Main Memory Storage Engines

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Roadmap

- Paper 1: Data-Oriented Transaction Execution
- Paper 2: OLTP Through the Looking Glass
- Paper 3: Generic Database Cost Models for Hierarchical Memory Systems

Storage Engine?

- the part of the database that actually stores and retrieves data
  - responsible for db performance
    - concurrency, consistency
  - separate from the database "front end"
- A single database can have several database engine options
  - e.g. MySQL supports InnoDB and MyISAM

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Paper 1

- Data Oriented Transaction Execution
  - I. Pandis at al. (CMU/EPFL/Northwestern)
  - VLDB '10

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Motivation

- Hardware has changed
  - recently, we've run into "thermal wall"
    - hard to fit more resistors per chip
    - …must abide by Moore's Law!
      - add more cores per chip
      - rely on thread-level parallelism
  - most current architectures designed in the 80's
    - what assumptions were made about the hardware?

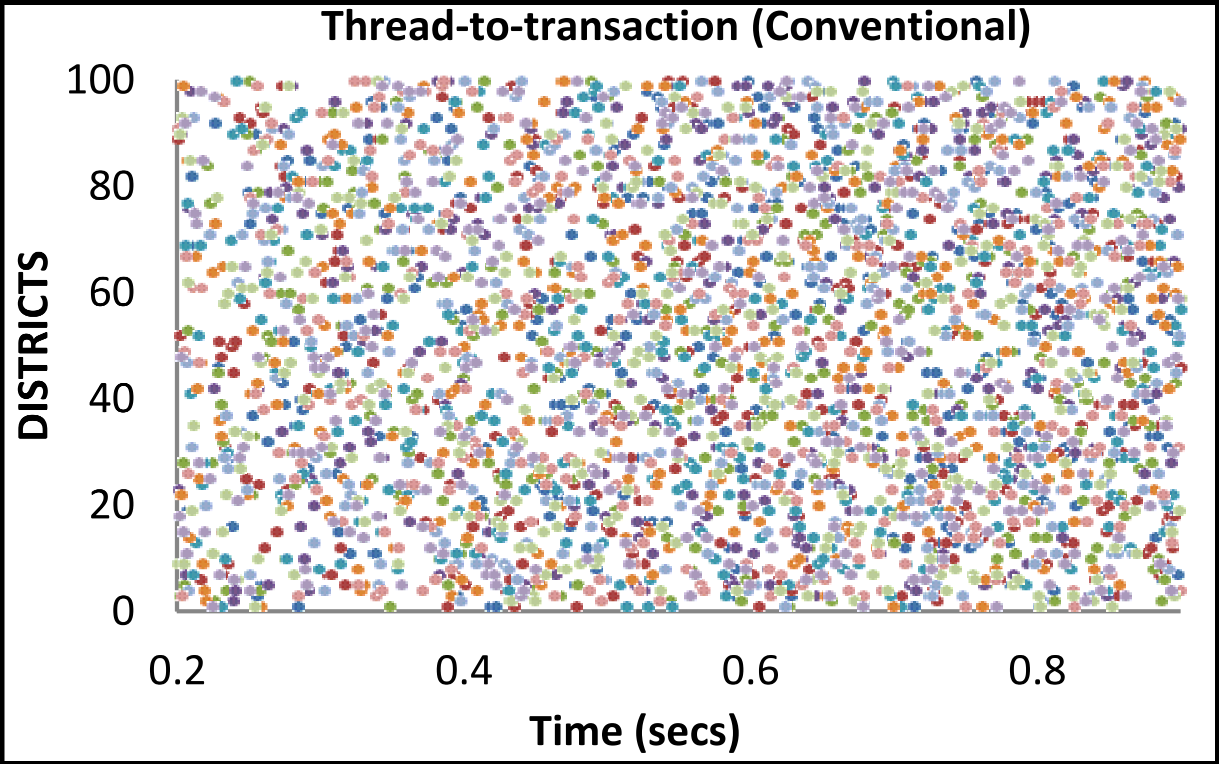
Thread-to-Transaction Model

- in most database engines, each transaction assigned to its own thread
  - more cores = more parallel threads
  - each thread responsible for locking shared resources as needed
    - works fine with a few threads, how about thousands executing concurrently on hundreds of hardware contexts?

