# The End of an Architectural Era (It's time for a complete rewrite)

by

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# Who We Are

- Dan Abadi, Stavros Harizopoulos
  - H-Store implementation
- Nabil Hachem
  - TPC-C benchmarking
- Mike Stonebraker, Sam Madden, Pat Helland
  - Kibitzers

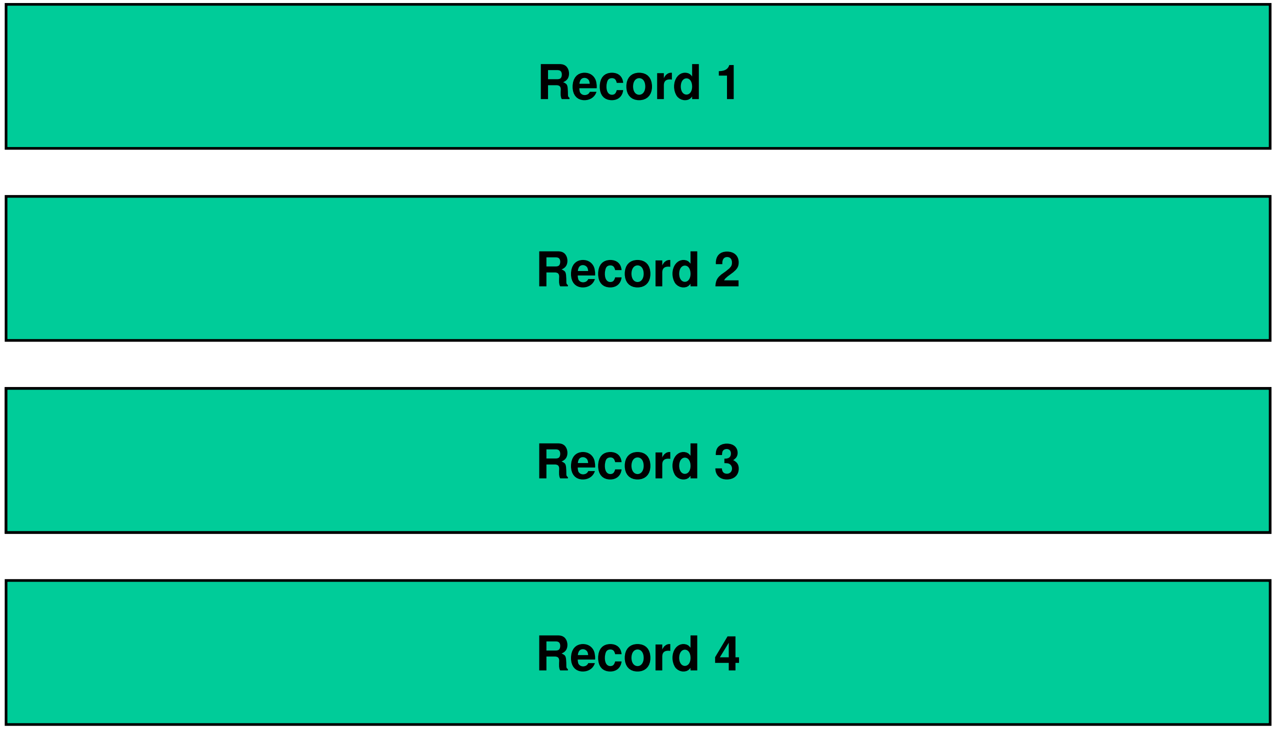
# Outline

- The current state of the world
- Why current architecture is “long in the tooth”
- How to beat it by a factor of 50 in every market I can think of
- Implications for the research community

# Current DBMS Gold Standard

- Store fields in one record contiguously on disk
- Use B-tree indexing
- Use small (e.g. 4K) disk blocks
- Align fields on byte or word boundaries
- Conventional (row-oriented) query optimizer and executor

# Terminology -- “Row Store”




**E.g. DB2, Oracle, Sybase, SQLServer, …**

# Row Stores

- Can insert and delete a record in one physical write
- Good for business data processing (the IMS market of the 1970s)
- And that was what System R and Ingres were gunning for

# Extensions to Row Stores Over the Years

- Architectural stuff (Shared nothing, shared disk)
- Object relational stuff (user-defined types and functions)
- XML stuff
- Warehouse stuff (materialized views, bit map indexes)
- ….

