Meet the Walkers

Accelerating Index Traversals for In-Memory Databases

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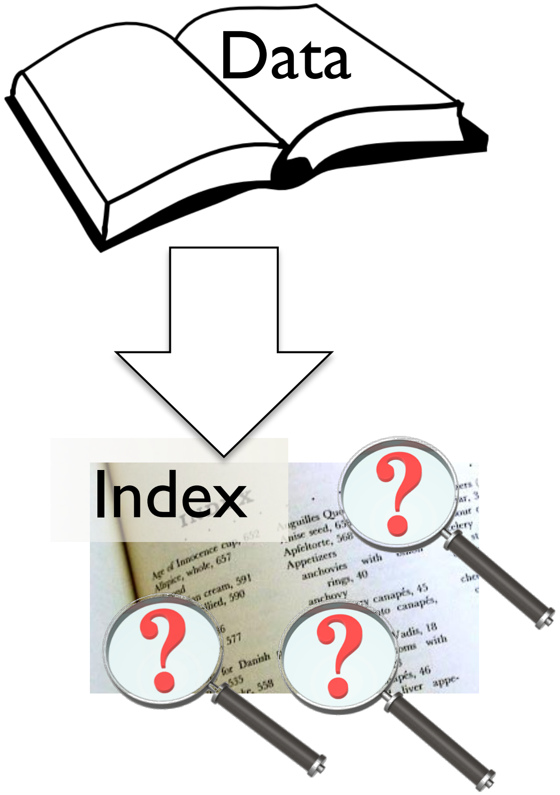
Our World is Data-Driven!

Data resides in huge databases
- Most frequent task: find data

Indexes used for fast data lookup
- Rely on pointer-intensive data structures

Indexing efficiency is critical
- Many requests, abundant parallelism
- Power-limited hardware



Need high-throughput and energy-efficient index lookups

Index Lookups on General-Purpose Cores

Index Lookups

- Data in memory
- Inherent parallelism

OoO Cores

- Pointer-chasing → Low MLP
- Limited OoO inst. window
  - One lookup at a time

OoO cores are ill-matched to indexing

Widx: an Indexing Widget

Specialized: Custom HW for index lookups

- Switch fewer transistors per lookup

Parallel: Multiple lookups at once

- Extract parallelism beyond the OoO exec. window

Programmable: Simple RISC cores

- Target a wide range of DBMSs

3x higher throughput, 5.5x energy reduction vs. OoO

Outline

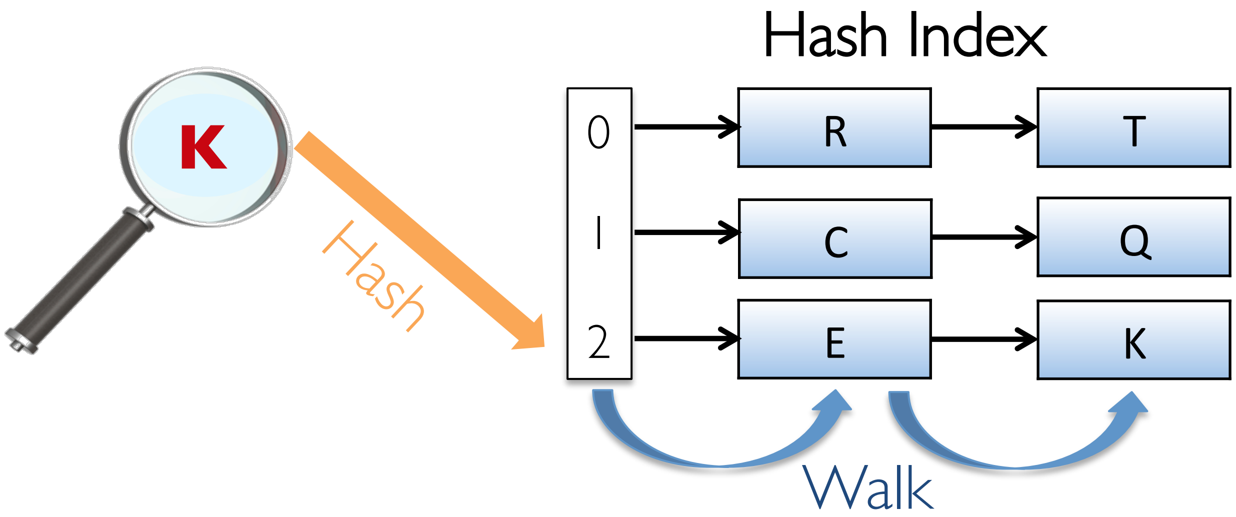
- Introduction
- Indexing in database systems
- Indexing inefficiencies in modern processors
- Widx
- Evaluation highlights
- Summary