Data Access Pattern

- Each thread only worries about its own transaction
  - no coordination among transactions
    - i.e. uncoordinated data access
  - leads to high lock contention, especially at data "hot spots"

Data Access Visualization



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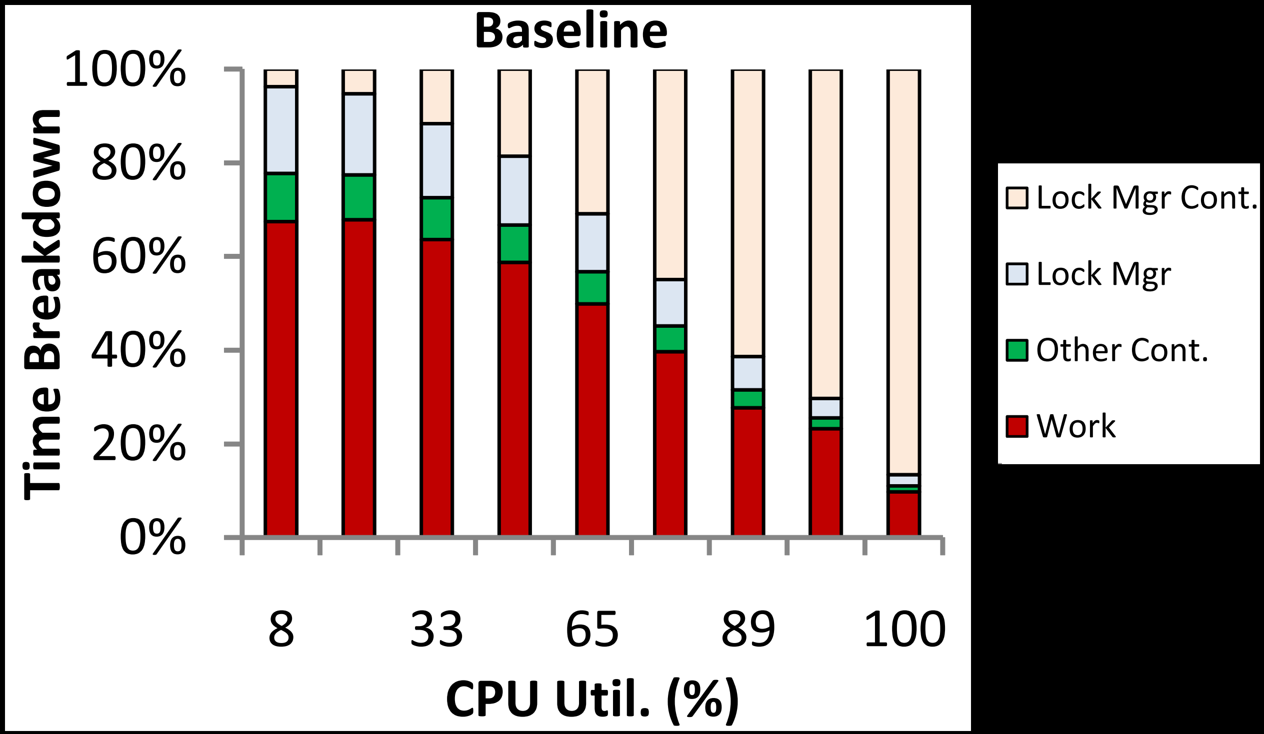
Lock Contention As a Bottleneck



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The future looks bleak…

- Not quite!
- Idea: "Coordinate" data access patterns
  - rather than having threads contending for locks, have transactions contending for threads
  - distribute the transactions to the data, not data to the transactions

