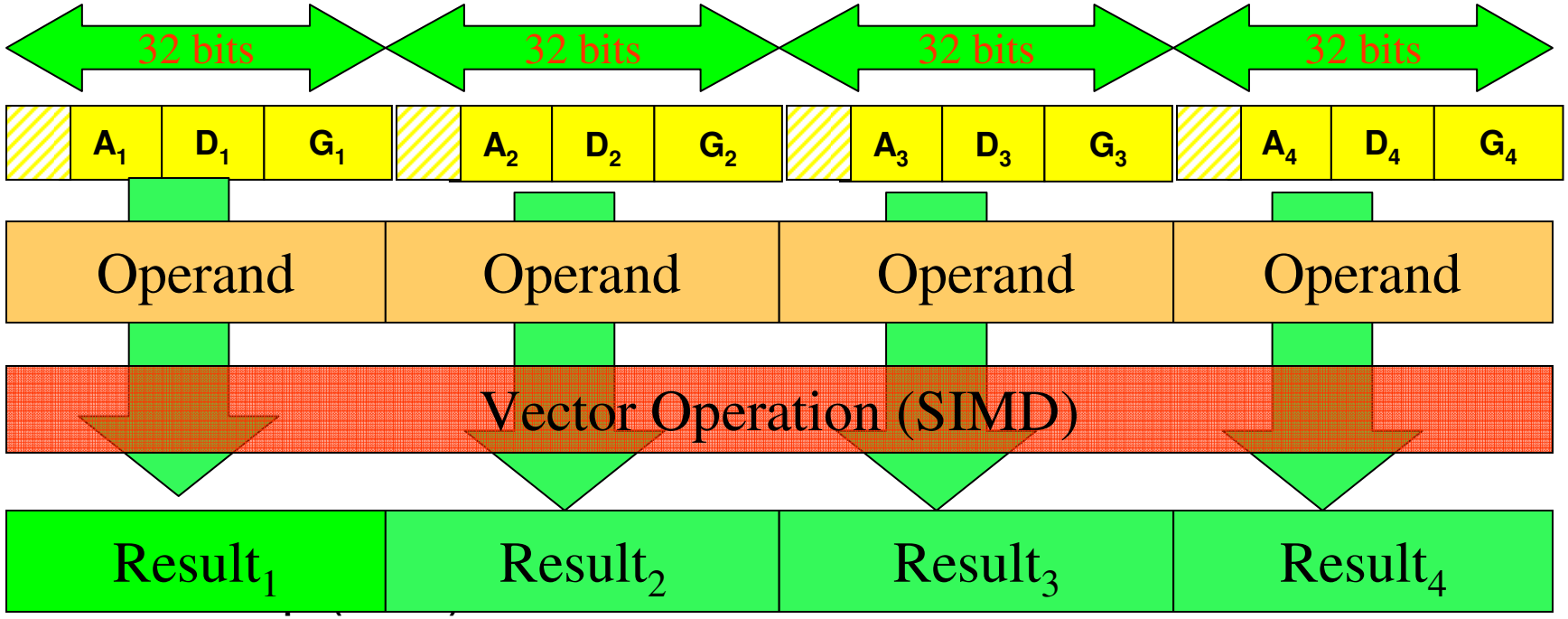
Register Stores Facilitate SIMD Parallelism

- **Access only the banks referenced in the query (like a column store):**
  - **SELECT SUM (T.G)**
  - **FROM T**
  - **WHERE T.A > 5**
  - **GROUP BY T.D**



Register Stores Facilitate SIMD Parallelism

- **Access only the banks referenced in the query (like a column store):**
  - **SELECT SUM (T.G)**
  - **FROM T**
  - **WHERE T.A > 5**
  - **GROUP BY T.D**
- **Pack multiple rows from the same bank into the 128-bit register**
- **Enables yet another layer of parallelism: SIMD** (Single-Instruction, Multiple-Data)!