Modern Databases & Indexing

Indexes are essential for all database operators

- Data structures for fast data lookup

Hash index: fundamental index structure

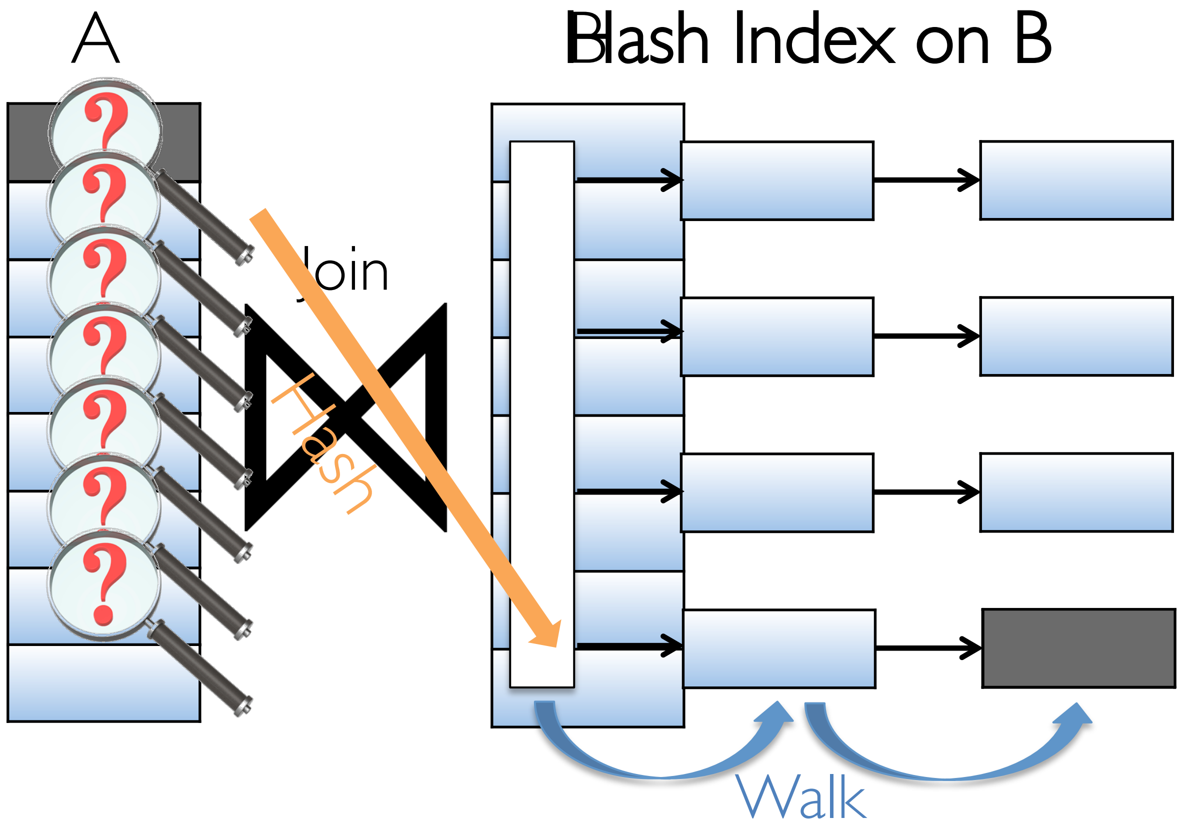


Dominant operation: join via hash index

Join via Hash Index

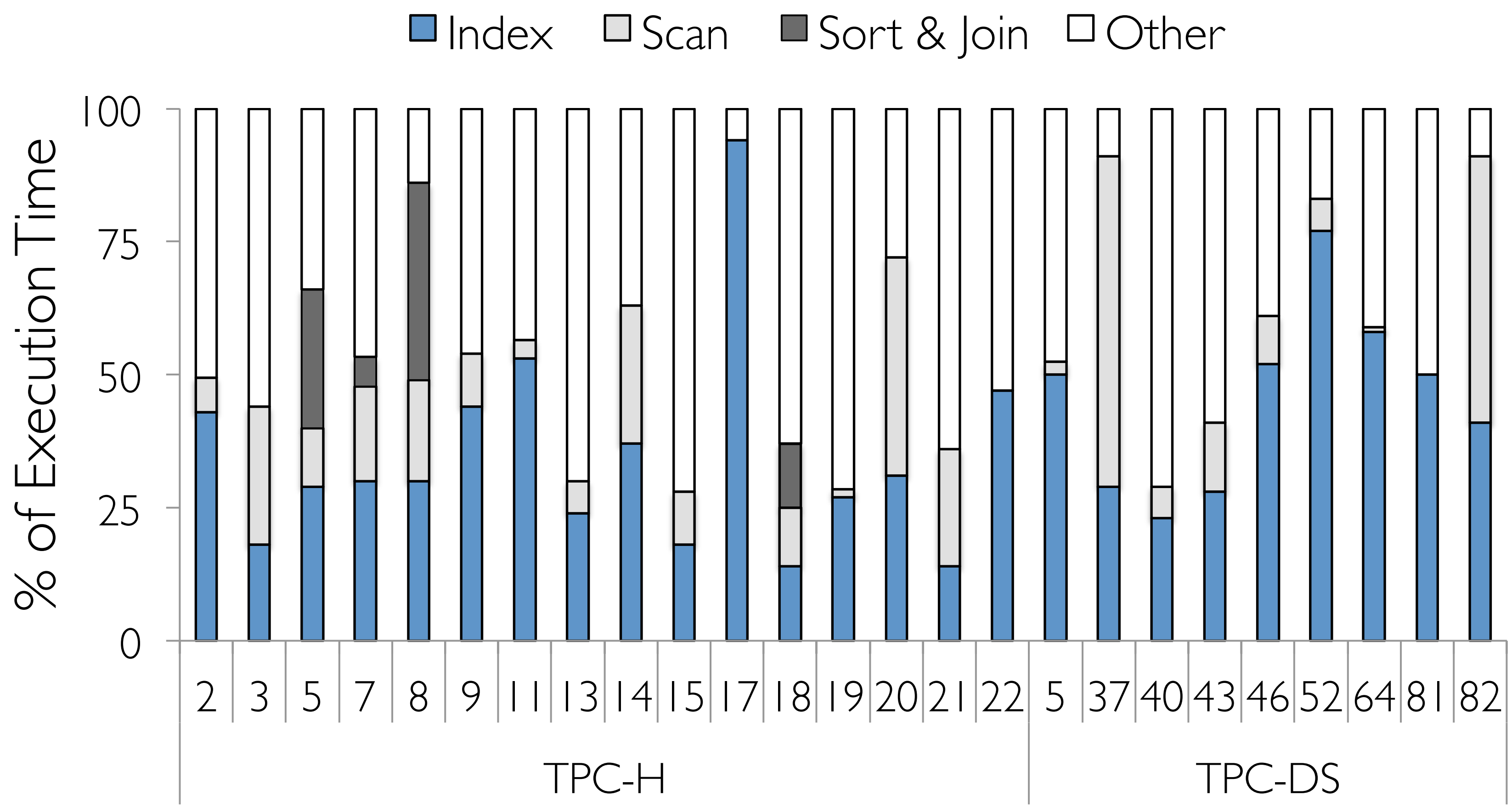
Join: find the matching values in A and B

Lookup the index for every entry in A



How Much Time is Spent Indexing?

Measurement on Xeon 5670 CPU with 100GB Dataset