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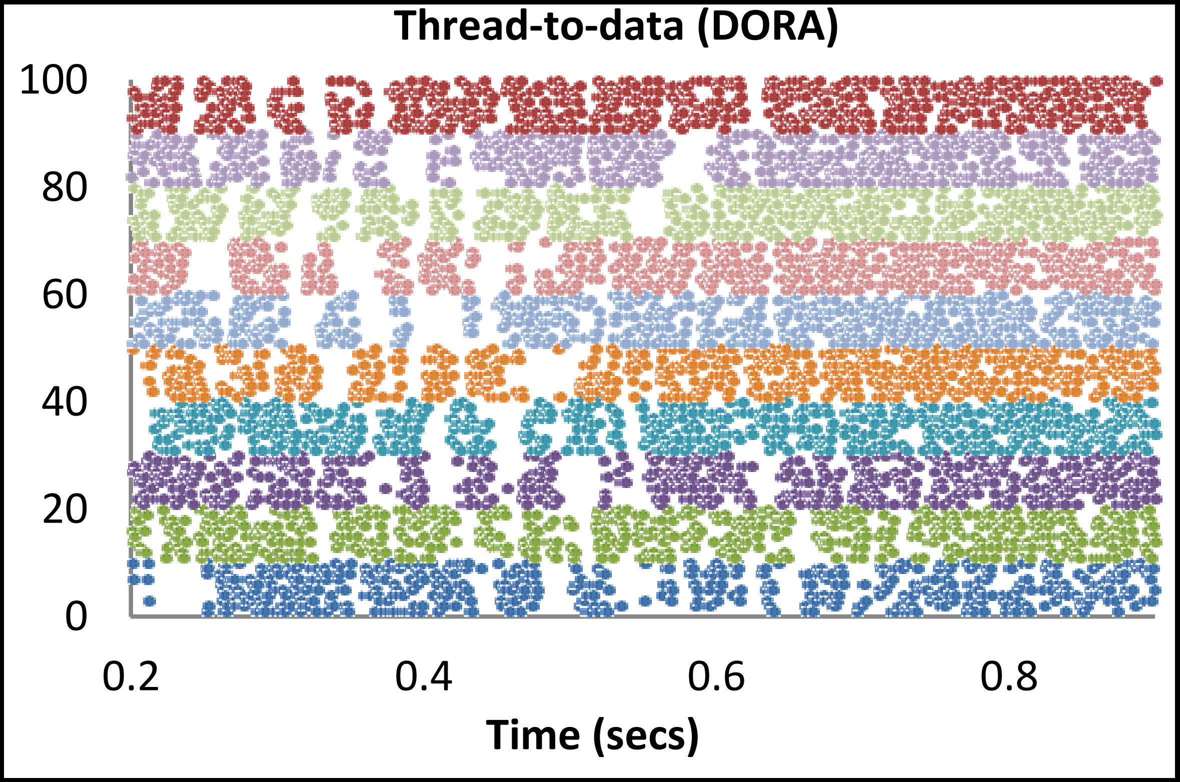
Thread-to-Data Model

- each thread is coupled with a disjoint subset of the database
- threads coordinate access to their own data using a private locking mechanism

"Coordinated" Data Access



A Data Oriented Architecture (DORA)

- a shared-everything architecture designed to scale to very high core counts
- retains ACID properties
- data (i.e. relations) are divided into disjoint datasets
  - 1 executer (thread) per dataset

Routing

- How to map datasets?
  - use a routing rule
- Routing rules use a subset of columns from a table, called *routing fields*, to map rows to datasets
  - in practice, columns from primary or candidate keys are used
  - can be dynamically updated to balance load

Transaction Flow Graphs

- used to map incoming transaction to executers
- *actions* are the data access parts of the query
- *identifiers* describe which columns an action uses
- What about actions that don't match routing fields?
  - called *secondary actions*, more difficult

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Secondary Actions

- which executer is responsible?
  - for indexes that don’t index the routing fields, store the routing fields in the leaf nodes
    - added space overhead?
    - expensive to update indexes if routing fields are changed?

Rendezvous Points

- often, data dependencies exist between actions
  - insert *rendezvous points* between actions with data dependencies
    - logically separates execution into different phases
    - system cannot concurrently execute actions from different phases

Executing an Action

- 3 structures:
  - – incoming action queue
    - processed in order received
  - – completed action queue
  - – thread-local lock table
    - use action identifiers to “lock” data to avoid conflicts

Inserts and Deletes

- Still need to acquire row-level locks through centralized locking manager
  - why?
    - T1 deletes a record
    - T2 inserts a record into the slot vacated by the record deleted by T1
    - T1 aborts but can’t roll back, slot is taken
  - row-level locks often not a source of contention