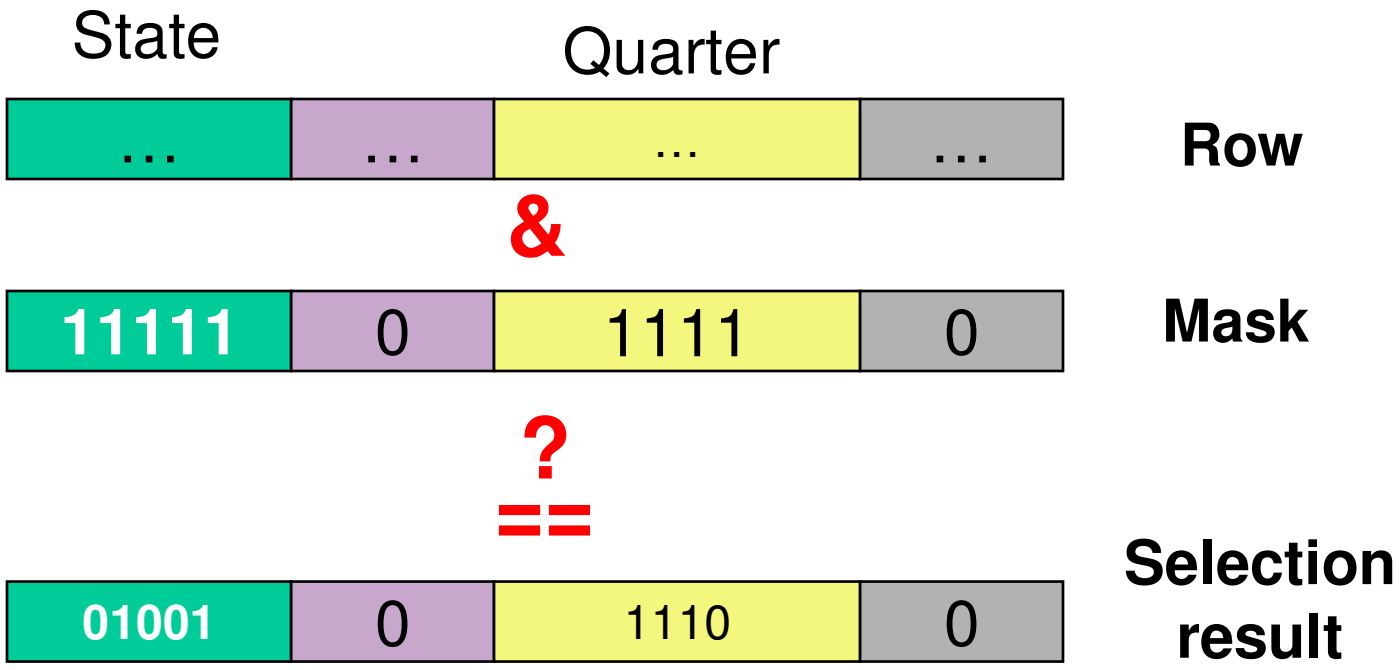
Simultaneous Evaluation of Equality Predicates

- CPU operates on 128-bit units
  - Lots of fields fit in 128 bits
- These fields are at fixed offsets
- Apply predicates to all columns simultaneously!
- Also works for range queries!

State=='CA' && Quarter == '2011Q4'

Translate Value Query to Coded Query

State==01001 && Quarter==1110



Joins

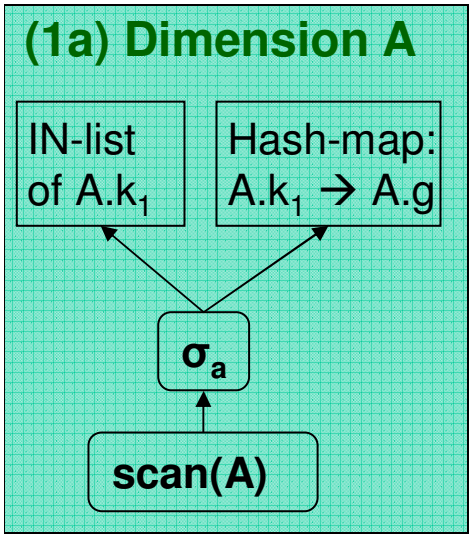
No shuffle needed:

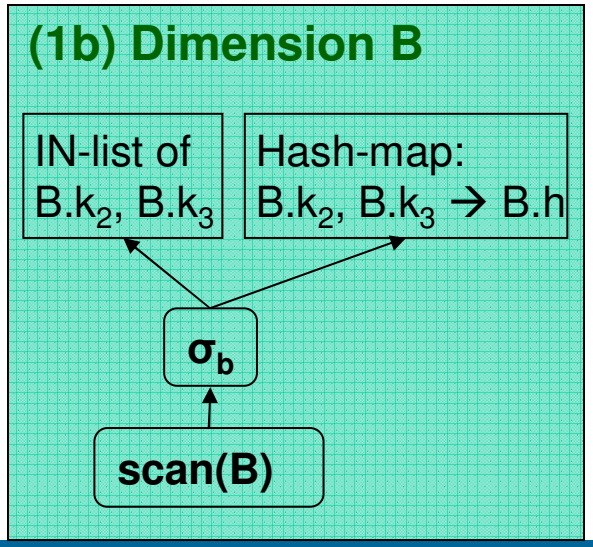
- Fact table partitioned among nodes and cores
- Dimension tables replicated