# At This Point, RDBMS is "long in the tooth"

- There are at least 4 (non trivial) markets where a row store can be clobbered by a specialized architecture (CIDR 07 paper)
  - Warehouses (Vertica, SybaseIQ, KX, …)
  - Text (Google, Yahoo, …)
  - Scientific data (MatLab, ASAP prototype)
  - Streaming data (StreamBase Coral8, …)

# At This Point, RDBMS is "long in the tooth"

- Leaving RDBMS with only the OLTP market
- But they are no good at that either!!!!!!

# Alternate OLTP Proposal

- First part
    - Main memory
    - Grid orientation
    - Threading
    - Redo Recovery
- Second part
    - Concurrency control
    - Undo
    - 2 phase commit

# OLTP Has Changed

- 1970's:  disk
- Now:  main memory

TPC-C is 100 Mbytes per warehouse; 1000 warehouses is a HUGE operation;

i.e. 100 Gbytes;

i.e. main memory

# OLTP Has Changed

- 1970's:  terminal operator
- Now:  unknown client over the web

**Cannot allow user stalls inside a transaction!!!!!**

**Hence, there are no user stalls or disk stalls!!!!!**

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# Result: No Multi-threading!!!

- Heaviest TPC-C Xact reads/writes 200 records
    - Less than 1 msec!!
- Run all commands to completion; single threaded
- Dramatically simplifies DBMS
    - No B-tree latch crabbing
    - No pool of file handles, buffers, threads, ..

Multiple cores can be handled by multiple logical sites per physical site

# Grid Computing

- Obviously cheaper
- Obvious wave of the forseeable future (replacing shared disk)
- Horizontally partition data
  - Shared nothing query optimizer and executor
- Add/delete sites on the fly required

**High end OLTP has to "scale out" not "scale up"**

# OLTP Has Changed

- 1970's:  disaster recovery was "tape shipping"
- Now:  7 x 24 x 365 no matter what

**Tandem-style HA over a LAN and/or WAN is now required!!!**

# Built-in HA

- Redundancy (at the table level) in the grid
- If grid has a WAN, then get disaster recovery
- Optimizer chooses which instance of a table to read, writes all instances (transactionally)

# Recovery in a K-safe Environment

- Restore dead site
- Query up sites for live data
- When up to speed, join the grid
- Stop if you lose K+1 sites
- No redo log!!!!
  - No slower than log recovery (Lau paper – SIGMOD 06)

Vertica has shown this to be perfectly workable – albeit sometimes outside customer's comfort zone….

# Main Sources of Overhead in Main Memory DBMS

- Disk I/O (gone)
- Resource control (gone)
- Synchronization (gone)

- Undo log (but in main memory and discard on commit)
- Concurrency control
- 2 phase commit (for multi-site updates and copies)

# OLTP Has Changed

- 1970's:  conversational transactions
- Now: stored procedures;
  - Can ask for all of them in advance

# Structure of H-Store

- Get all transaction classes in advance
  - Instances differ by run-time parameters
- Construct a physical data base design (manually now; automatically in the future)
  - Table partitioning
  - Table-level replication
- Create a "gamma-style" query plan for each class

# Analyze Transaction Classes for Leverage Points

- Whole bunch in the paper
  - Constrained tree applications, Single site transactions, one shots, …
- Two allow leverage in TPC-C
  - Commutativity  (Ants pioneered this)
  - Two-phase

# Two Phase

- **In phase one, Xact can read and abort but not write**
- **In phase two, Xact can read and write but not abort**

All TPC-C Xacts can be made two phase, with rearrangement of new_order logic

# Commutativity

- **All pairs of Xacts produce the same final data base state**
  - **With any statement-level ordering at each site**

With this definition and a little trickery (in the paper), all TPC-C transactions are commutative

# Overhead Reduction

- Commutativity and two-phase
  - No locking
  - No 2 phase commit
  - No undo log

Tested configuration also used selective redundancy of read-only objects to improve site locality

# TPC-C Performance on a Low-end Machine

- Elephant
  - 850 TPS (1/2 the land speed record per processor)
- H-Store
  - 70,416 TPS (1/2 the land speed record with $2K of hardware)

**Factor of 82!!!!!**

# Open Research Problems

- Teasing apart the factor of 82
  - In process
- Automatic data base designer
  - Create a physical data base design that is as fast as possible