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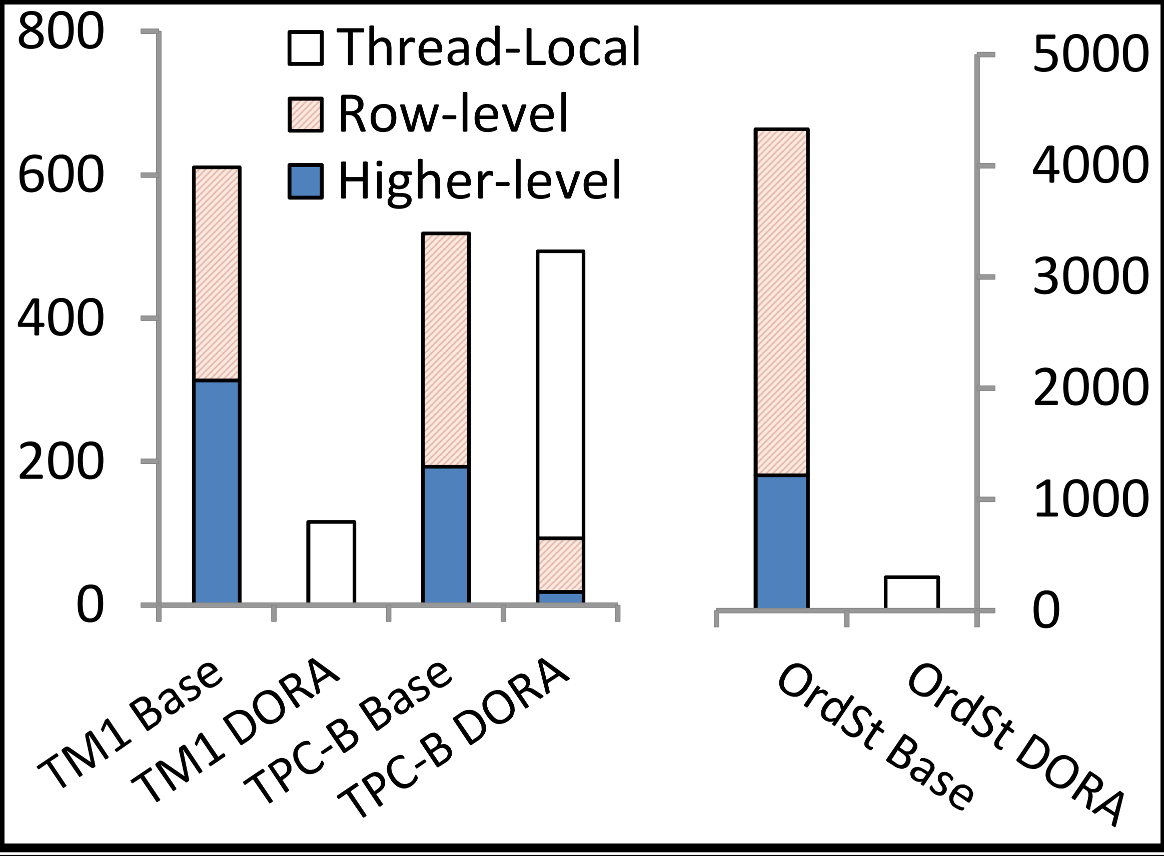
Experimental Setup

- 3 benchmarks used, all OLTP
  - TM-1
    - 7 transactions, 4 with updates
  - TPC-C
    - 150 warehouses (approx. 20 GB)
  - TPC-B
    - 100 branches (approx. 2 GB)