Indexing is the biggest contributor to execution time

Dissecting Index Lookups

Hash: Avg. 30% time of each lookup

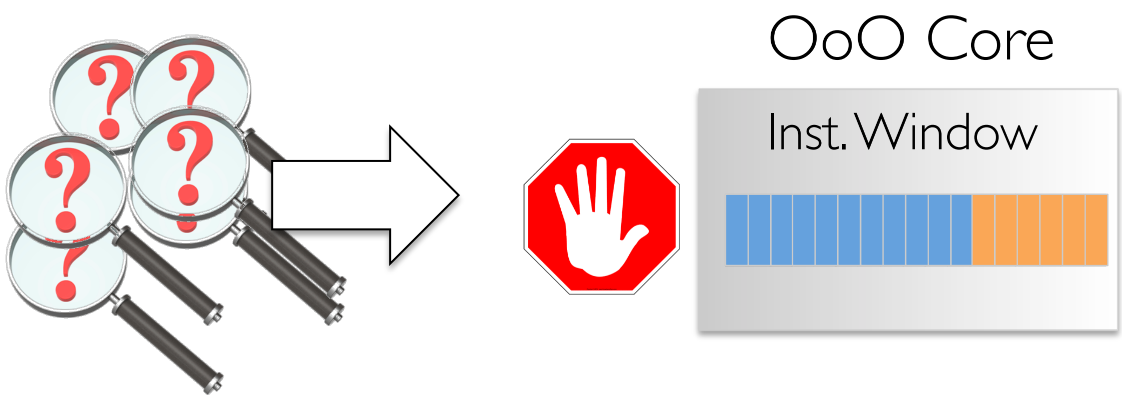
– Computationally intensive, high cache locality

Walk: Avg. 70% time of each lookup

– Trivial computation, low cache locality

Next lookup: Inherently parallel

– Beyond the inst. window capacity



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Roadmap for Efficient and High-Throughput Indexing