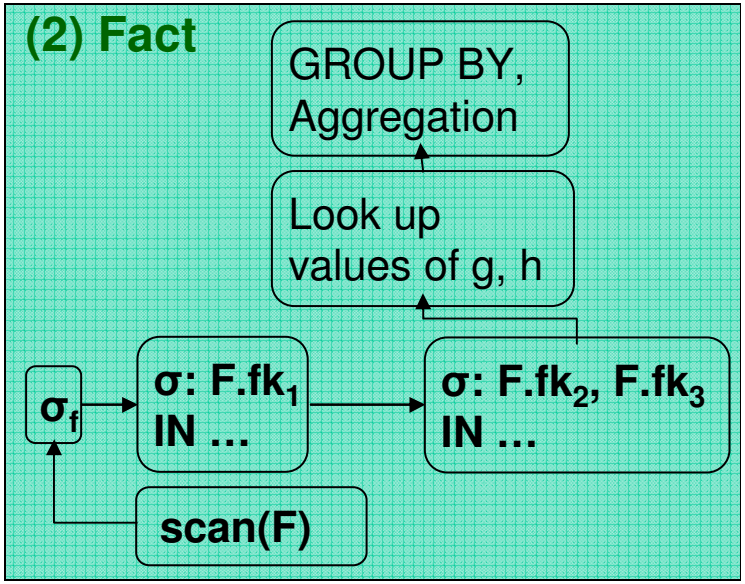
Basic idea: Re-write Join as multiple scans:

1. Over each **dimension**, to form:
   - A list of qualifying ***primary keys (PKs),*** decoded
   - A ***hash-map*** of primary key ➔ ***auxiliary columns*** (those used later in query for GROUP BY, etc.)
2. Over **fact** table:
   - First convert PKs to ***foreign keys (FKs)*** in fact table column
   - Apply as (very big) IN-list predicates (a semi-join), one per dimension
   - Look up into hash-maps to pick up other columns
   - Complete Grouping and Aggregation

Snowflakes: apply repeatedly, outside in







What About Updates?

- Blink uses **snapshot semantics** (batch updates), common in BI
- System maintains a **currentEpoch** number (monotone increasing)
  - Think of it as a batch or version number
  - Prevents seeing incomplete updates, without needing locking
  - Bumped (N++) atomically after each batch of inserts & deletes completes
- Tables have two new columns
  - **startEpoch** – epoch in which that row inserted
  - **endEpoch** – epoch in which that row deleted (initially Infinity)
- Queries are automatically appended with two predicates:
  - startEpoch < currentEpoch AND
  - endEpoch > currentEpoch
- Encoding of updated values
  - If value is in dictionary, use that encoding
  - Otherwise, store unencoded in a special cell, called the "catch-all" cell

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Blink Refereed Publications

- **VLDB 2008:** *"Main-Memory Scan Sharing for Multi-core CPUs",* Lin Qiao, Vijayshankar Raman, Frederick Reiss, Peter Haas, Guy Lohman
- **VLDB 2008:** *"Row-Wise Parallel Predicate Evaluation",* Ryan Johnson, Vijayshankar Raman, Richard Sidle, Garret Swart
- **ICDE 2008**: *"Constant-time Query Processing",* Vijayshankar Raman, Garret Swart, Lin Qiao, Frederick Reiss, Vijay Dialani, Donald Kossmann, Inderpal Narang, Richard Sidle
- **SIGMOD 2007**: *"How to barter bits for chronons: compression and bandwidth trade offs for database scans",* Allison L. Holloway, Vijayshankar Raman, Garret Swart, David J. DeWitt
- **VLDB 2006**: *"How to wring a table Dry: Entropy Compression of Relations and Querying Compressed Relations",* Vijayshankar Raman, Garret Swart

Related Work

- **SAP HANA / HYRISE**
  - claim OLTP and BI workloads
  - single copy
  - single node (HYRISE)
- **VectorWise**
  - pure column store, disk-based
  - single copy
  - single node
- **Vertica**
  - pure column store, disk-based
  - projections
  - many (specialized) kinds of compression
- **ParAccel, Exasol** – ??