Lock Contention



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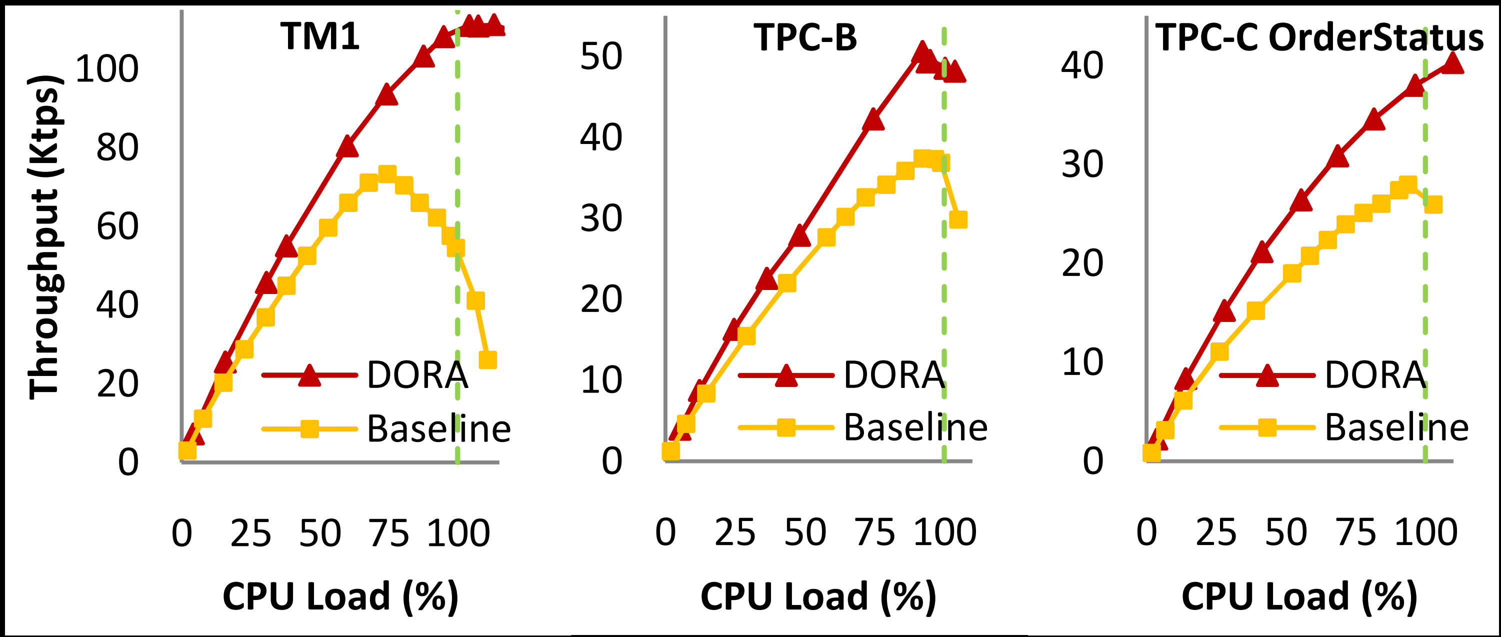
Throughput



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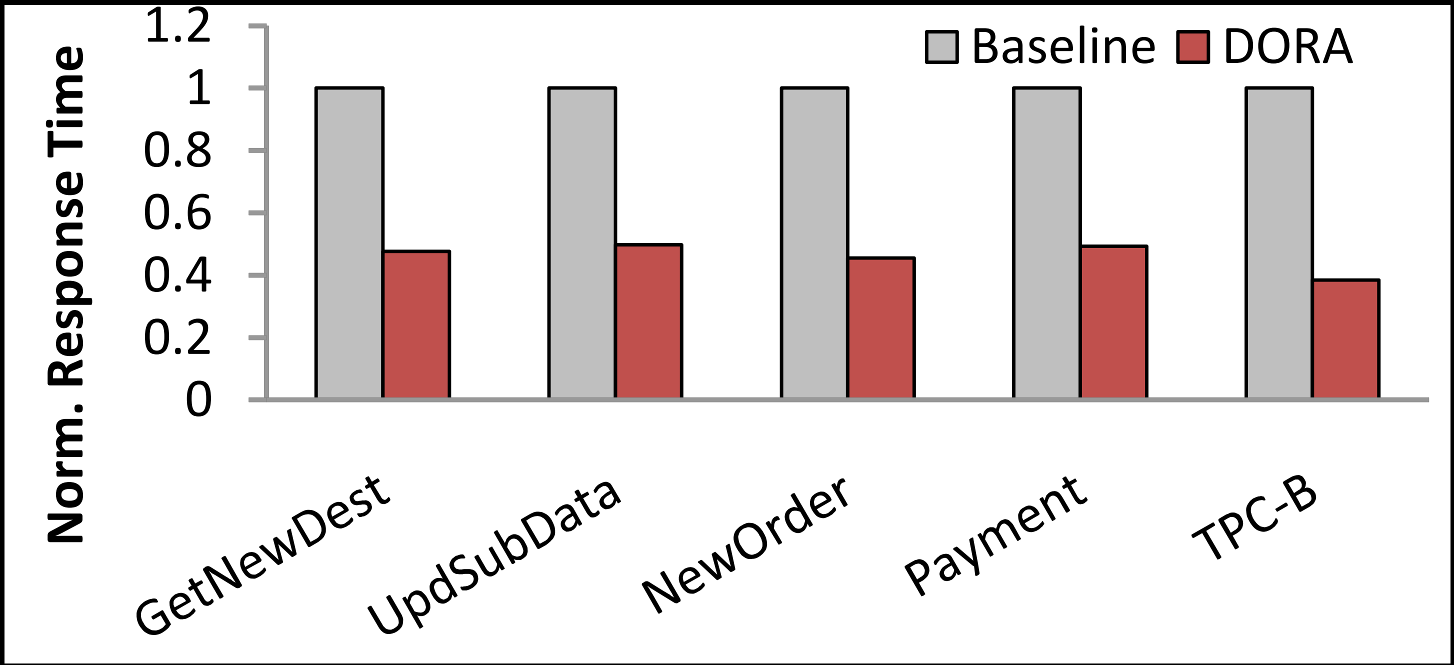
Response Times