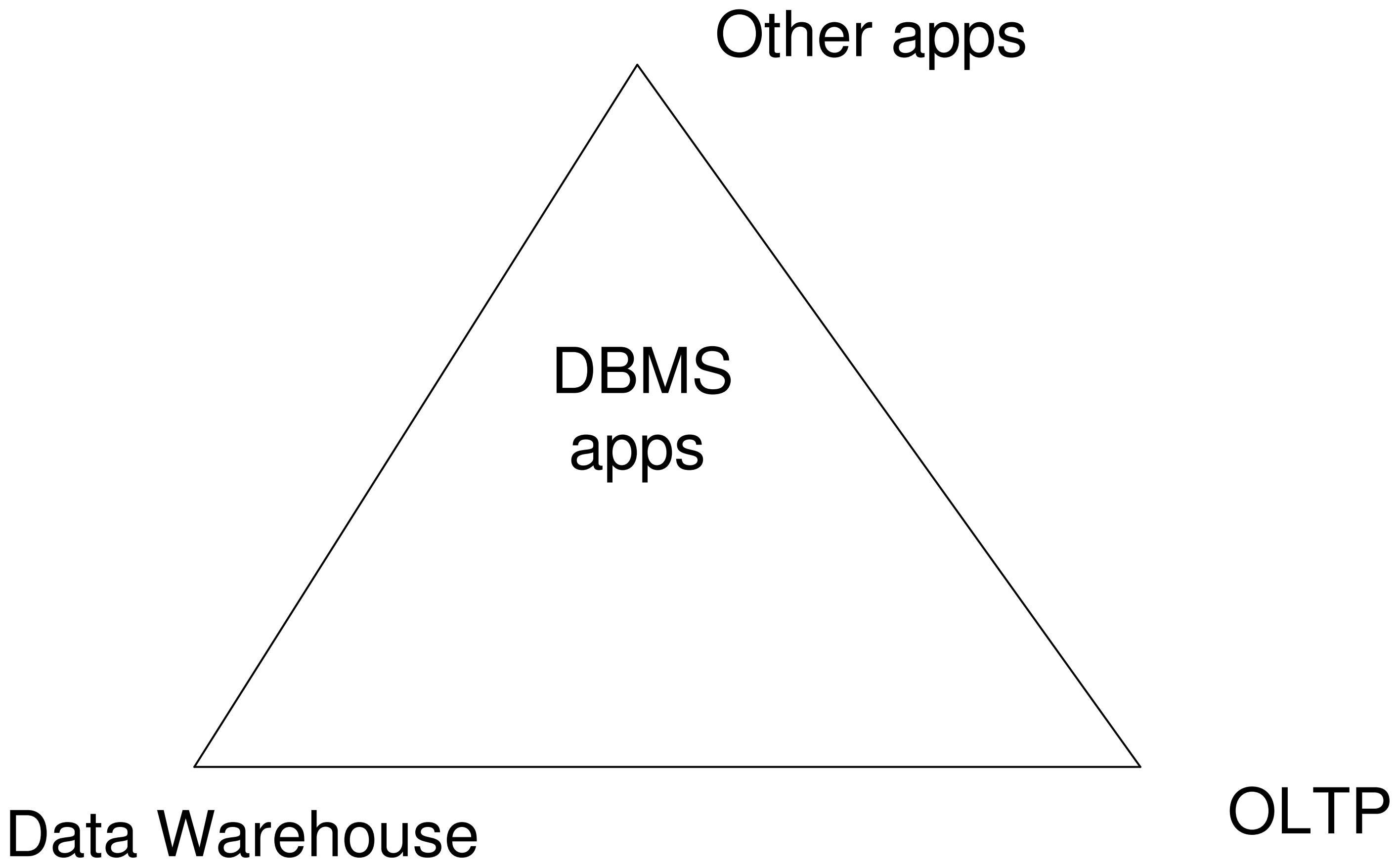
# Open Research Problems

- Concurency control
  - Which variation on OCC to use when application is not “well behaved”
- Theory question
  - Characterize carefully the leverage points

