SAP HANA: Delivering A Data Platform for Enterprise Applications on Modern Hardware

HANA Platform Team
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anil goel


BECAUSE
WE CAN!!

Agenda

Who is SAP?

Why did SAP decide to build HANA?

What is SAP HANA™?

How are customers using HANA?

Where is HANA going next?

Conclusion

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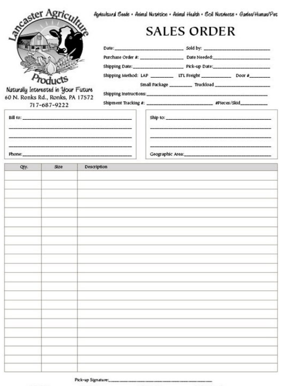
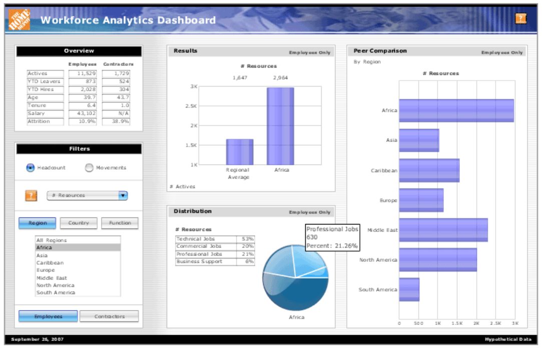
Who was SAP (before HANA)?

Sales Order Management



Financial/Mgmt Accounting

Business Intelligence



Production Planning

Talent Management


74% of the world's
transaction revenue
touches an SAP system.

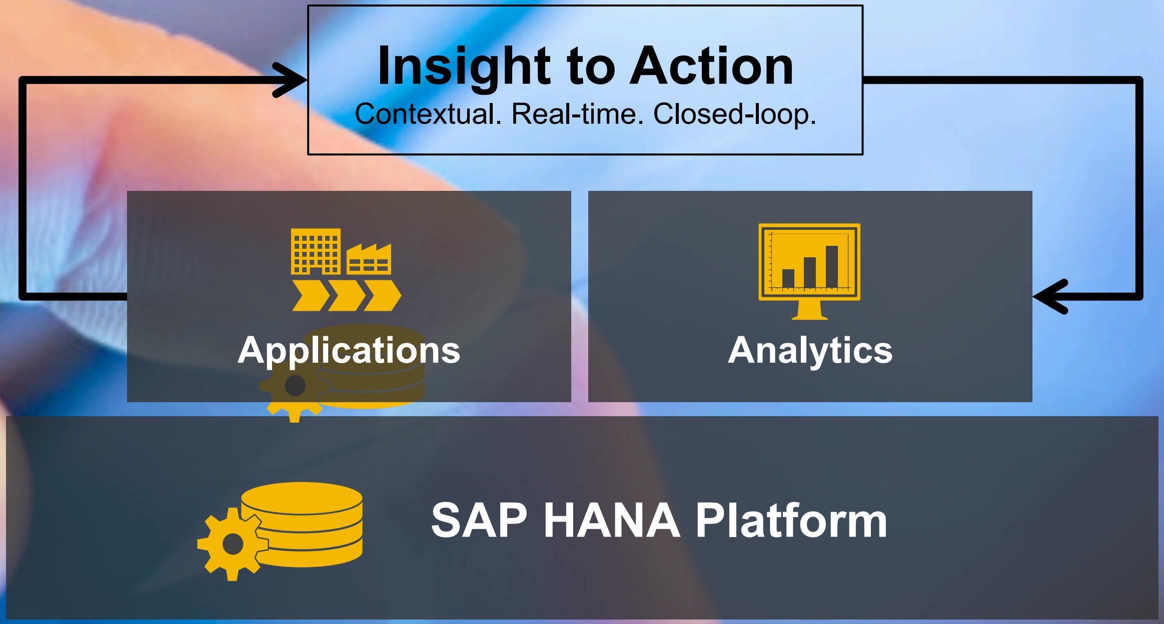
How Did the SAP Use Database Before HANA?

See "The SAP Transaction Model: Know Your Applications", SIGMOD 2008 Industrial Talk

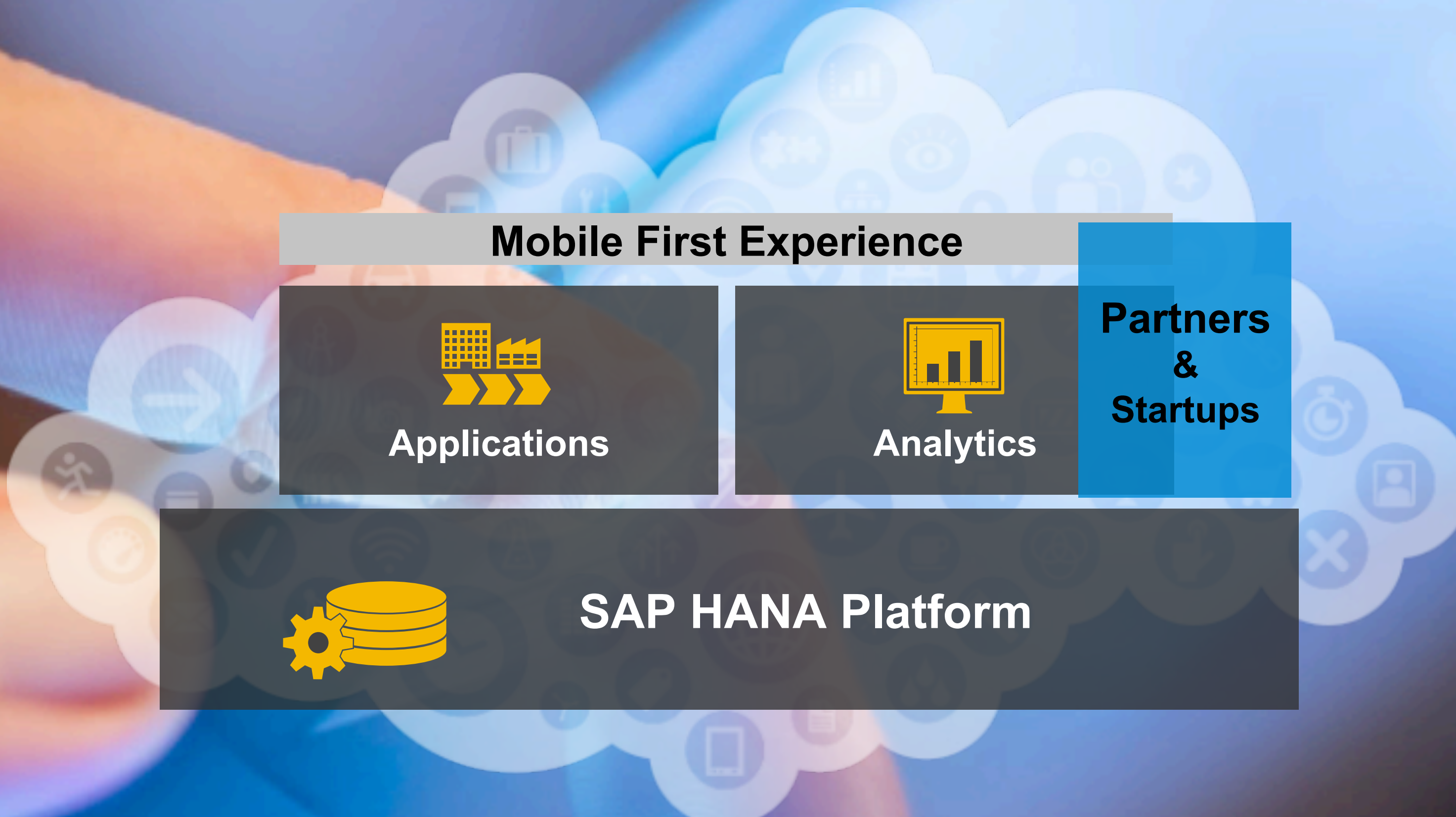
- Database was mainly a dumb store …
  - Retrieve/Store data (Open SQL, no stored procedures)
  - Transaction commit, with locks held very briefly
  - Operational utilities
- … because SAP kept the following in the application server:
  - Application logic
  - Business object-level locks
  - Queued updates
  - Data buffers
  - Indexes

With the HANA platform, computation-intensive data-centric operations are moved to the Database

Simplify Technology Stack with the SAP HANA Platform



Mobile First, Cloud, Open Platform



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DRAM Price/GB

Year	Price/GB
2013	$5.50
2010	$12.37
2005	$189
2000	$1,107
1995	$30,875
1990	$103,880
1985	$859,375
1980	$6,328,125