Conclusions

- Traditional database engines not made for the amount of thread-level parallelism seen in machines today
  - lock contention a major part of that
- A thread-to-data approach can significantly reduce lock contention

Paper 2

- OLTP Through the Looking Glass, and What we Found There
  – Stavros Harizopoulos et al.
  – SIGMOD ‘08

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Motivation

- Hardware has changed
  - db systems were designed when memory was sparse
  - many OLTP databases can fit entirely in memory
- Even in memory, there are other bottlenecks
  - logging, latching, locking, buffer management

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Alternative Architectures

- logless
  - removing logging
- single transaction
  - remove locking/latching
- main memory resident
  - remove transaction bookkeeping

Goals

- Remove each of the "unnecessary" parts, one by one, and evaluate performance
  - Determine relative performance gains by removing each feature

Instruction Count Breakdown

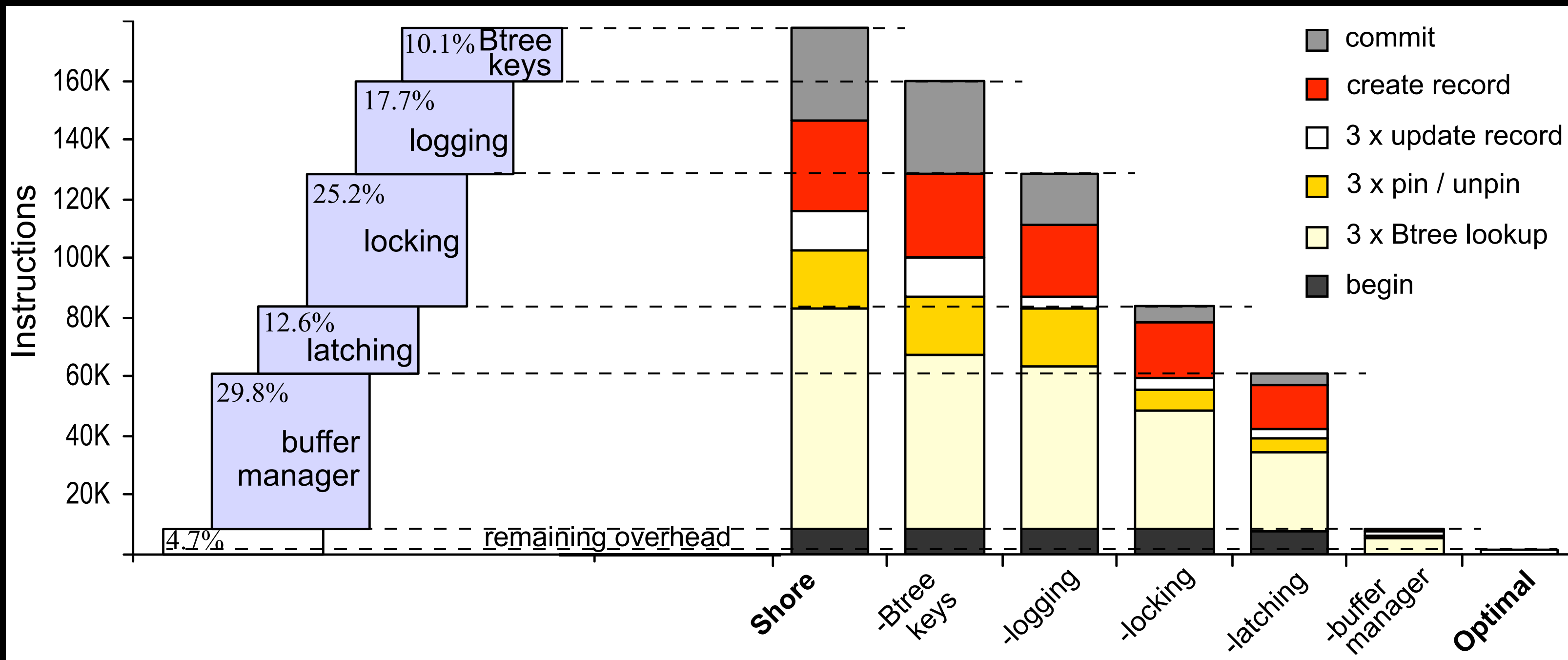

Figure 5. Detailed instruction count breakdown for Payment transaction.

