Cache-Efficient Aggregation: Hashing *Is* Sorting

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Textbook Algorithms for Aggregation

Hash-Aggregation

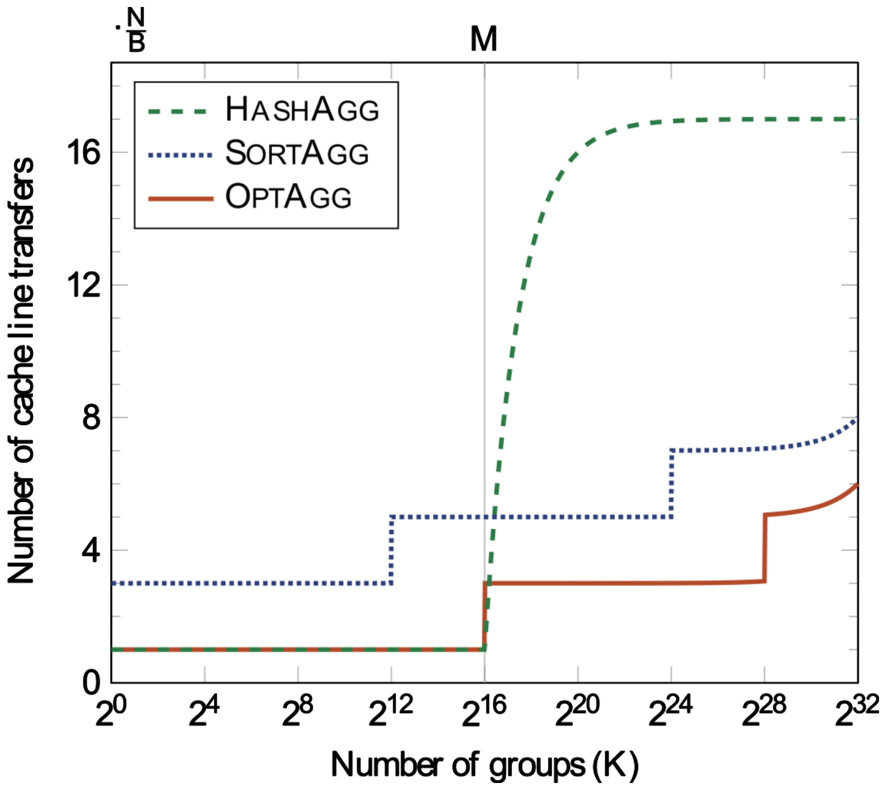
- Insert every row into hash map with grouping attributes as key
- Aggregate to existing intermediate result

Sort-Aggregation

- Sort input by grouping attributes
- Aggregate consecutive rows in a single pass

Traditional approach

- Optimizer selects physical operator based on cardinality estimation → error prone.



M = cache size
N = input size
B = block size
K = output size

Our goal: *Hashing* and *Sorting* in a single operator.