Source: http://www.statisticbrain.com/average-historic-price-of-ram/

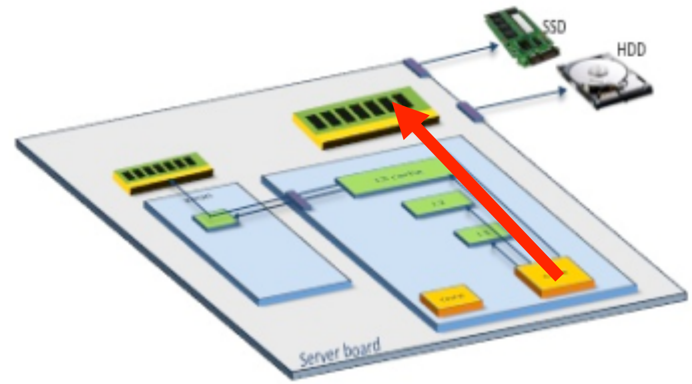
In-Memory Computing

CPU

Core	Core
L1 Cache	L1 Cache ← 1 NS
L2 Cache	L2 Cache ← 3 NS
L3 Cache	← 8 NS

Main Memory ← 80 NS

Disk ← SSD: 100K NS
HD: 10M NS

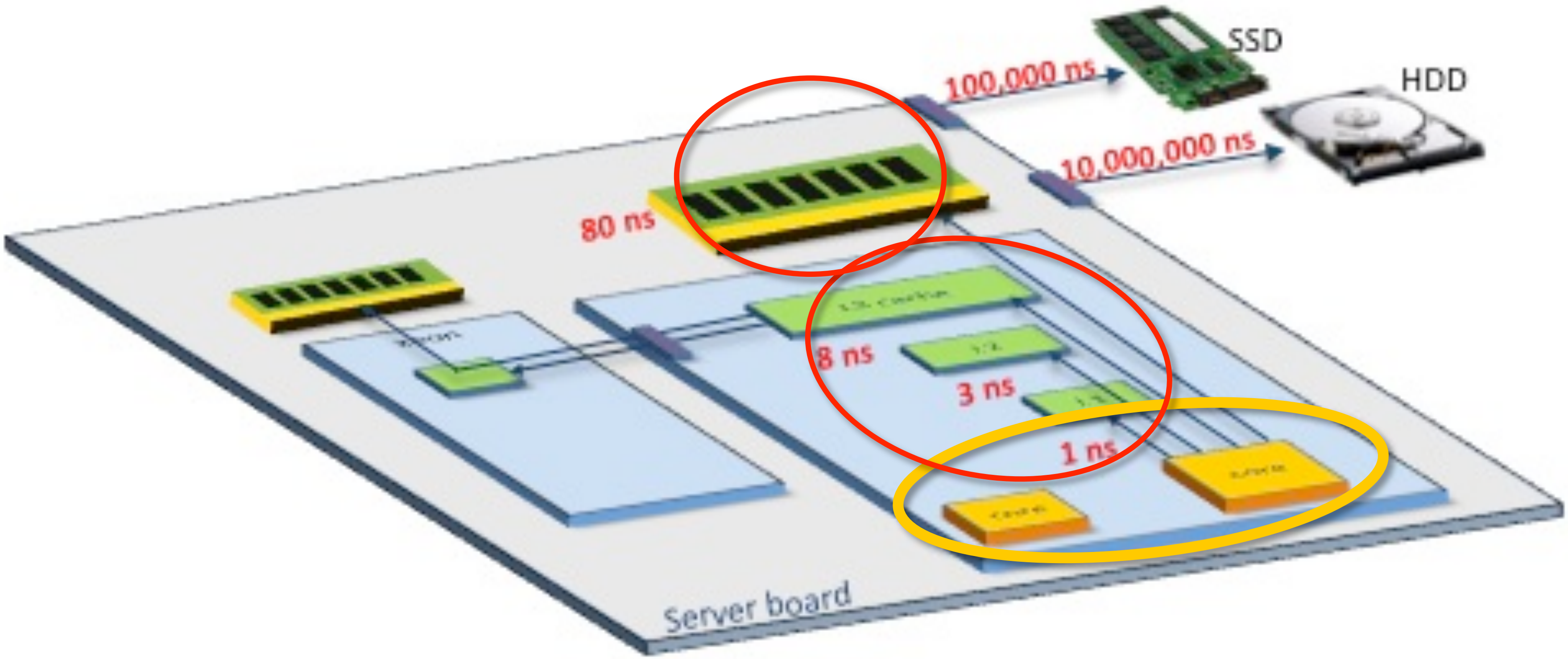


Yes, DRAM is 125,000 times faster than disk, but DRAM access is still 10-80 times slower than on-chip caches

Using Intel Ivy Bridge for approximate values.
Actual numbers depends on specific hardware.

Software Advances: Build for In-Memory Computing

Reduce Memory Access Stalls

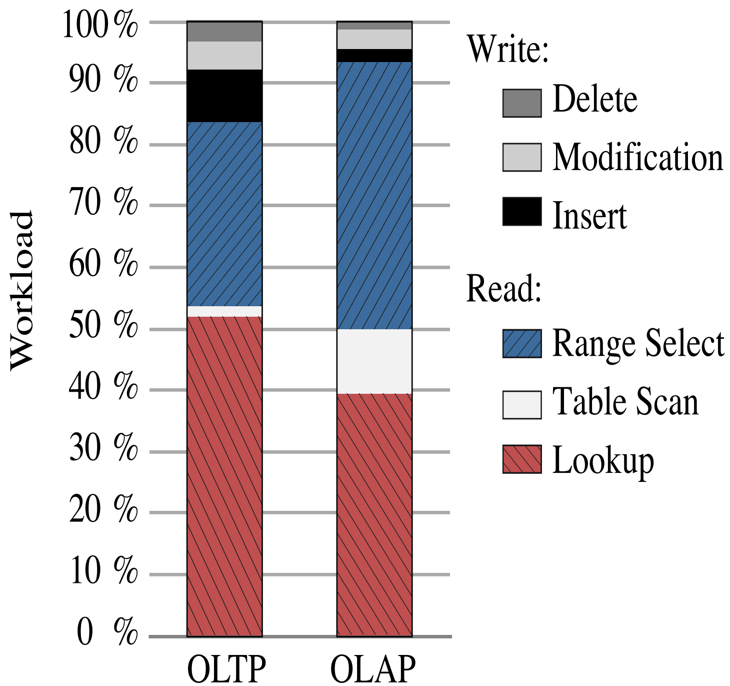


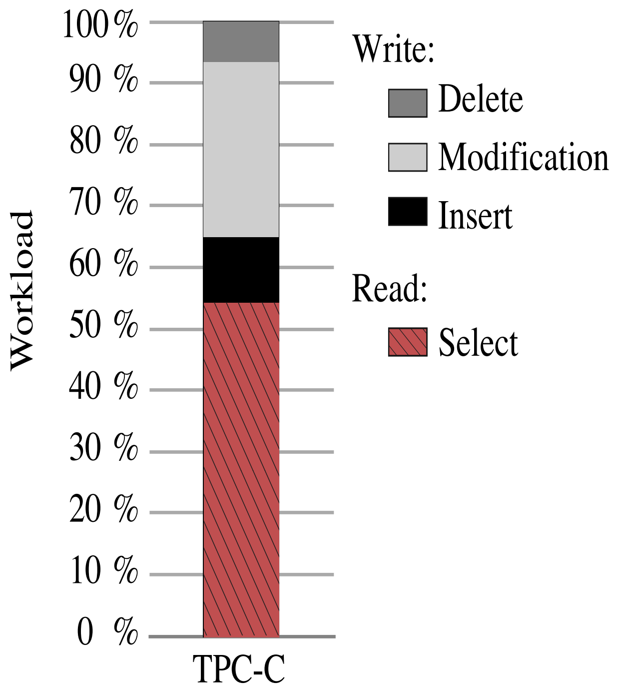
- **In-Memory Computing:** It is all data-structures (not just tables)
- **Parallelism:** Take advantage of tens, hundreds of cores
- **Data Locality:** On-chip cache awareness

Enterprise Workloads are Read Dominated

Workload in Enterprise Applications consists of:

- Mainly read queries (OLTP 83%, OLAP 94%)
- Many queries access large sets of data





 Public

Evolution of traditional business models is happening faster and faster

→ **Interactive**
→ **Real-time**
→ **Complex**

From unpredictability to 360º view of risk and reward

From generic treatments to personalized medicine

From gridlocks to smart cities of the future

From mass production to 3-D manufacturing

From transactions to 1:1 engaging relationships

The explosive pace of tech trends

Creating a ripple effect that compels us to re-think how we conduct businesses

Re-think IT

In-Memory Revolution

Driving real-time and massive simplification

Re-think Relationship

1 billion people in social networks

Rewires business and personal boundaries

Re-think Big Data Insights

Data doubling every 18 months, 80% with locations

Creates new opportunities and risks for value creation

Re-think Customer Experience

Personalization Squared

What if machine learning starts to anticipate your interests & desires?

Re-Think User Experience

More devices than people

Require fresh thinking designed for an “always-on” world

Leading Businesses Across Industries are Showing the Way

Transforming Business with Database & Technology

From
Mass Retail to 1:1 interaction
Experiences

From
Manufacturing to Full Services
Experiences

From
Passive Commerce Enabler to
Active Market-Maker

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One Global Database Platform Team

SAP HANA Collaborative Research

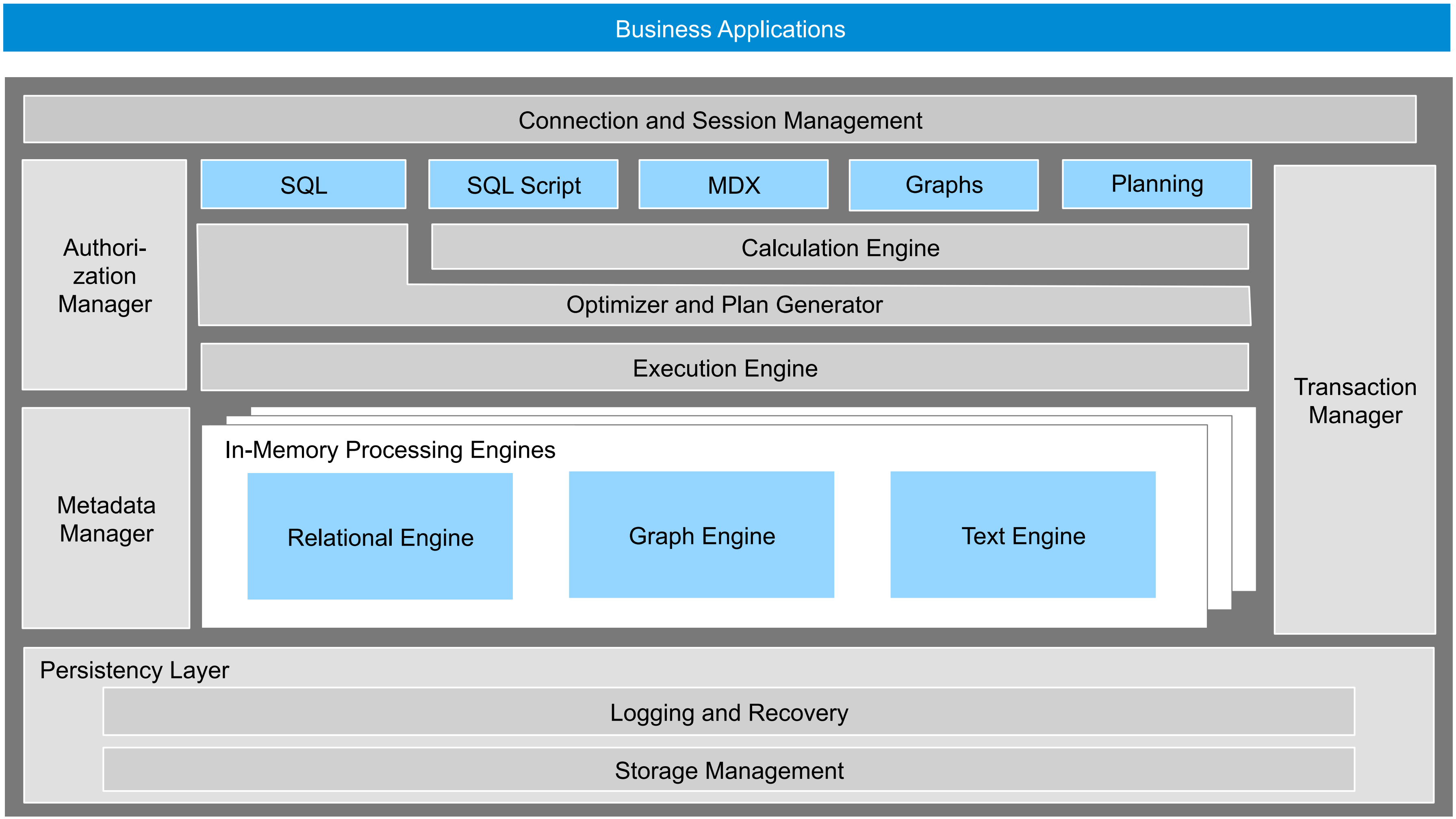
Research overview: http://scn.sap.com/docs/DOC-27051