1. Specialize
   – Customize hardware for hashing and walking

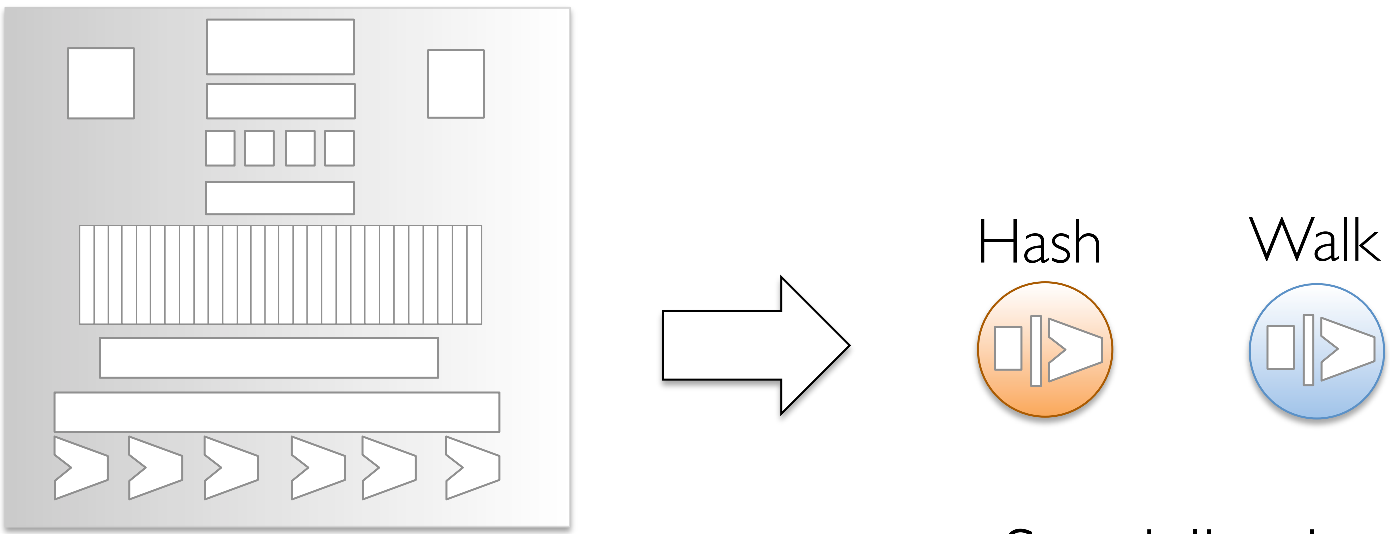
2. Parallelize
   – Perform multiple index lookups at a time

3. Generalize
   – Use a programmable building block

Step 1: Specialize

Design a dedicated unit for hash and walk

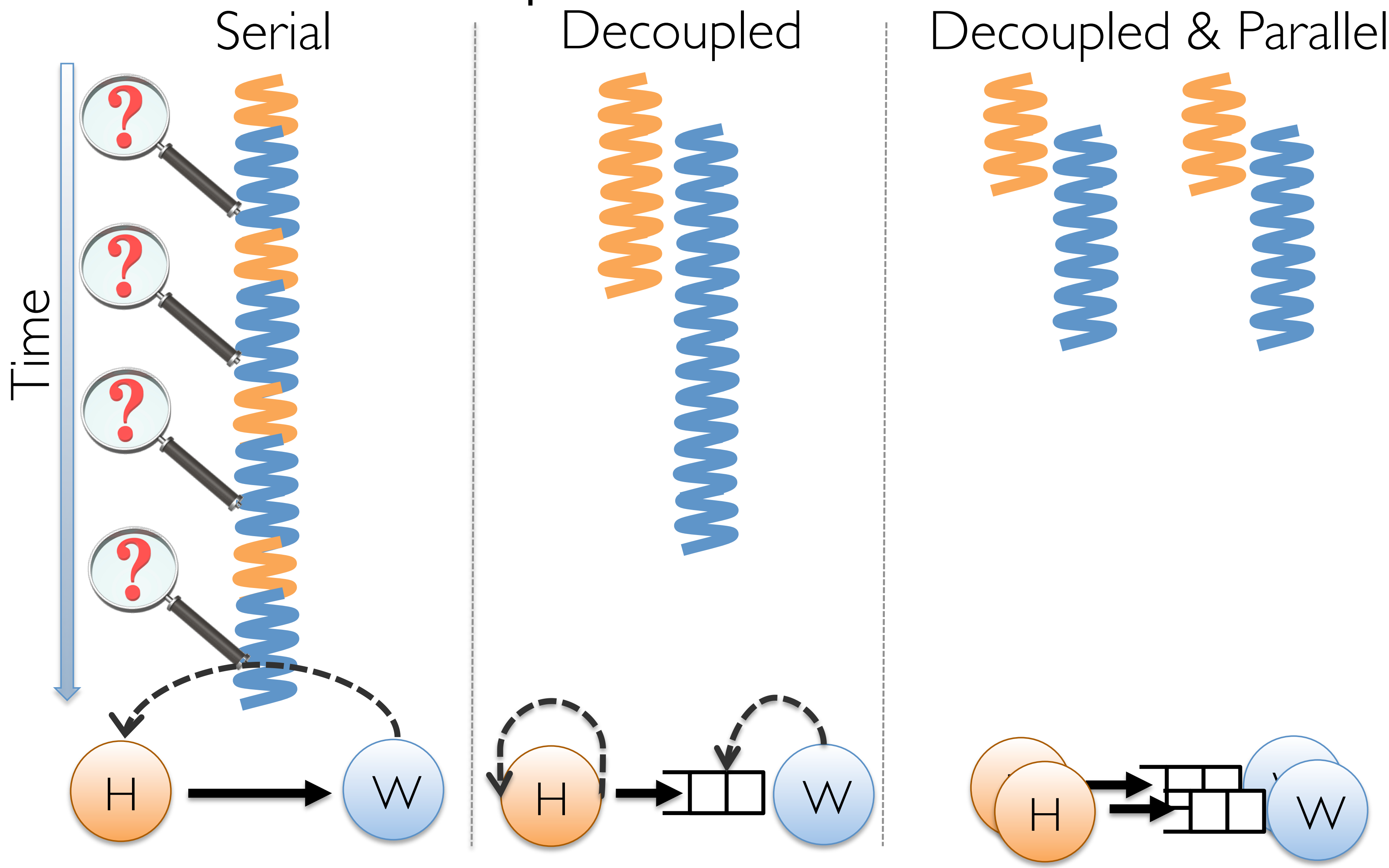
- Hash: compute hash values from a key list
- Walk: access the hash index and follow pointers