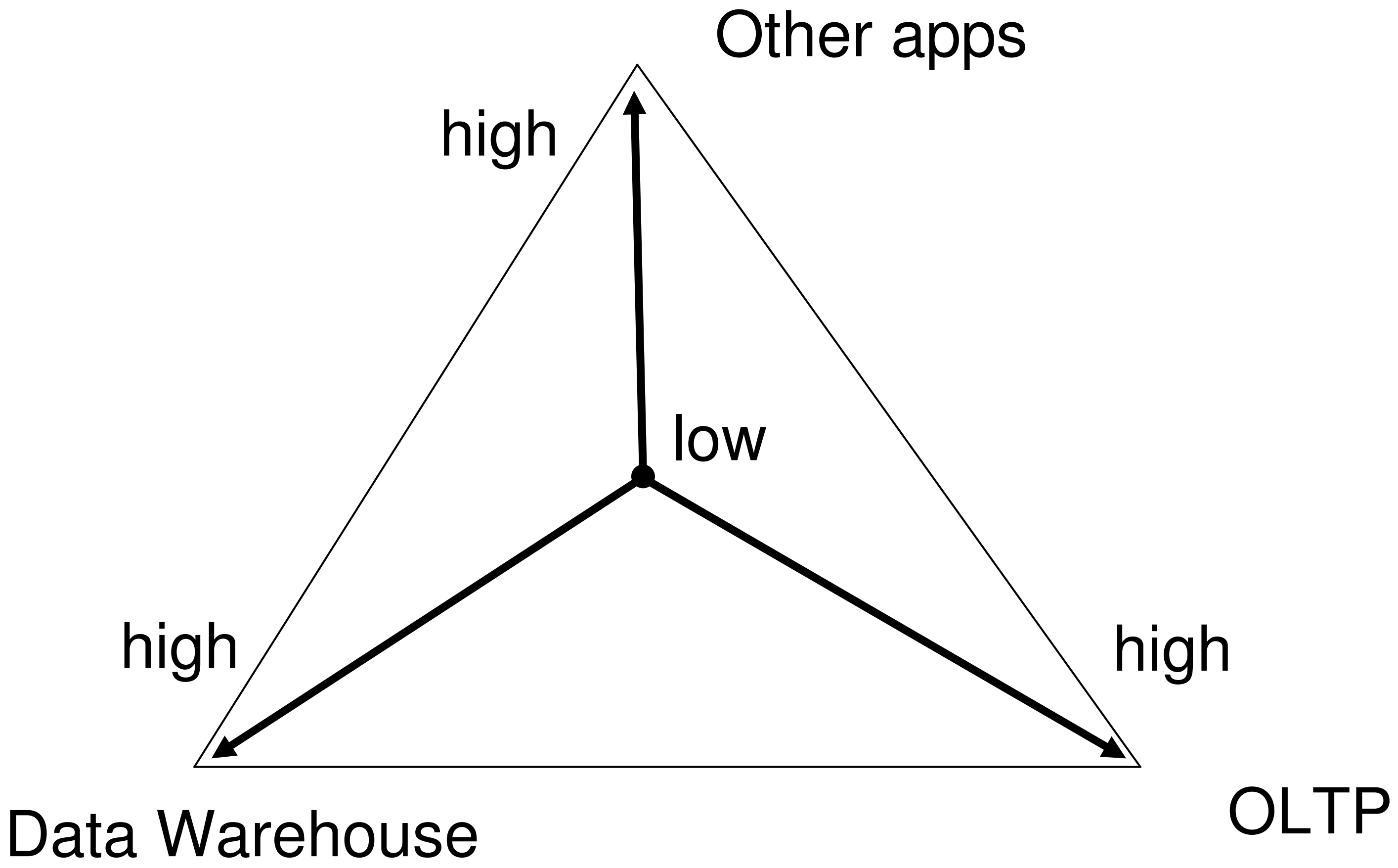
# Implications for the Elephants

- They are selling "one size fits all"
- Which is 30 year old legacy technology that is good at nothing