- Publications: http://scn.sap.com/docs/DOC-26787
- Academic partners: http://scn.sap.com/docs/DOC-26786
- Students and alumni: http://scn.sap.com/docs/DOC-26824

University collaborators at PhD level include:

- TU Dresden, Prof. Wolfgang Lehner
- University of Mannheim, Prof. Guido Moerkotte
- TU München, Prof. Alfons Kemper & Prof. Thomas Neumann
- ETH Zürich, Prof. Donald Kossmann
- EPFL, Prof. Anastasia Ailamaki
- HPI, Prof. Hasso Plattner
- DHBW Mannheim, Prof. Carsten Binnig
- TU Ilmenau, Prof. Kai-Uwe Sattler
- TU Karlsruhe, Prof. Peter Sanders
- University of Heidelberg, Prof. Michael Gertz
- University of Toronto, Prof. Ryan Johnson & Nick Koudas
- Conversations with others in-progress

SAP HANA Database
Multi-Engine for Different Application Needs



SAP HANA Technology & Features
Combined in one DBMS Platform

In-memory DBMS
- Exploit SSD/disk for spilling, aging/archiving, durability/fault-tolerance

Standard RDBMS features
- SQL, stored procedures
- ACID, MVCC with snapshot isolation, logging and recovery

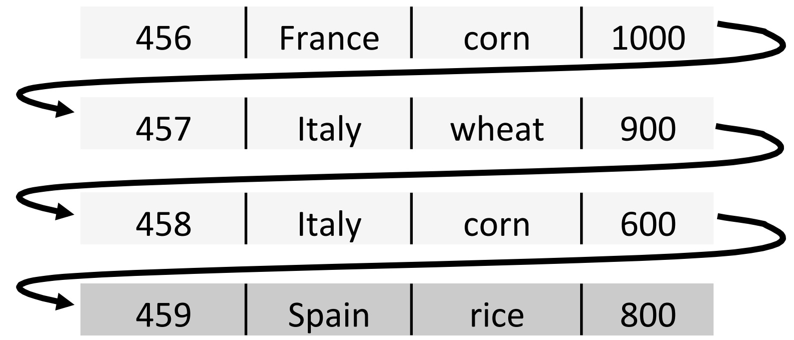
Focus on column store
- Late materialization and decompression
- Row store capability, e.g. for system catalogs

High Performance
- Efficient compression techniques
- Parallelization at multiple levels
- Scanning operations co-optimized with hardware

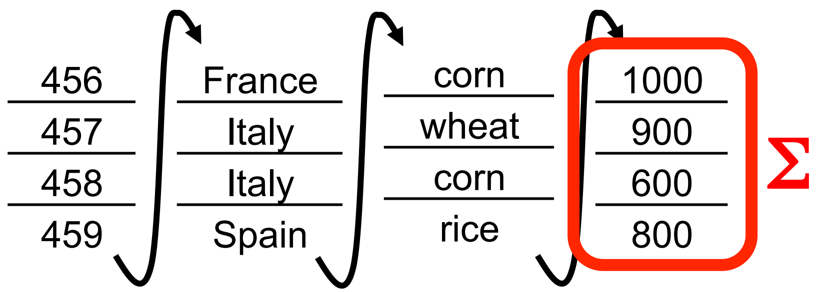
Reduced TCO and administration
- Avoid indexes, aggregates and materialized views, with exceptions (like primary key indexes)

In-Memory Computing – Data Structures

Order	Country	Product	Sales
456	France	corn	1000
457	Italy	wheat	900
458	Italy	corn	600
459	Spain	rice	800