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Instruction Count Breakdown

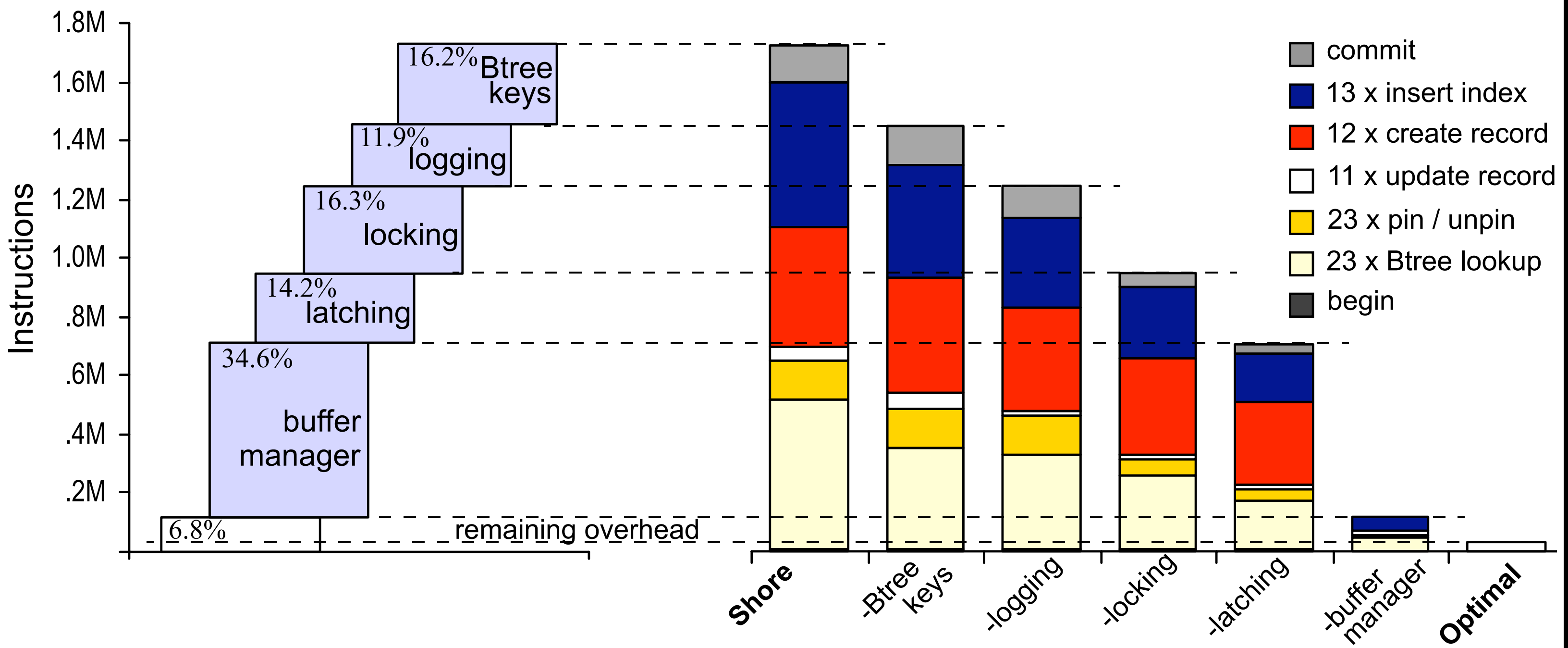

Figure 6. Detailed instruction count breakdown for New Order transaction.

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Conclusions

- Antiquated disk-based features can cause significant overhead in a main memory system
- Each component of a system should be carefully evaluated

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Paper 3

- Generic Database Cost Models for Hierarchical Memory Systems
  - S. Manegold et al.
  - VLDB '02

Motivation

- Cost models are a key part of query optimization
  - traditional cost models based on disk accesses
- What about in a main memory system?
  - memory hierarchy
    - L1, L2, L3, main memory, (solid-state?)