# Pictorially:



# The DBMS Landscape – Performance Needs

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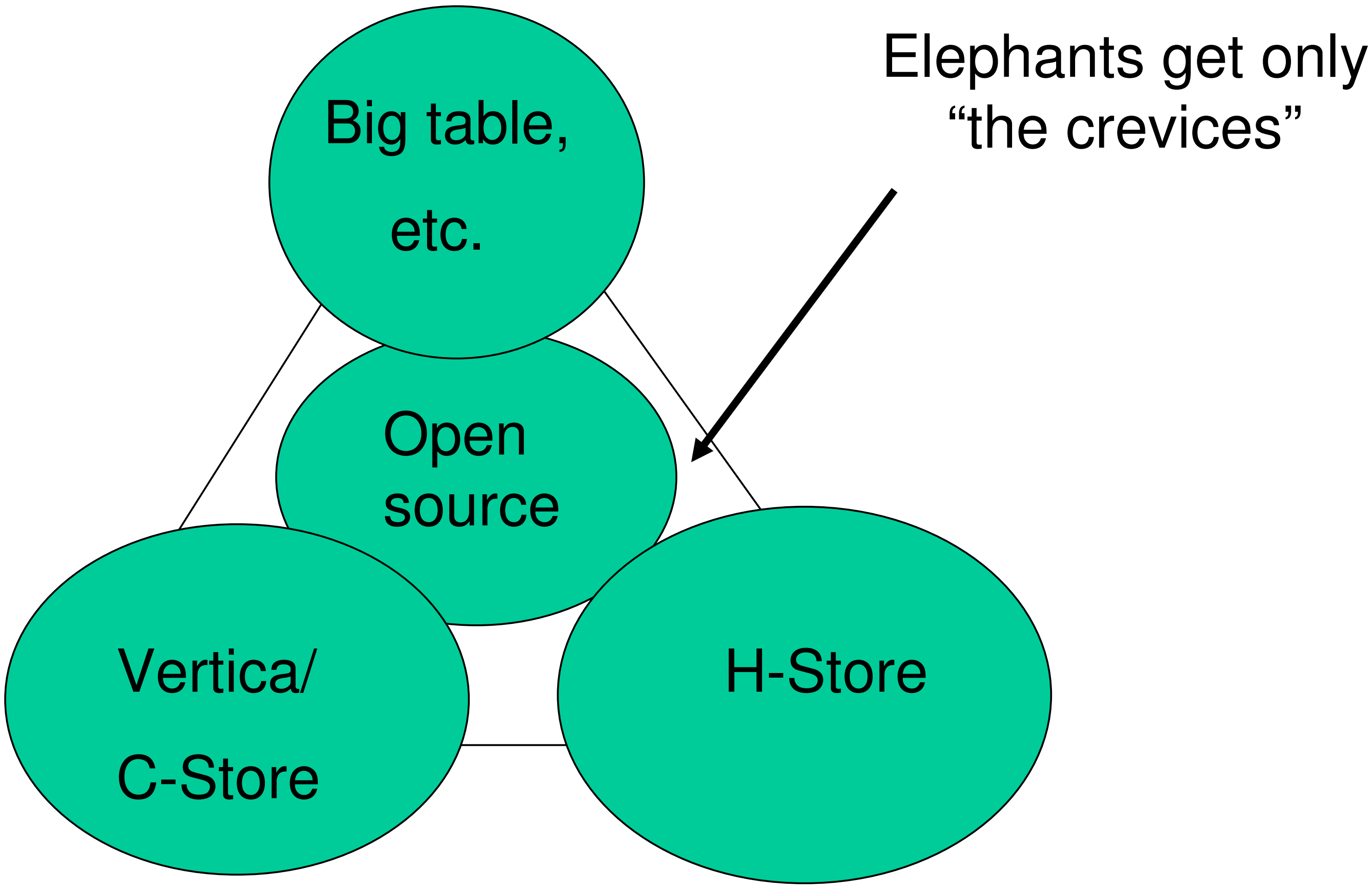
# One Size Does Not Fit All -- Pictorially

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# Other Implications

- Data model
- Query language
- Programming style

# Data Model -- Total Heresy….

- Relational model was the answer for OLTP in 1970s
- Time to rethink the “hallowed halls”
  - Warehouses are ER
  - Semi-structured data is RDF or XML
  - OLTP usually hierarchical (true for “one site” transactions)
- One size does not necessarily fit all!!!

# Query Language

- SQL is a "one-size-fits-all" language
  - OLTP can be a (possibly small) subset (e.g. no aggregates)
  - Warehouses do not require fancy consistency stuff

# Programming Style

- In the 1970’s there were two proposals
  - Data sublanguage, e.g. SQL Quel, … with ODBC/JDBC, …
  - Extended programming language (Rigel, Pascal R, PL/1 extension)

Data sublanguage is 20x the lines of code

But won in the marketplace

# Programming Style -- Today

- ODBC/SQL is 20x Ruby on Rails
- High time to embed DBMS stuff cleanly in the PL

# Implications for the Research Community

- Find a problem area where there might be a factor of 50 and study it
- Lots of good choices
  - Web 2.0
  - Bio (RDF?)
  - Science in general
  - Integration of structured and unstructured data (Google meets DBMS)

# Implications for the Research Community

- If you have a a good idea -- prototype it
  - Ok to have a market-specific data model
  - And query language
- Could make use of existing systems in novel ways
  - RDF on a column store (Abadi paper)