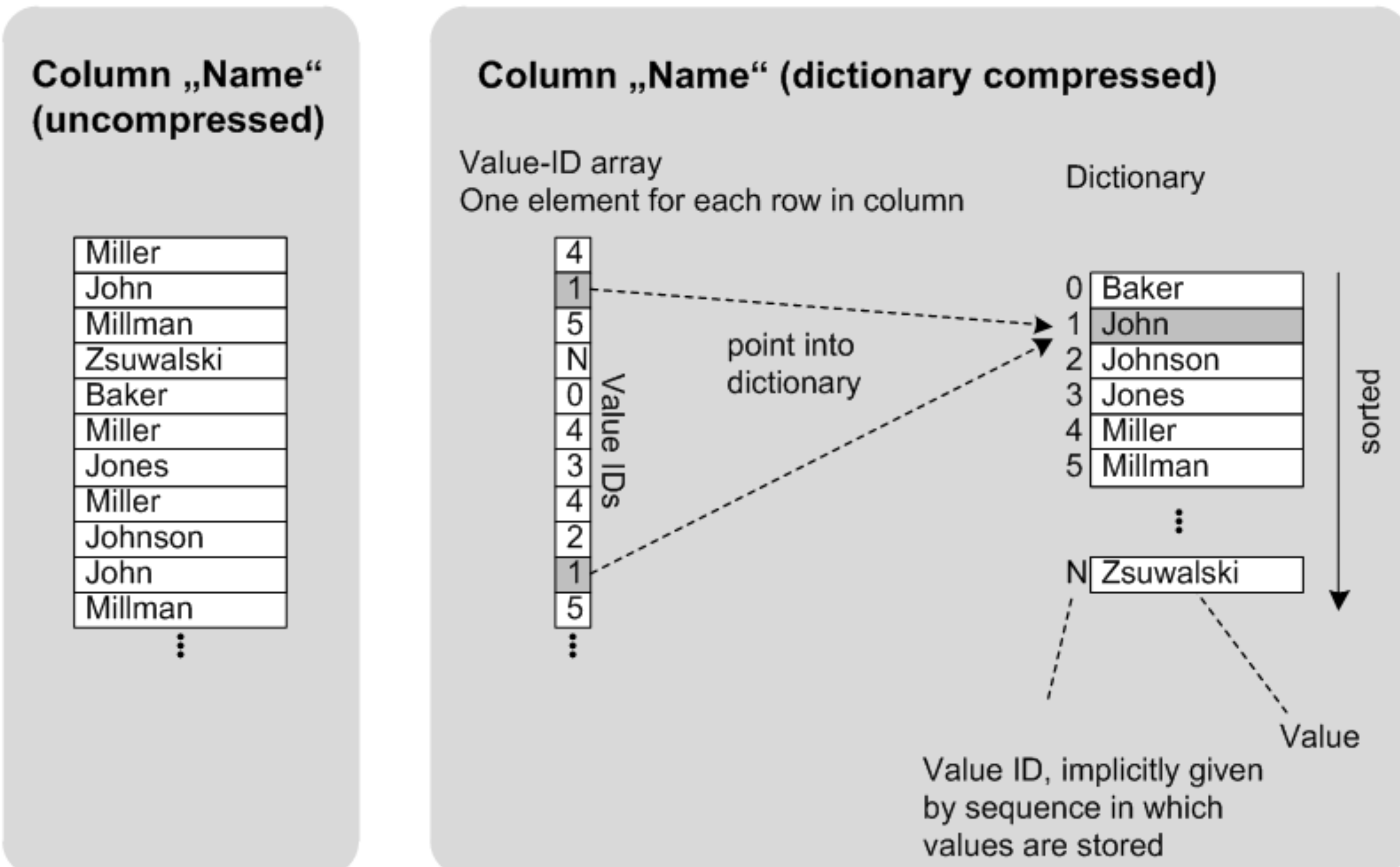
Typical Database



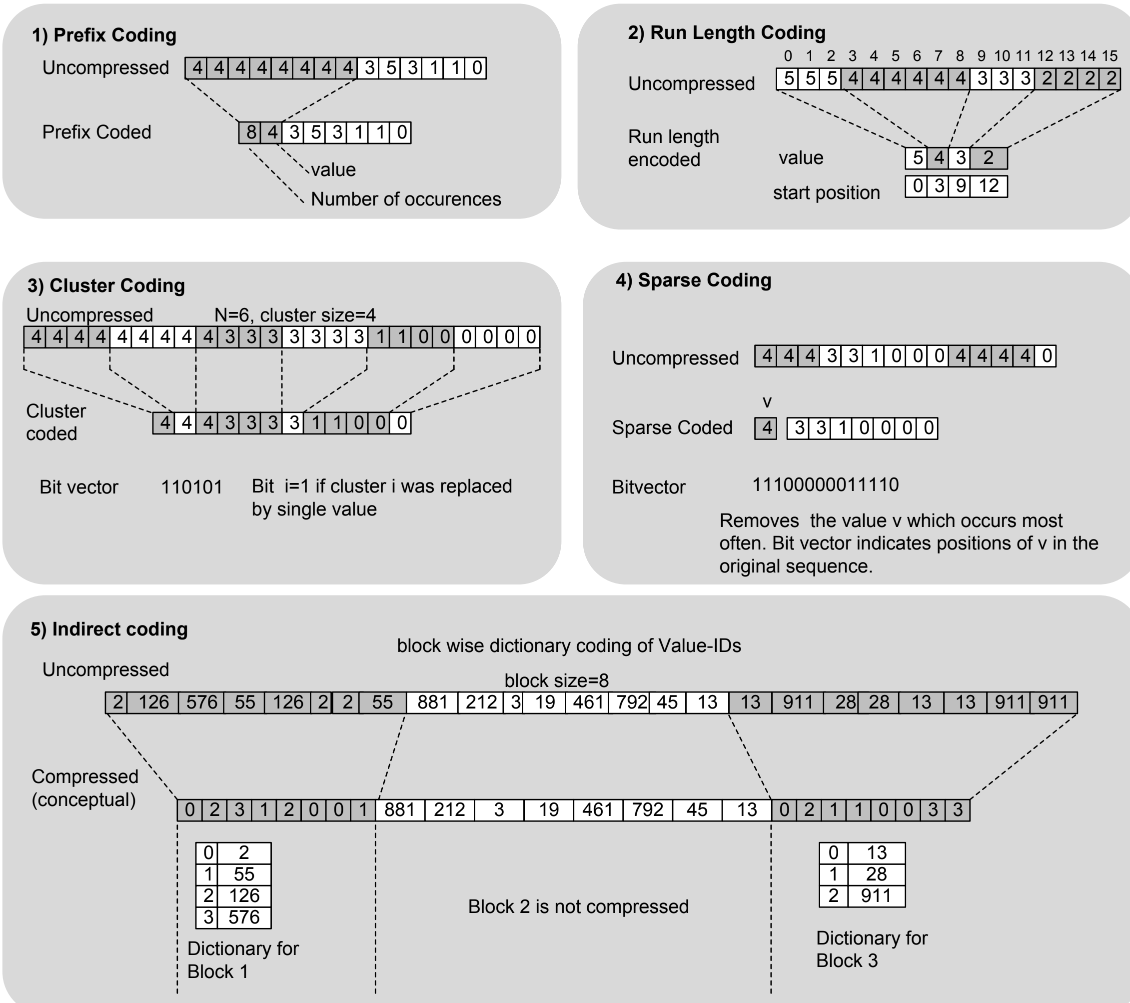
SAP HANA: column order

```
SELECT  Country, SUM(sales) FROM SalesOrders
WHERE Product = 'corn'
GROUP  BY  Country
```


SAP HANA: Dictionary Compression



Additional Compression Technologies



SAP HANA Column Store

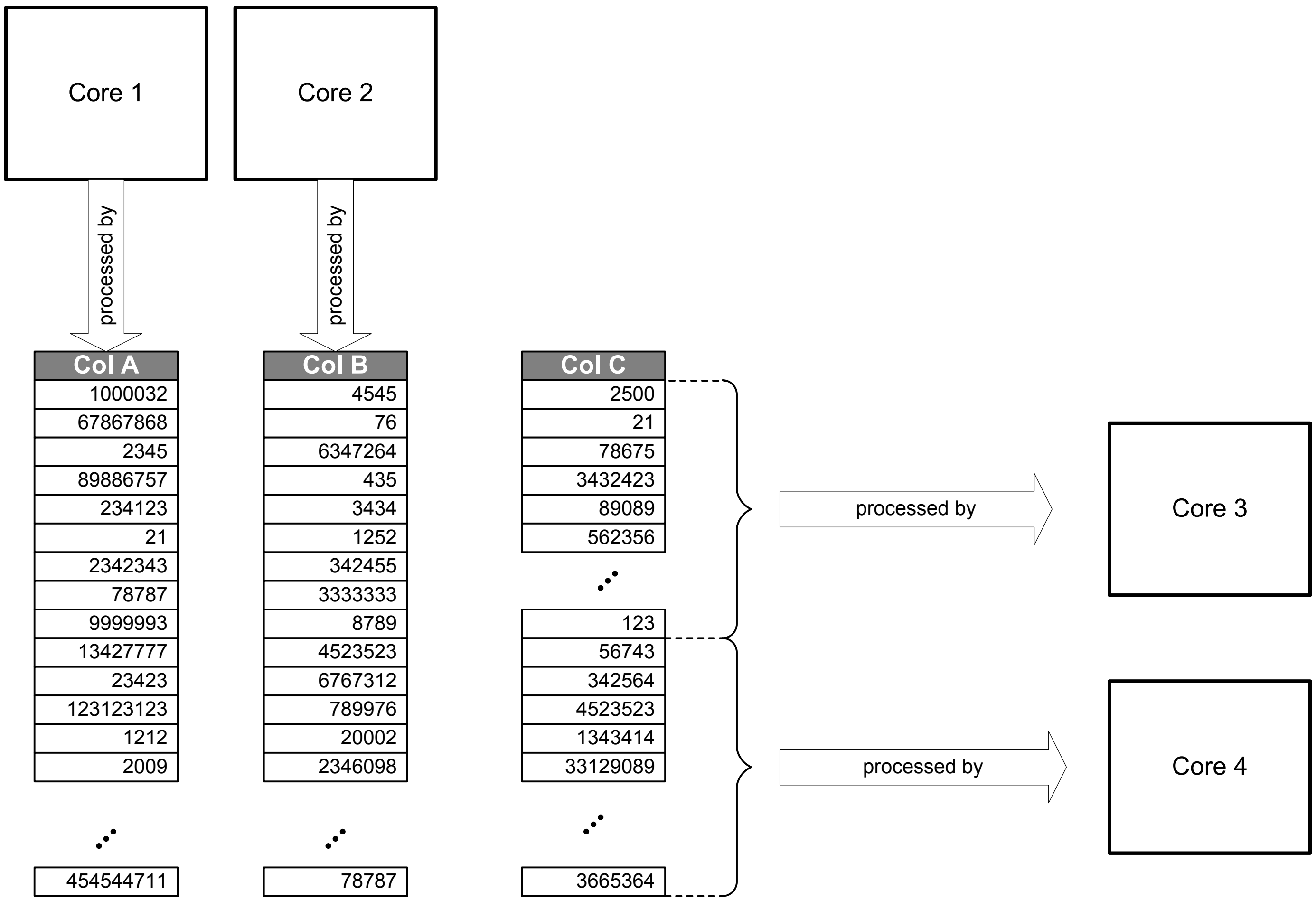
Column Main: Read-optimized store for immutable data

- High data compression
- Efficient compression methods (dictionary and run-length, cluster, prefix, etc.)
  - Dictionary values for main are sorted in same order as data
- Heuristic algorithm orders data to maximize secondary compression of columns
- Compression works well, speeding up operations on columns (~ factor 10)

Column Delta: Write-optimized store for inserts, updates and deletes

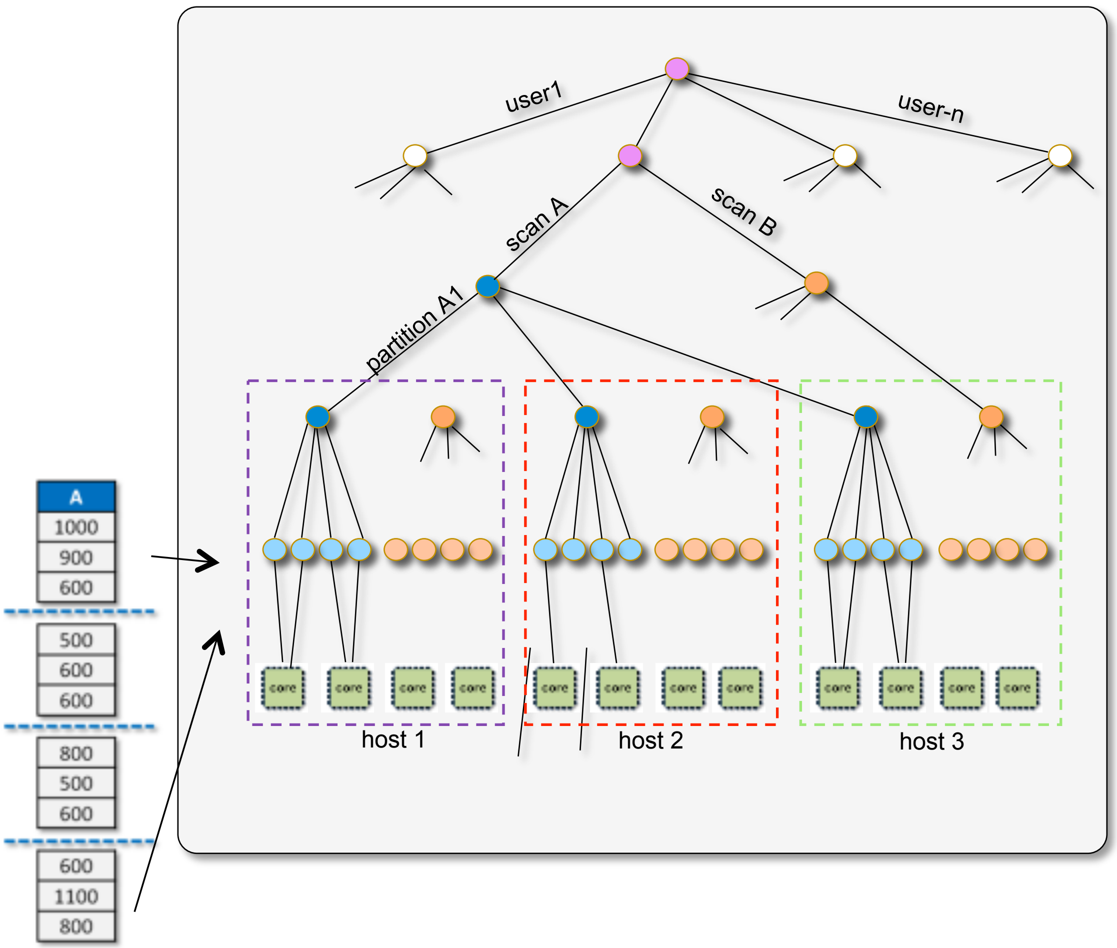
- Less compression of data
- Data is appended to delta to optimize write performance
- Unsorted dictionary on delta helps speed write performance
- Delta is merged with main periodically, or when thresholds are exceeded
  - Delta merge for a table partition is done on-line, in background
  - Enables highly efficient scan of Main again