General-purpose OoO

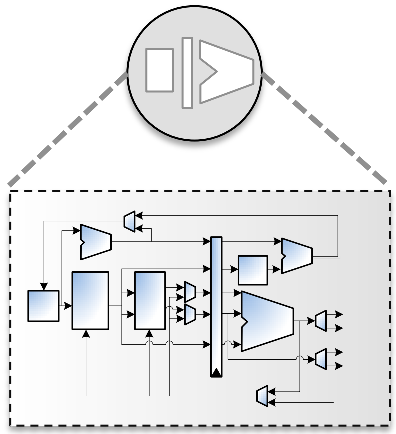
Specialized hash and walk hardware

Step 2: Parallelize



Step 3: Generalize

Widx unit

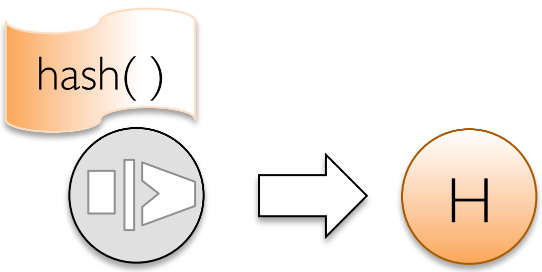


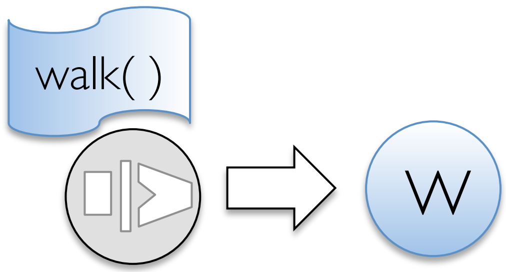
Widx unit: common building block for hash and walk