Goals

- An accurate cost model should weight each memory hierarchy differently
  - overall “cost” of an operator should be the sum of the cost at all memory hierarchies
  - each level has different access cost
    - weight each access by that level’s cost

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Data Access Patterns

- different operators exhibit different data access patterns
  - pattern dictates both cost and number of caches misses
- How to accurately model access patterns?
  - basic access patterns
    - single/repetitive sequential traversal, single/repetitive random traversal, random
    - compound access patterns

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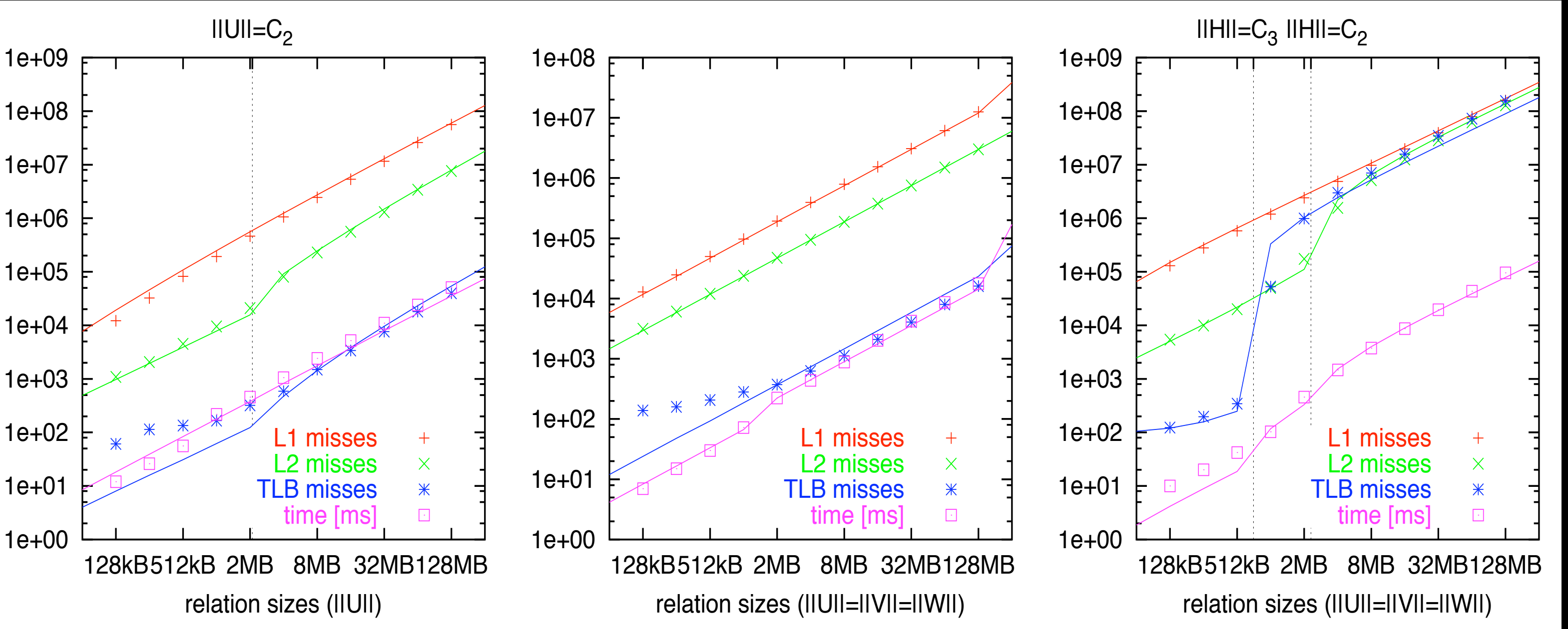
Cost Models

- For each basic access pattern, derive custom cost model (not shown)
- Combine basic access pattern cost models to derive compound access pattern cost models
- For each database operator (i.e. sort), map to a cost model

Experimental Analysis



a) Quick-Sort b) Merge-Join c) Hash-Join

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Conclusions

- Basic cost models presented can model the costs in main memory systems
- These memory-based cost models could also be used to enhance current disk-based cost models

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Questions?