SAP HANA: Multi-Core Parallelization



Parallelization at All Levels

- Multiple user sessions
- Concurrent operations within a query (… T1.A … T2.B…)
- Data partitioning on one or more hosts
- Horizontal segmentation, concurrent aggregation
- Multi-threading at Intel processor core level
- Vector processing



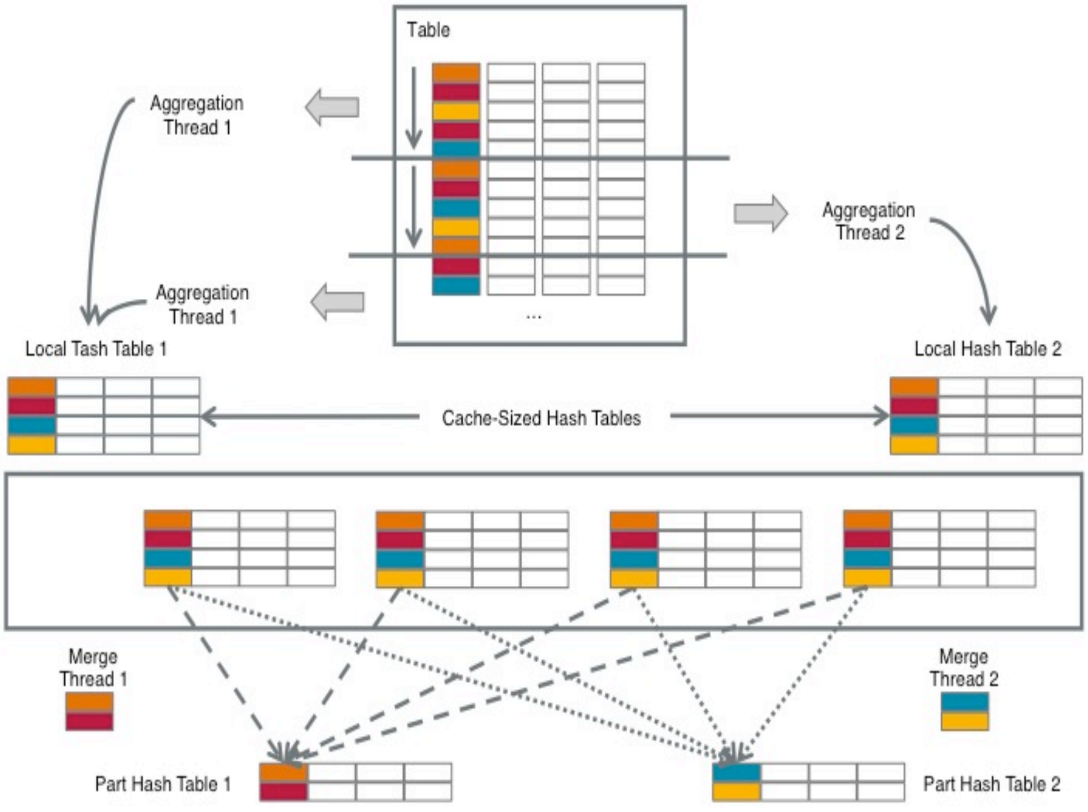
Parallel Aggregation Execution

n Aggregation Threads

- Each thread fetches a small part of the input relation.
- Aggregate part and write results into a small hash-table.
  - If the entries in a hash-table exceed a threshold, the hash-table is set aside, and aggregation in that thread continues on a new empty hash-table.

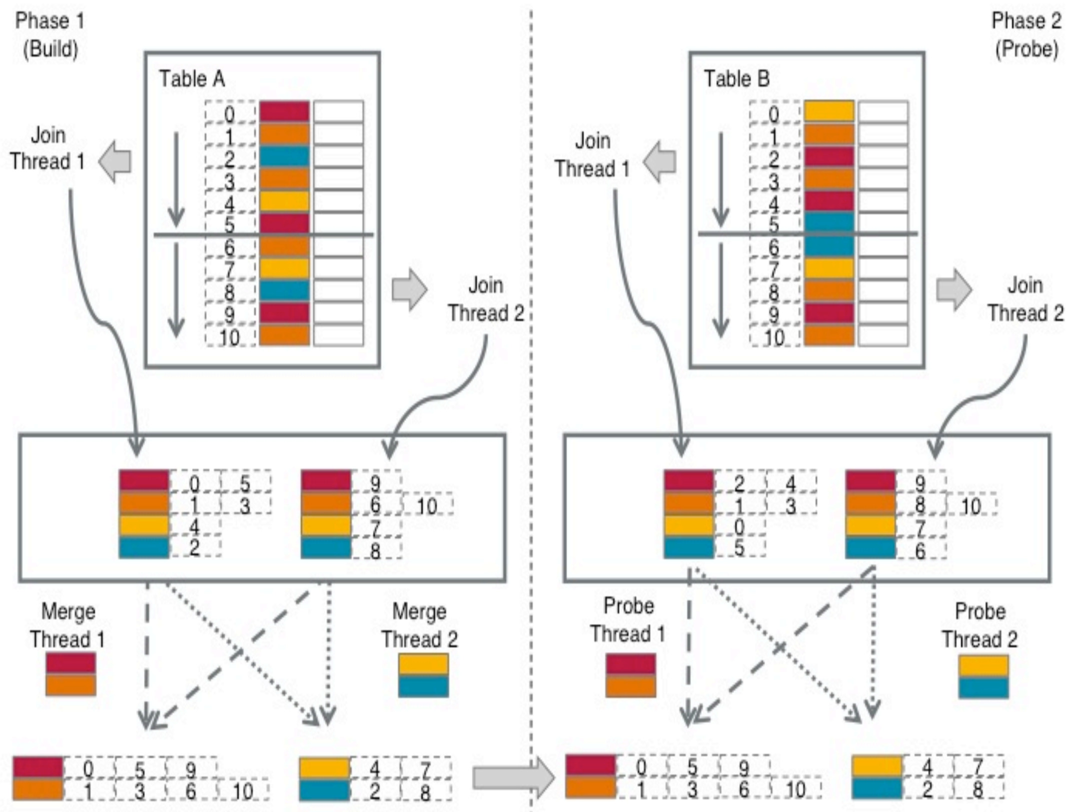
m Merge Threads

- Merge thread aggregate a specific range and write results into a private part hash-table.
- The final result is obtained by concatenating all the part results.

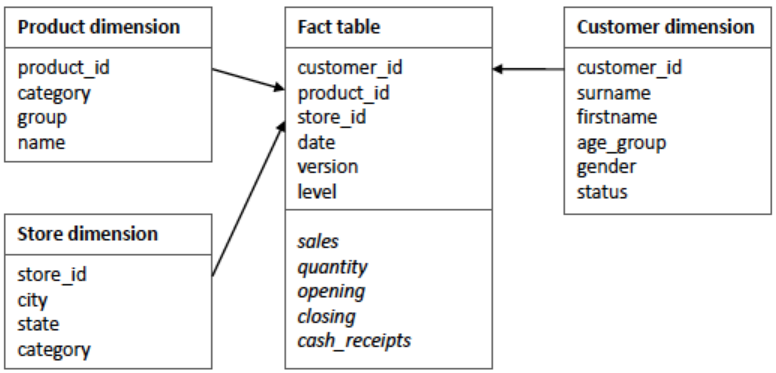


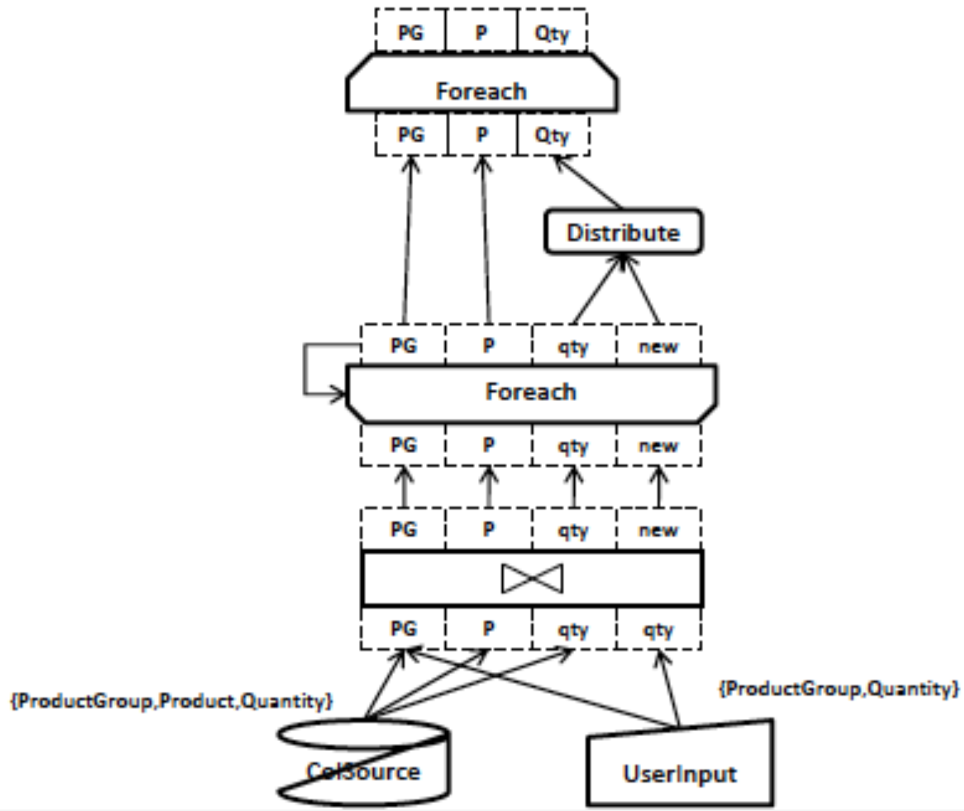
Parallel Join Execution

- Like aggregations, joins can be computed using hash-tables.
- **Build Phase**: Parallel computation of part hash-tables on the smaller table, Table A
- **Probe Phase:** Probing of the larger table, Table B, against the part hash-tables:
  - A set of hash-maps is created in parallel.
  - Local hash-maps are compared with part hash-maps.