- Two-stage RISC core
- Custom ISA

Widx units are programmable

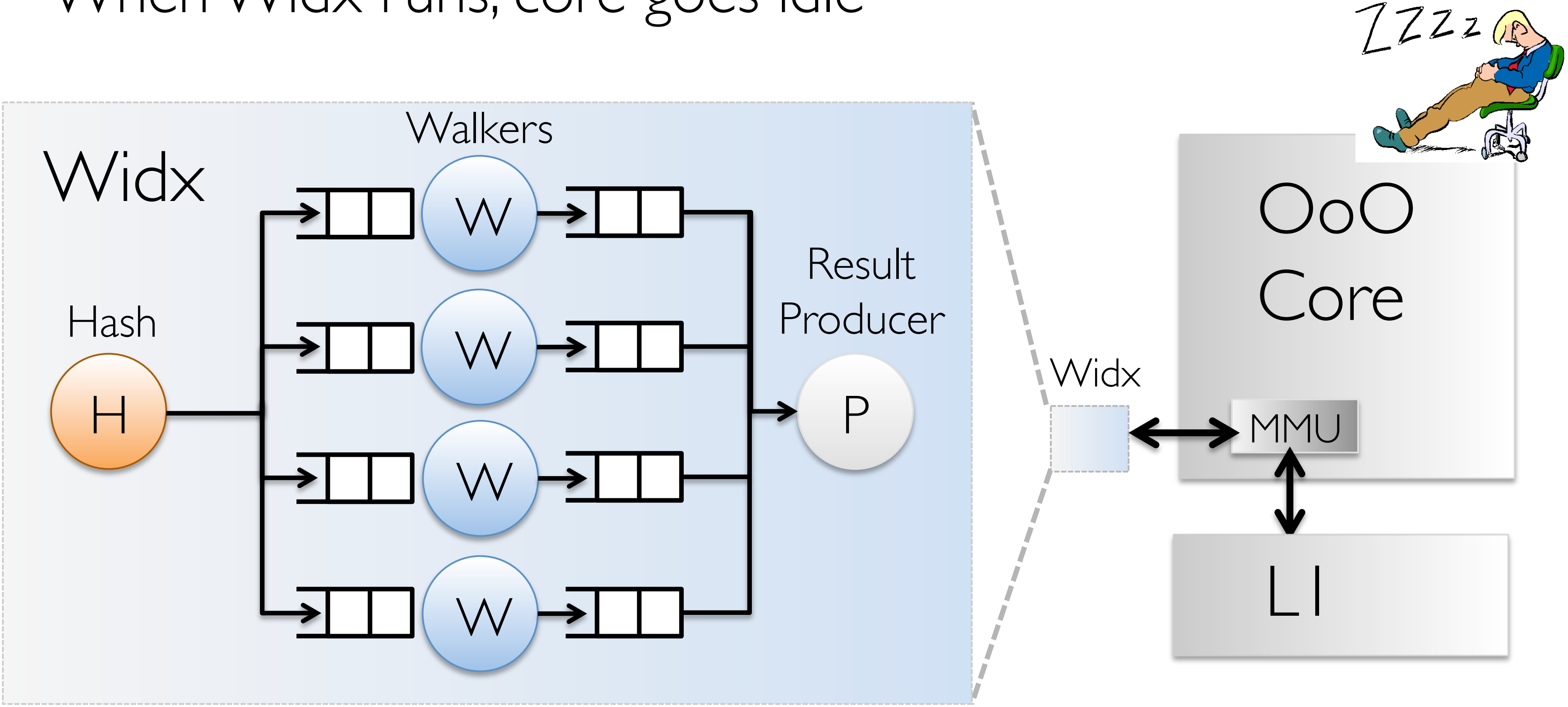
- Execute functions written in Widx ISA
- Support limitless number of data structure layouts