Next Steps: BLink Ultra (BLU)

- What, you can't afford to put 100 TB in RAM?
  - ➔ Relax main-memory-only to disk-based
- You say your dimension table has 2000 columns?
  - ➔ Allow and exploit pure column store
- You've got HOW MANY fact tables?
- Yikes, your dimension table is HOW BIG?
  - ➔ Allow multiple partitioned tables
  - ➔ Need traditional MPP optimization for join ordering
- Yeah, synchronizing multiple copies is a pain.
  - ➔ Have Blink store the only copy
- What, you have point queries, too?
  - ➔ May need some indexes
- Um, we haven't implemented that yet…
  - ➔ Tighter coupling with traditional DBMS

Summary – Not Your Father's Database!

- Radical changes are happening in hardware
  - Large, cheap memories
  - Multi-core processors promise cheap, massive CPU parallelism
- Blink exploits these trends:
  - Special-purpose accelerator (BI only, snapshot semantics, no transactions)
  - Main-memory DBMS
  - Massive parallelism of commodity multi-core hardware (blade center format)
  - Query processing on compressed values!
  - Cache-conscious algorithms
- Blink speeds up your problem queries the most!
- Blink is an appliance product that is transparent to the user
  - Minimal set-up
  - Applications need not change
  - Tuning not needed!
  - Lower TCO

Questions?