Parallel OLAP Execution





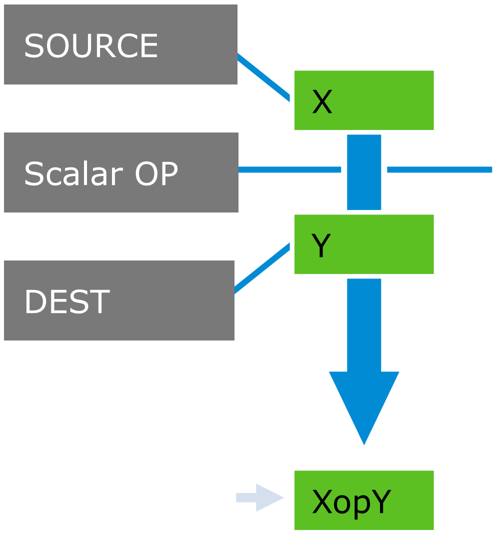
- Column processing, with late materialization and decompression
- Distribution and parallelism at many levels
  - Dimension tables may be replicated
- Generalized calculation operations

See "A Plan for OLAP", B. Jäcksch, et al, EDBT 2010

Single Instruction Multiple Data (SIMD)

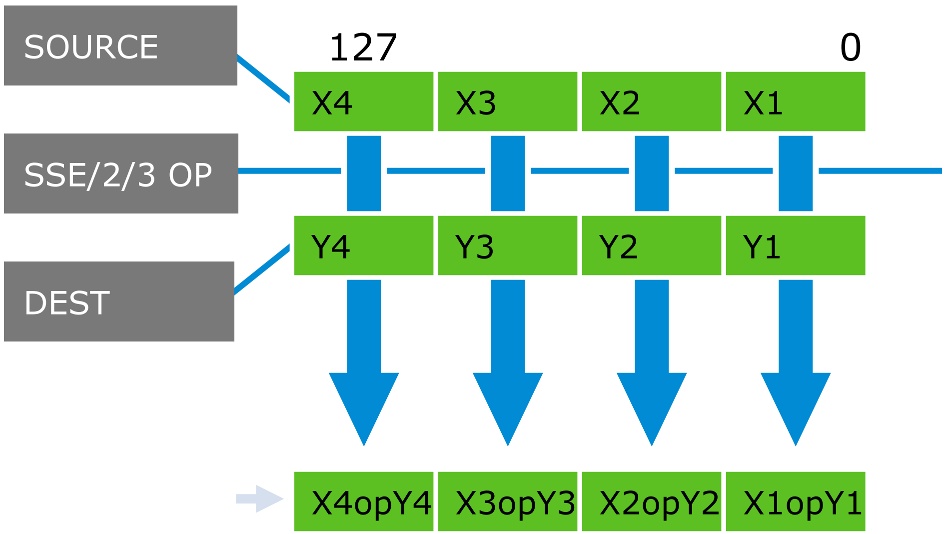
Scalar processing

- traditional mode
- one instruction produces one result



SIMD processing

- with Intel® SSE
- one instruction produces multiple results



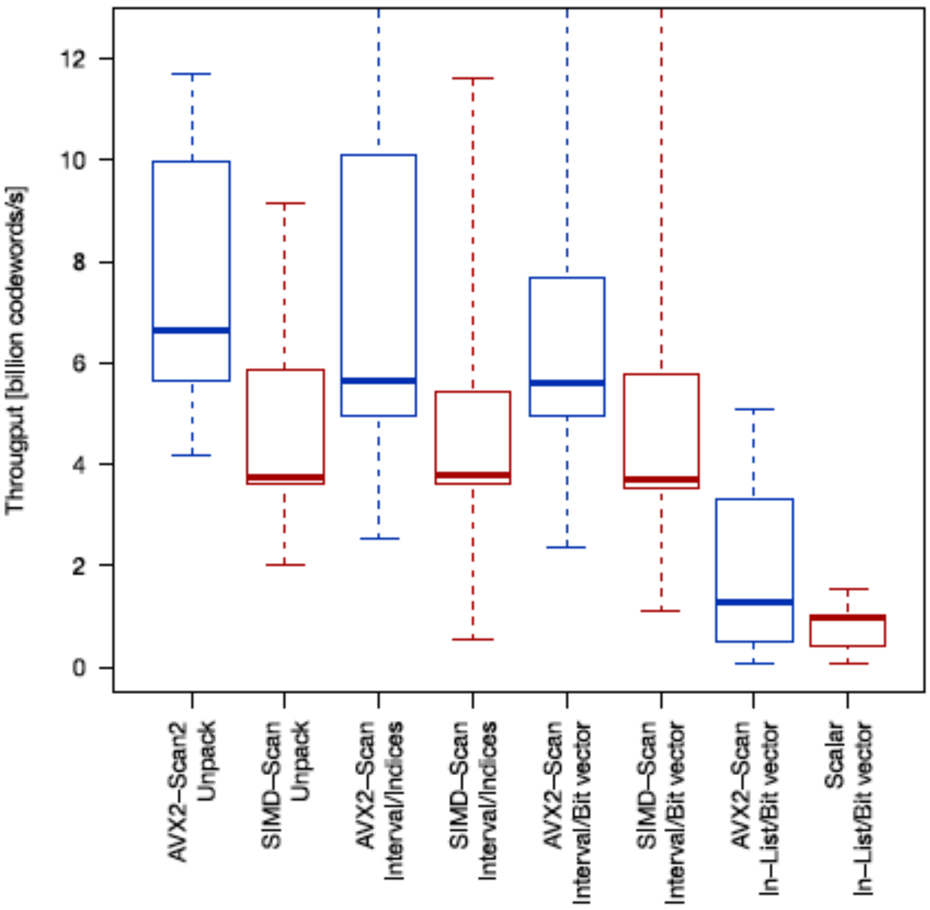
SAP HANA Use of SIMD

SIMD-Scan: Ultra Fast in-Memory Table Scan using on-Chip Vector Processing Units, VLDB 2009, by Intel, SAP and HPI

- 3.2B Codeword Scans / Second / Core
  - A “codeword” is a compressed integer value
- 12.5M Aggregates / Second / Core
- 1.5M Inserts / Second (Load)

- Use vector-based processing (SIMD)
- Leverage data locality
- Act on compressed data, not word aligned
- Cache line (64 Bytes) aligned data
- Hyper-threading

Vectorizing Database Column Scans with Complex Predicates
VLDB 2013 ADMS Workshop



- AVX2-Scan consistently 30% faster than SIMD-Scan.
- Throughputs between 4 and 10 billion codewords per second with peaks of 17 billion.

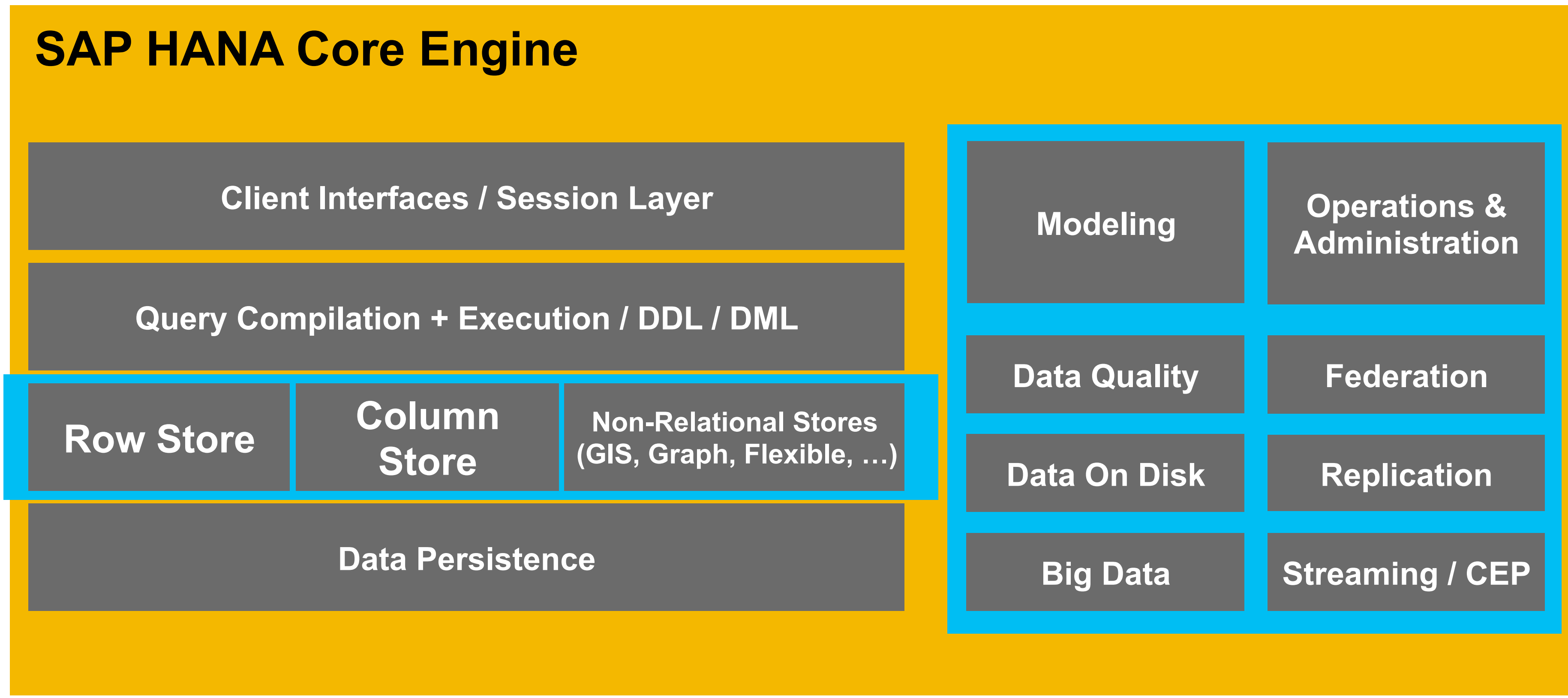
Vectorized Scan Framework

Two AVX2 instructions are key to achieving the parallelization of the Scan with in-list predicate algorithm:

- Vector-vector shift instruction: The new vector-vector shift instruction allows shifting each word of the AVX register with an independent value. We use it to convert the value into word where only the bit at the index that equals the value is set to 1.
- Gather instruction: The new gather instruction loads elements from memory based on a base address and offsets for each data element. We use it to gather the different chunks of the predicates relevant to vectorized comparison.