Putting it all together: Widx

When Widx runs, core goes idle

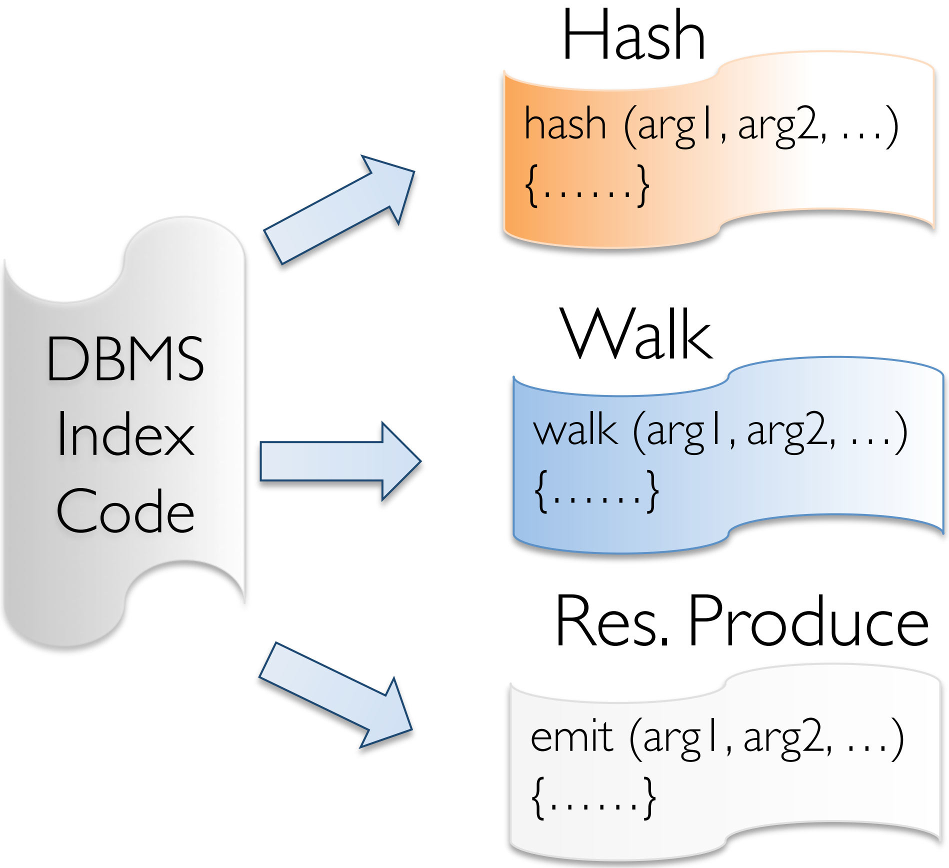


Simple, parallel hardware

Programming Model

Development

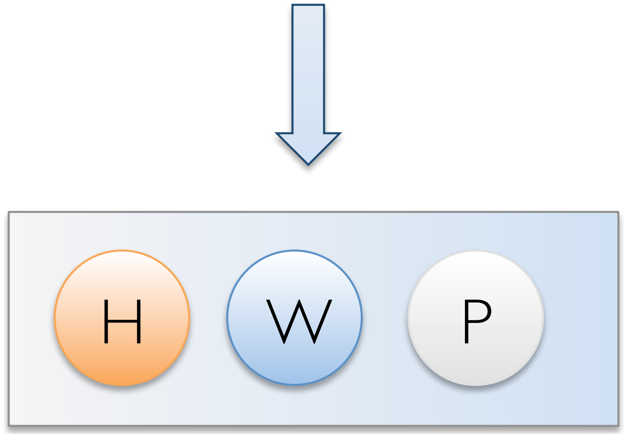
Write code for each unit
and compile for Widx ISA



Execution

Communicate
query-specific inputs

Load the code



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Methodology

Flexus simulation infrastructure [Wenisch '06]

Benchmarks

- TPC-H on MonetDB
- TPC-DS on MonetDB
- Dataset: 100GB

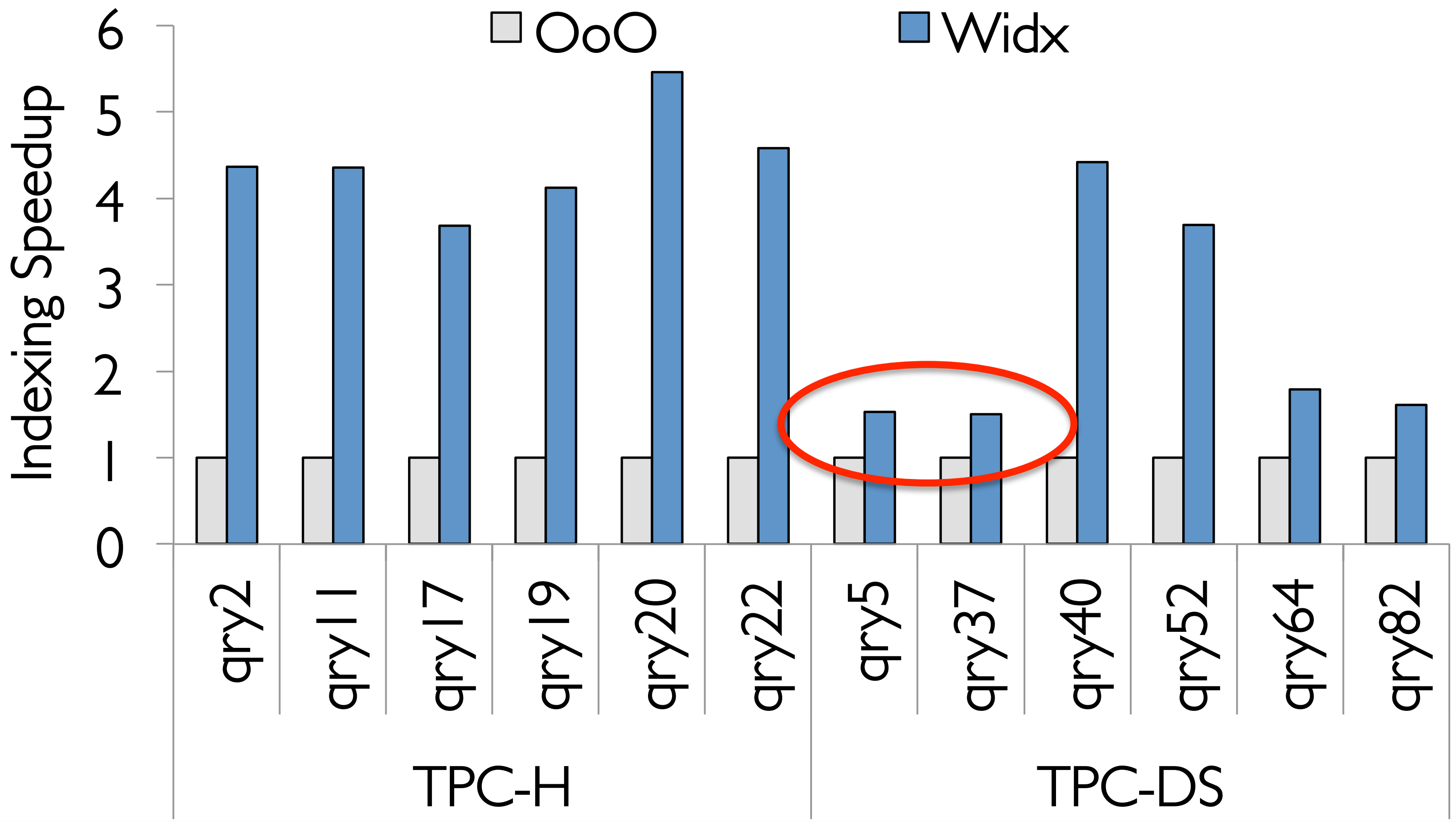
Area and Power

- Synopsys Design Compiler
- Technology node: TSMC 40 nm, std. cell
- Frequency: 2GHz
- Widx Area: 0.24mm^2
- Widx Power: 0.3W