धन्यवाद
Hindi

多謝
Traditional Chinese

ขอบคุณ
Thai

Спасибо
Russian

Gracias
Spanish

Thank You
English

شكرا
Arabic

Obrigado
Brazilian Portuguese

Danke
German

Grazie
Italian

多谢
Simplified Chinese

Merci
French

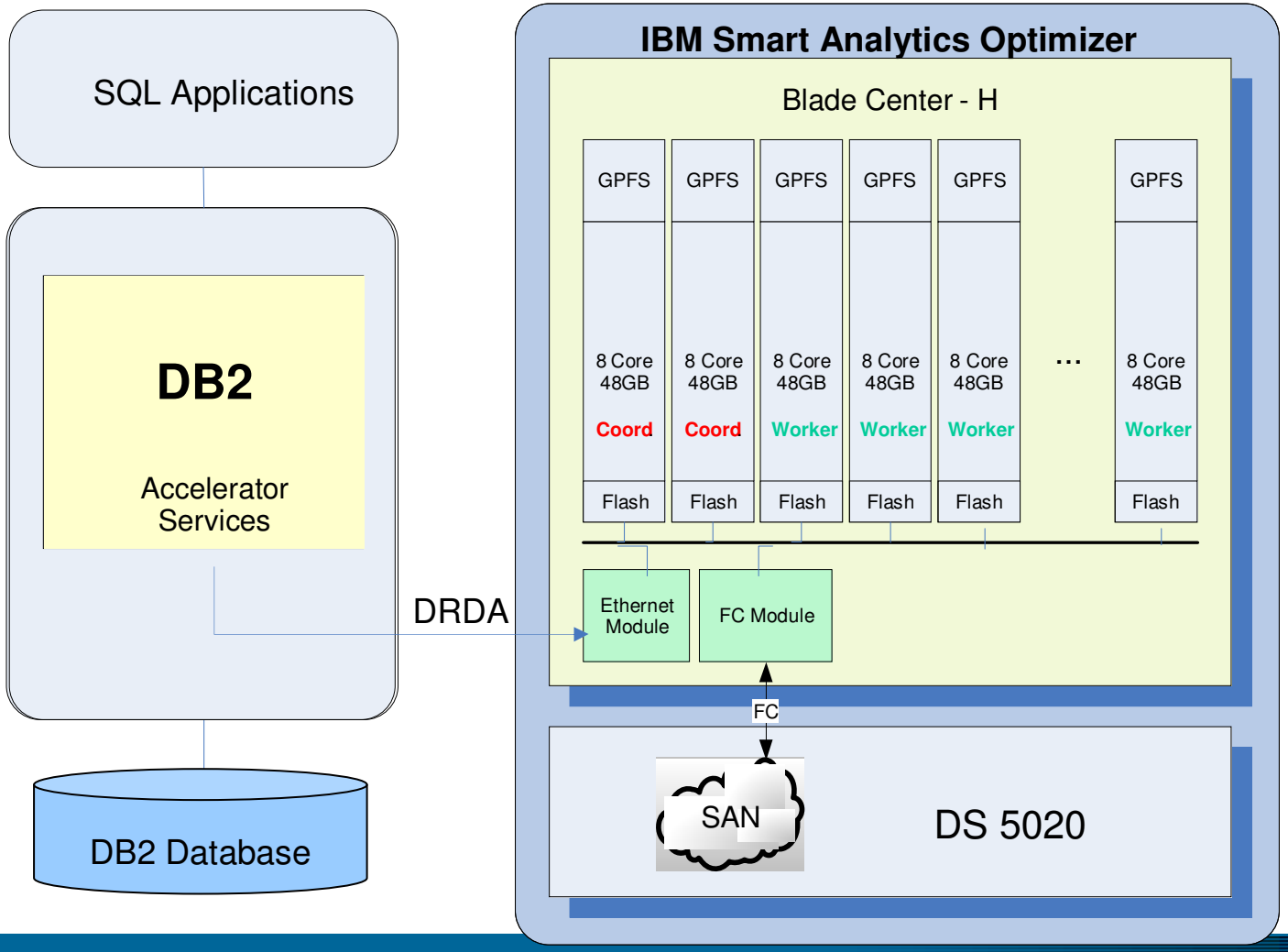
நன்றி
Tamil

ありがとうございました
Japanese

감사합니다
Korean

BACKUP SLIDES

IBM Smart Analytics Optimizer Architecture

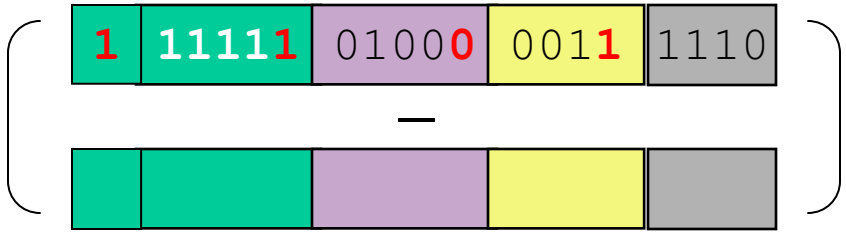


Evaluation of Range Predicates on Encoded Values

B<='CA' and C < 17 and D <= 'Q4'

Translate value query to encoded query
(exploits ***order-preserving code***)

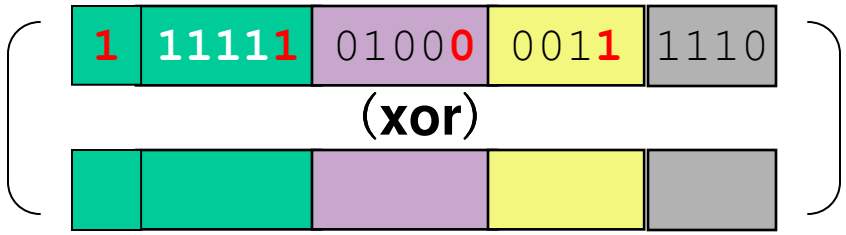
A <= 11111 and B<=01000 and C <=0011 and D<=1110



upper bounds + **borrow trappers**

Tuple

==



Tuple

General result: (UB – Tuple) xor (Tuple – LB) == UB xor LB

Blink vs. a Column Store

Aspect	Column Store	Blink
Compression	Every column padded to word boundary ➔ more padding/column ➔ worse compression	Multiple columns / word ➔ less padding overhead

Query Processing	▪ Like having an index on every column
	▪ To answer query:
	  ▪ Determine list(s) of matching records
	  ▪ Intersect these lists on RID
		▪ Can skip blocks based upon predicates
		▪ To answer query:
		  ▪ Do table scan

Updating	▪ Insert requires:
	  ▪ Separate updates to every column
	➔ Multiple random I/Os, 1/column
		▪ Insert requires:
		  ▪ Single update to each bank, 1 / bank
		➔ One I/O to one cell block

Evaluation Matches Hardware?	**Evaluation doesn't match w/ Hardware:** ▪ Index navigation involves random accesses ▪ Index navigation involves branches ▪ Predicate evaluation has to be done serially	**Evaluation matches with Hardware** ▪ Scan does sequential memory access ▪ Almost no branches ▪ Simultaneous predicate evaluation ▪ SIMD predicate evaluation