HANA Core Platform

ONE platform for simple and efficient data processing



Petabyte Test; see HANA Performance White Paper

The System

Single Instance of SAP HANA
100 Servers / 4,000 Cores / 100 TB RAM

The Data

1 Petabyte of Raw Data
10 Years / 1.2 Trillion rows of ECC SD Data

The Queries

Representative BI queries with varying complexity from moderate to very complex

18 Distinct Queries

- General Reporting
- Iterative Drill-Down
- Ranking
- Year-Over-Year Analysis

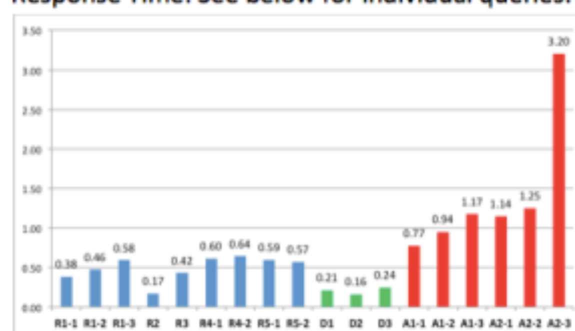
Ranging in Complexity

- Multiple Joins
- In-Lists
- Sub Queries
- Correlated Sub Queries
- Union All

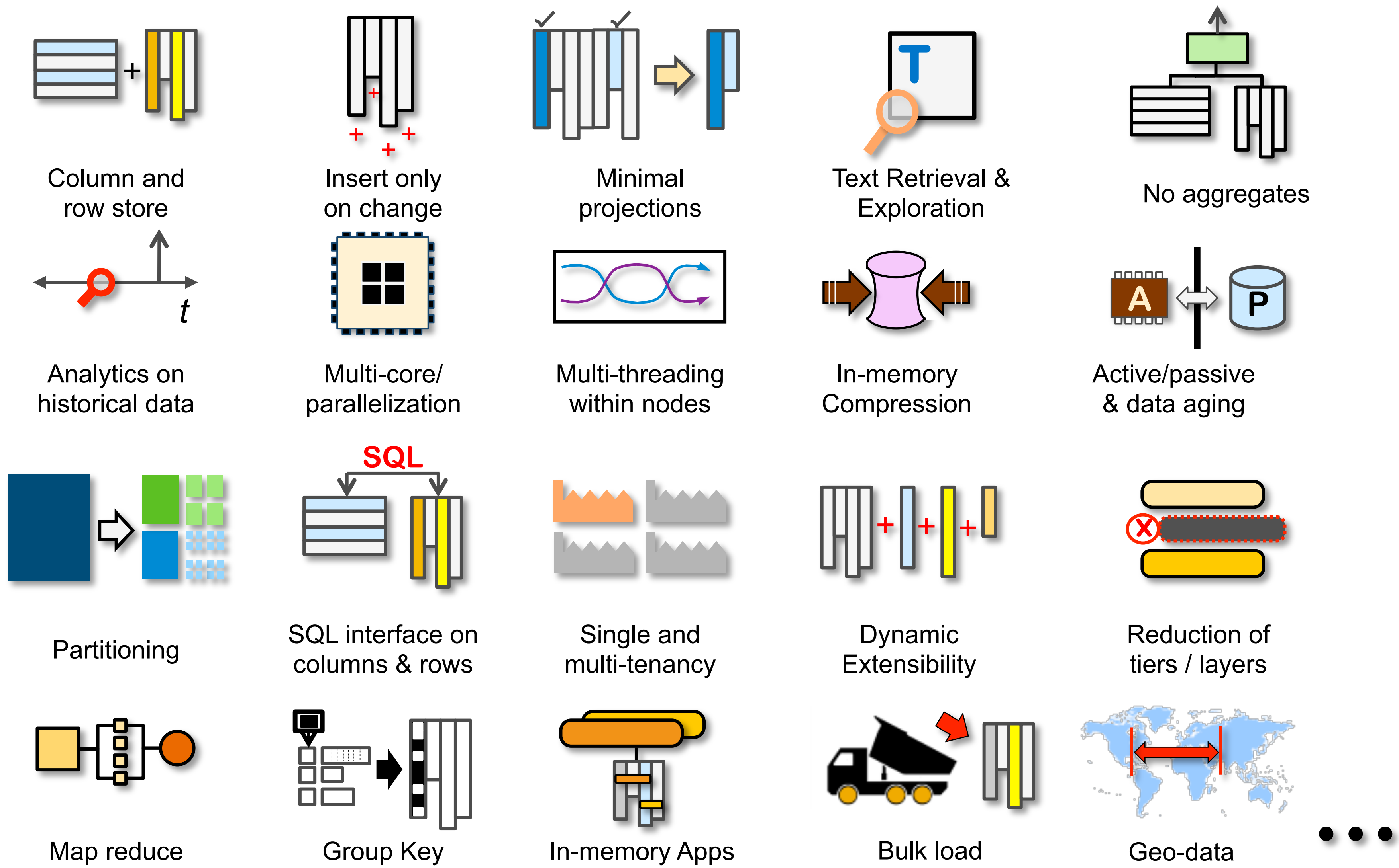
All queries were parallelized across all nodes in the cluster.

The Results

Throughput: 60 Streams running 112,602 queries per hour, representing > 5,000 concurrent BI users
Response Time: See below for individual queries.



SAP HANA Technology Innovation



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SAP Runs SAP
Building the Foundations

Mobile

P&L to Go
Management Contract Cockpit
Board Transparency App
Customer Briefing App
Goods Receipts
Receivables Manager & Financial Fact Sheet
Customer Value Intelligence
Invoice Receipts

Cloud for People
fully integrated with on-premise HCM

Cloud for Customer
fully integrated with on-premise CRM

Ariba
fully integrated with on-premise ERP

Travel on Demand
fully integrated with on-premise ERP

BW on HANA

4.500 + business users

- SAP's mainstream capabilities for financial management reporting representing single point of truth

CRM on HANA

15.000 + business users

- Big Bang Implementation – All Users, All Geographies

ERP on HANA

65.000 + business users

- Mission critical ERP system - All users, All geographies

Powered by **SAP HANA**

Customer Study: Dunning Run

Dunning run determines all open and due invoices

- Analyzes Days Sales Outstanding and history and determines action

Running SAP customer's queries on 250M records

- Before HANA: 20 min
- After HANA: 1.5 sec

Speed-up from factors including:

- In-memory column store
- Parallel stored procedures

High Performance Application: Customer Engagement Intelligence

*"We saw an opportunity with **SAP Audience Discovery & Targeting** to influence our customers' buying behavior and reduce product return rates. We sell over 1 million products to 8 million customers and estimate that **decreasing our return rate by only 1% can lead to 7-digit Euro savings** on the bottom line. SAP Audience Discovery & Targeting enables our marketing teams to **uncover hidden trends driving product returns** across different customer groups and build **high precision marketing campaigns** to target these groups and influence their return behavior."*

--Michael Künzl, VP IT Systems, Home Shopping Europe (HSE24)

Moving Complex Application Logic Close to the Data

Application logic deals with unit/measure pairs

- Calculation engine handles selection and aggregation for heterogeneous units

Data-driven conversion during query execution enables “what if” simulations

- Quantity unit conversion for stock reports, logistics, etc.
- Planning with disaggregation

Product Group	Product	Price	Quantity	Amount
Beverages	Cola	1.50 € / bottle	5 bottles	7.50 €
	Milk	3.00 $ / quart	2 quarts	6.00 $
	Bev Total	X	12.9 liters	11.88 €
Vegetables	Onions	1.00 € / kg	3 kg	3.00 €
	Tomatoes	2.00 € / kg	5 kg	10.00 €
	Veg Total	X	7 kg	13.00 €
Total		X	*	24.88 €

Top Ten Sales & Opportunity Planning (S&OP) Value Drivers Enabled by SAP HANA

1. Unlimited Simulation: What-if changes by anyone, anytime, on the full detailed demand-supply-finance model!
2. Scenario Comparison: Compare and promote scenario plans without compromising speed and model size.
3. Instant Financial Plan Impact: Change your plans and immediately see the effect on costs and gross and net profit across the entire business.
4. Real-time Alerts: No more waiting for the alert to show up, it's already there.
5. Real-time Customizable Analytics: See the impact of changes as you click refresh in state-of-art analytics!
6. Real-time Constrained Planning: Change demand and see the impact based on supply constraints – without having to get a cup of coffee.
7. Load in the Details: Bring in detailed data from Advanced Planning and Optimization (APO) and any other systems without pre-aggregating to simplify data integration among other things.
8. Calculate at the Detailed Levels: Get accurate results by computing financial and supply calculations at low levels. Even seemingly simple calculations like revenue will dramatically improve.
9. Drill Down, all the Way Down: Work at the aggregate level (e.g., by Family) and easily drill down to specific areas within the same view in Excel or analytics (and change the detailed mix).
10. Drive Execution: We keep and compute details by product, resource, customer, component, etc. So the data is ready for use in APO, other planning systems and your ERP—to drive even more value!

See S&OP Blog for more information.