uArch Parameters

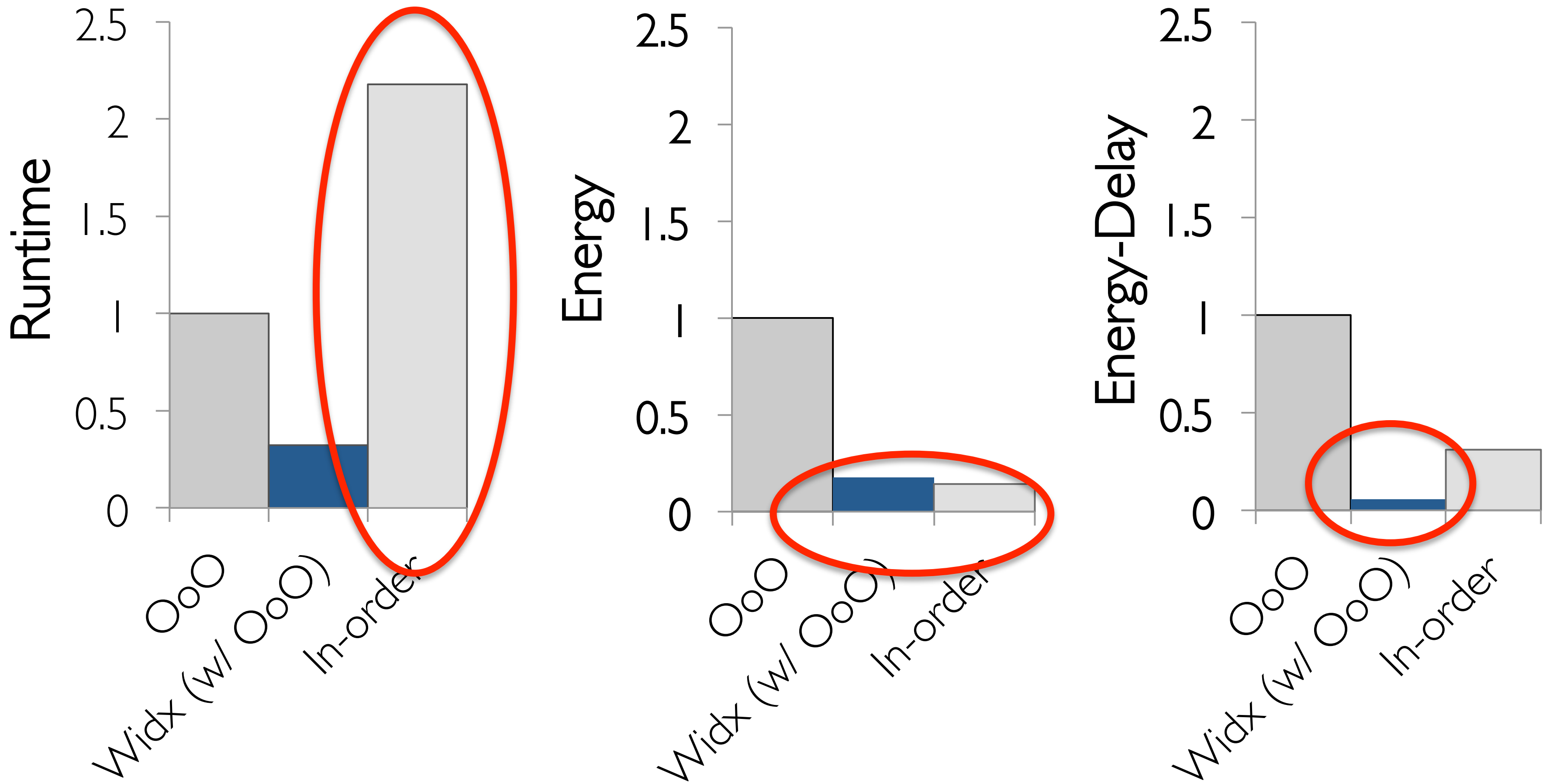
- Core Types
  - OoO: 4-wide, 128-entry ROB
  - In-order: 2-wide
- Frequency: 2GHz
- L1 (I & D): 32KB
- LLC: 4MB

Widx Performance



3x higher indexing throughput

Widx Efficiency



5.5x reduction in indexing energy vs. OoO

Conclusions

Indexing is essential in modern DBMSs

Modern CPUs spend significant time in index lookups

– Not efficient & fall short of extracting parallelism

Widx: Specialized widget for index lookups

– Efficient, parallel & programmable

3x higher throughput, 5.5x energy reduction vs. OoO

Thanks!

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