1 Simplify the Core Business Processes
To Uncover More Value

SIMPLIFIED FINANCIALS

Improved federal tax calculation

Improved federal tax calculations (PIS / Cofins) and adhering to Brazilian government's legal requirements within the stated deadline

Petróleo Brasileiro S.A

SIMPLIFIED MANUFACTURING

16x improvements results in multi-million dollar savings

Multi-million savings through 16x improvement in delivery of critical material list for manufacturing by implementing BW on HANA

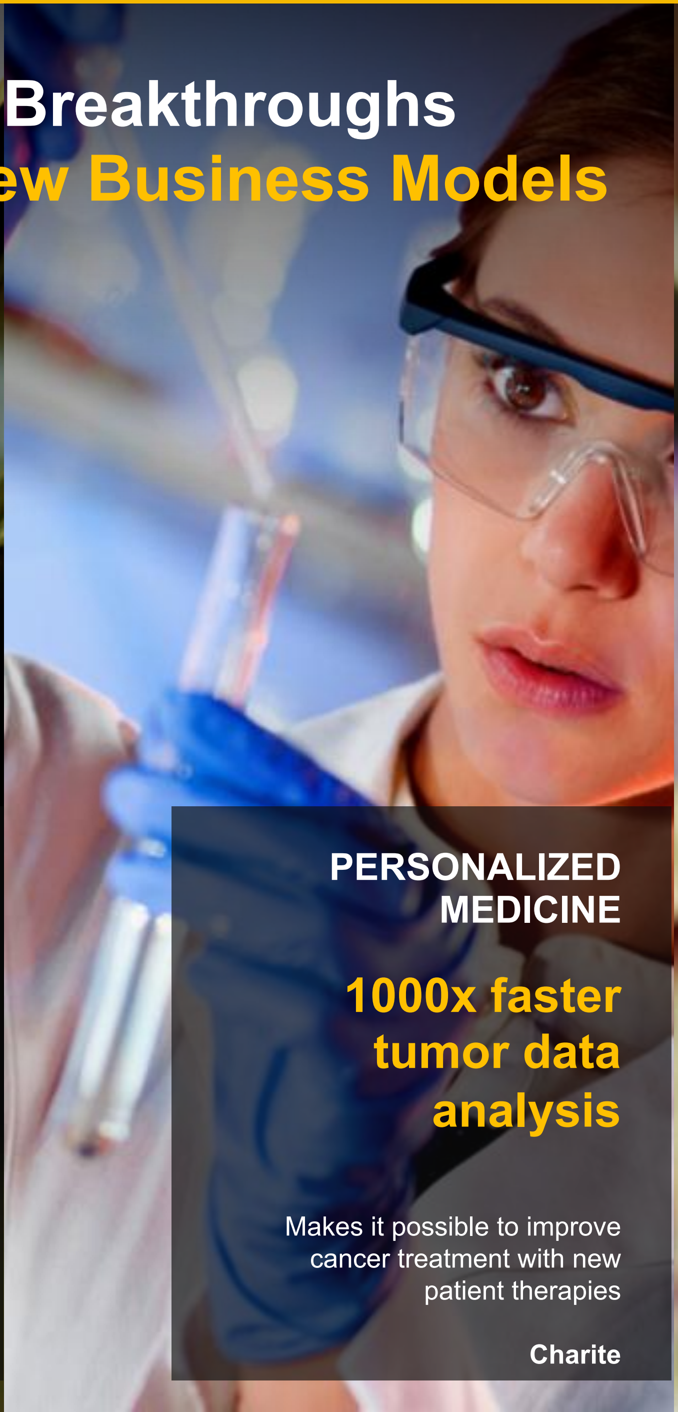
Large Auto Manufacturer

SIMPLIFIED INVENTORY

0.5% increase in monthly revenue

0.5% increase in monthly revenue through improving the fill-rate of outstanding sales orders by enabling ad-hoc inventory allocation

Under Armour


2 Foster More Breakthroughs To Enable New Business Models

CONNECTED CAR

3% customer fuel and cost reduction

Made possible through predictive maintenance based on sensor data

Pirelli

PERSONALIZED MEDICINE

1000x faster tumor data analysis

Makes it possible to improve cancer treatment with new patient therapies

Charite

IN-MOMENT PROMOTION

Real-time promotion led up to 0.25% possible margin improvement

On slow and non-moving products

Liverpool

3 Create More Experiences

To Share The Fruits Of Innovation With Everyone

TRANSFORM USER EXPERIENCE

Transform user experiences of ERP to extend its value to everyone in enterprise

190 SAP Fiori apps on HANA

TRANSFORM DEVELOPER EXPERIENCE

Sales Pipeline & Commission App for 5000 employees, reduce codes by 97%

SAP River used by NetApp

TRANSFORM SPORTS FAN EXPERIENCE

Enrich fan experiences, improve player performance, and maximizes digital ad revenue

Hoffenheim

TRANSFORM CONSUMER EXPERIENCE

Smart vending machine & Precision Marketing

TSM

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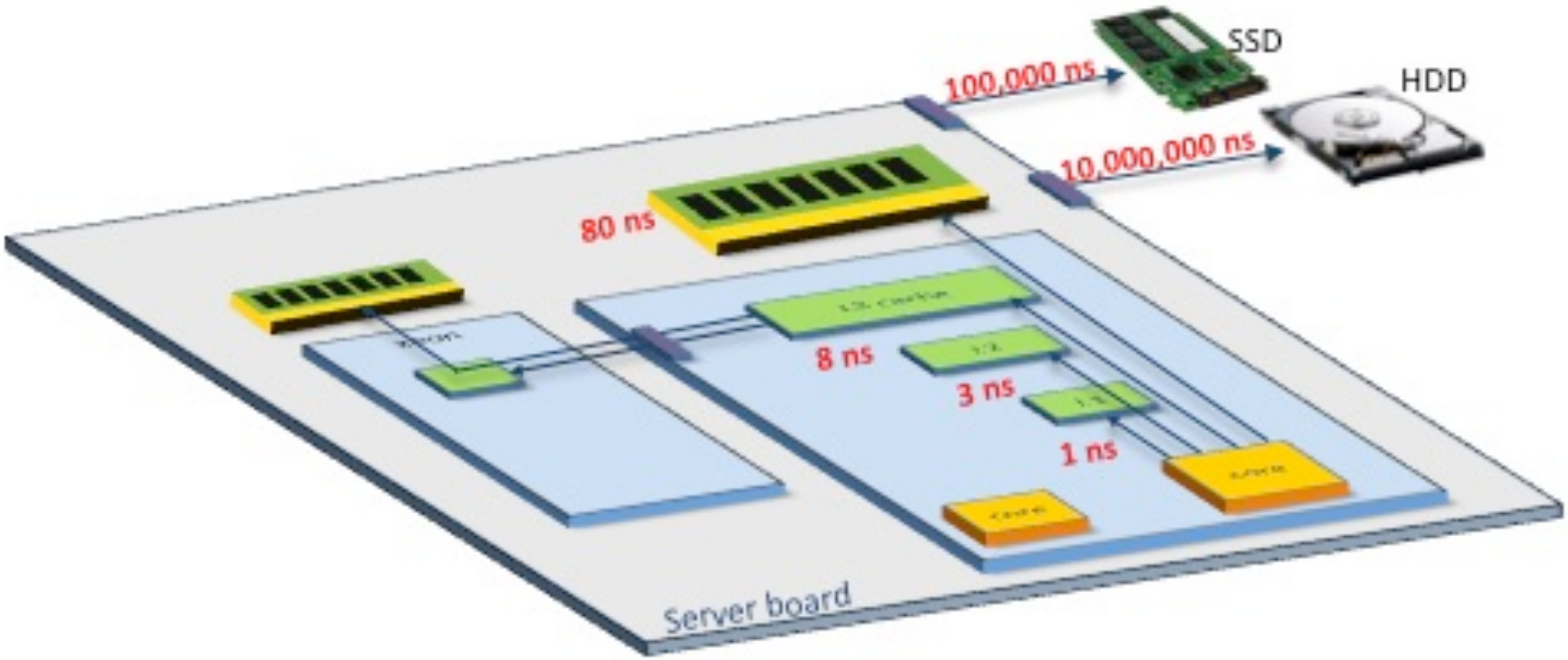
Continuing Challenges of Emerging Hardware



- Challenge 1: Parallelism: Take advantage of tens, hundreds, thousands of cores
- Challenge 2: Large memories & data locality/NUMA
  - Yes, DRAM is 125,000 times faster than disk…
  - But DRAM access is still 10-80 times slower than on-chip caches

HANA Platform On-Going Architectural Evolution

Data models

- Flexible schemas, graph functionality, geospatial, time series, historical data, Big Data, external libraries

Resource and workload management

- Memory, threads, scheduling, admission control, service level management, data aging

Application services

- XS Engine, CDS and River

Continuing performance improvements

- Hardware advances, NUMA, improved modularization and architecture

Cloud and multi-tenancy

Co-innovating the Next Big Wave in Hardware Evolution

Multi-Core and Large "Memory" Footprints

Storage Class Memories / Non-Volatile Memory

- Leverage as DRAM and/or as persistent storage

On-Board DIMMs

- Very high density, byte-addressable
- DRAM like (< 3X) latency and bandwidth; similar endurance
- Compete with disk on cost/bit by 2020

Extreme Speed Network Fabric/Interconnects

- Inter-socket NUMA gets worse while inter-host NUMA gets better
- Inter-socket and Inter-host latencies converge

Exploiting Dark Silicon for Database Hardware Acceleration

- Also exploit GPUs for specific use cases, such as regression analysis

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HANA is a new database platform built for modern hardware

HANA is designed for both existing and new enterprise applications

SAP and partners ship applications on HANA that help businesses run better

- More complex business models
- Faster answers
- Current data
- Simpler administration
- Better user experience

More Information about SAP HANA

About SAP HANA

HANA Developer Center

HANA Marketplace

HANA Academy

HANA Product and Solutions Center

HANA on Public Cloud

Customer Stories

Customer Reviews

Questions?

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Jobs at SAP: http://jobs.sap.com