Mixing Hashing and Sorting (1/3): Idea

Key observation: Hashing is the same as *Sorting by hash value.*

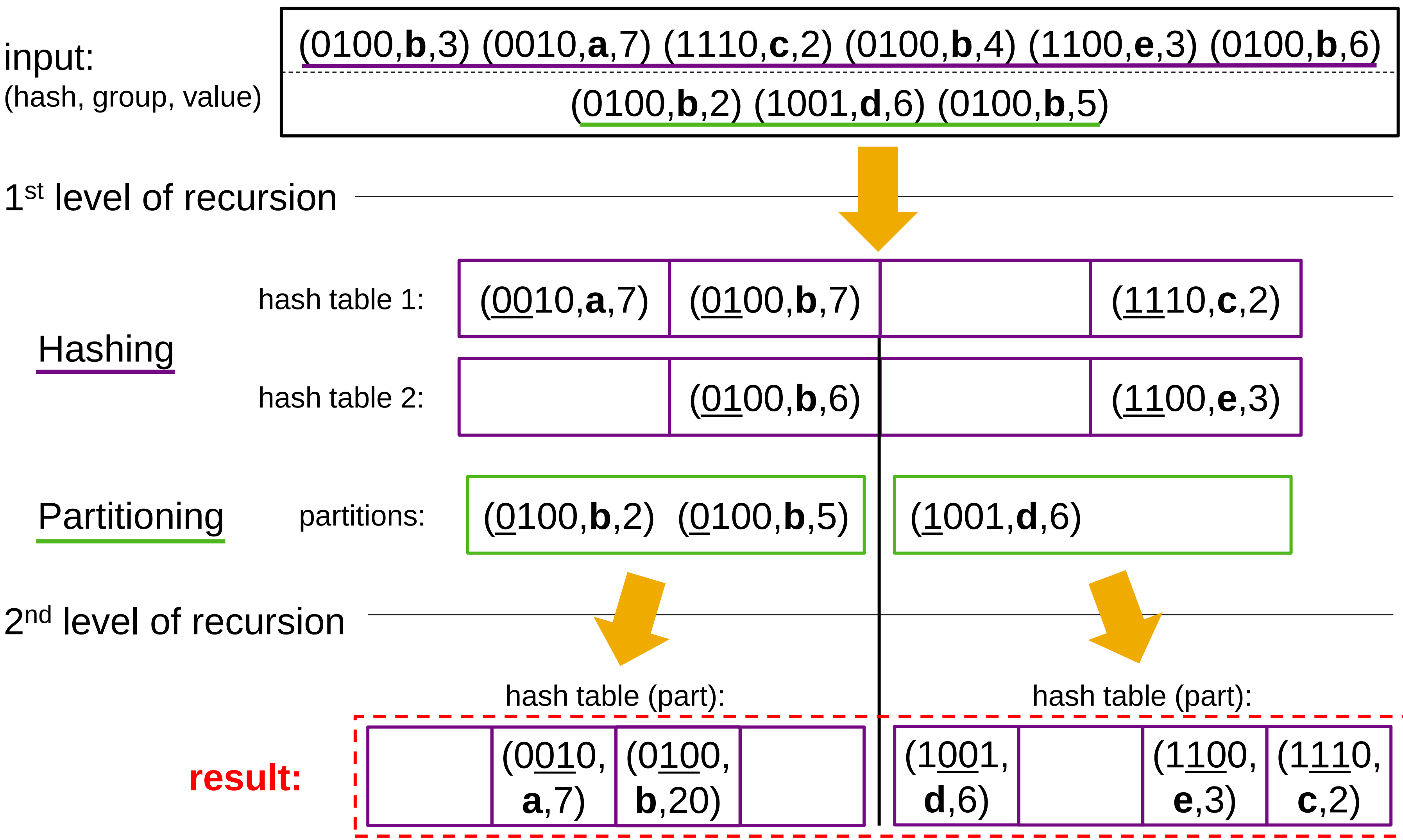
General idea:

- design an aggregation operator like a Divide’n’Conquer sort algorithm on the hash values of the grouping attributes.

Common technique:

- combine different sort routines into one algorithm.

Mixing Hashing and Sorting (2/3): Example Execution



Mixing Hashing and Sorting (3/3): Recap

Our approach: aggregation algorithm designed like a *sort algorithm on hash values* with built-in aggregation.

Subroutine “**Hashing**”:

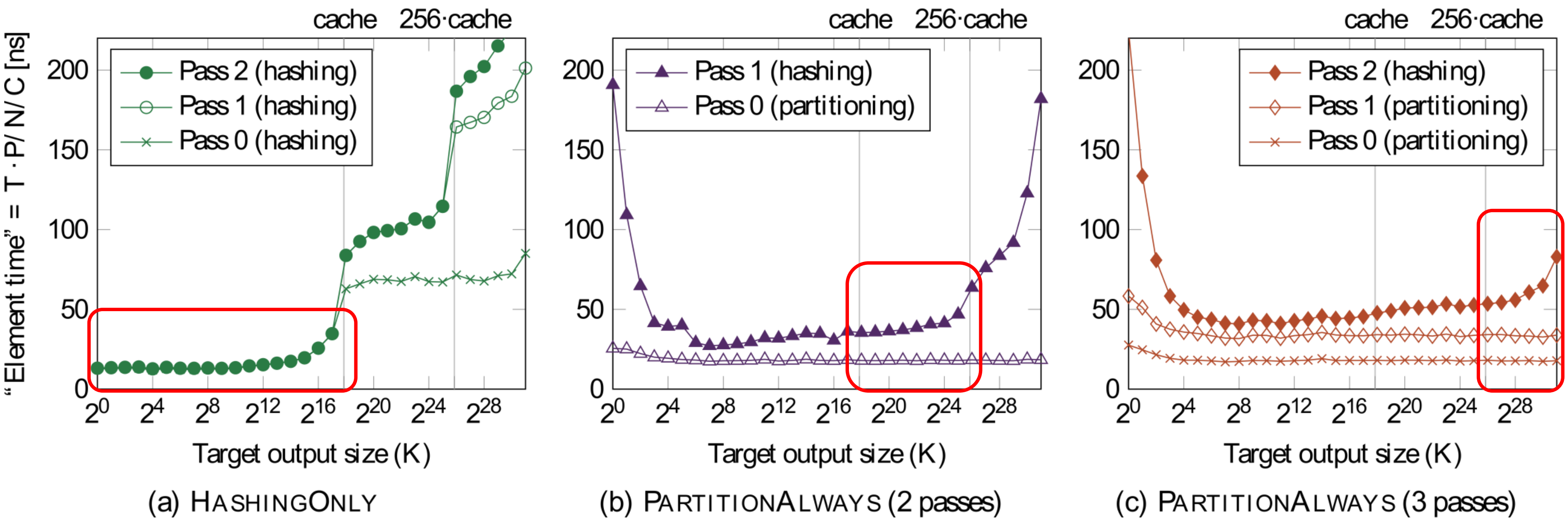
- Inserts into a *series* of hash tables (like insertion sort)
- Each of cache size → efficient (sort of)
- Does the actual aggregation

Subroutine “**Partitioning**”:

- Appends to hash partitions (like radix sort)
- Only sequential access → efficient
- Does no aggregation

Next question: when to use which routine?

Adaptation Mechanism (1/2)



"HashingOnly": **in cache** for small output size, slow recursive processing otherwise

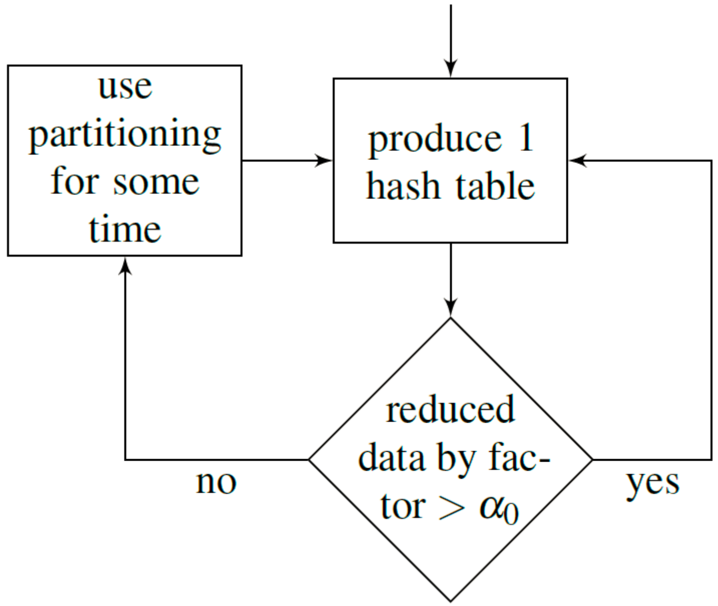
"PartitionAlways":

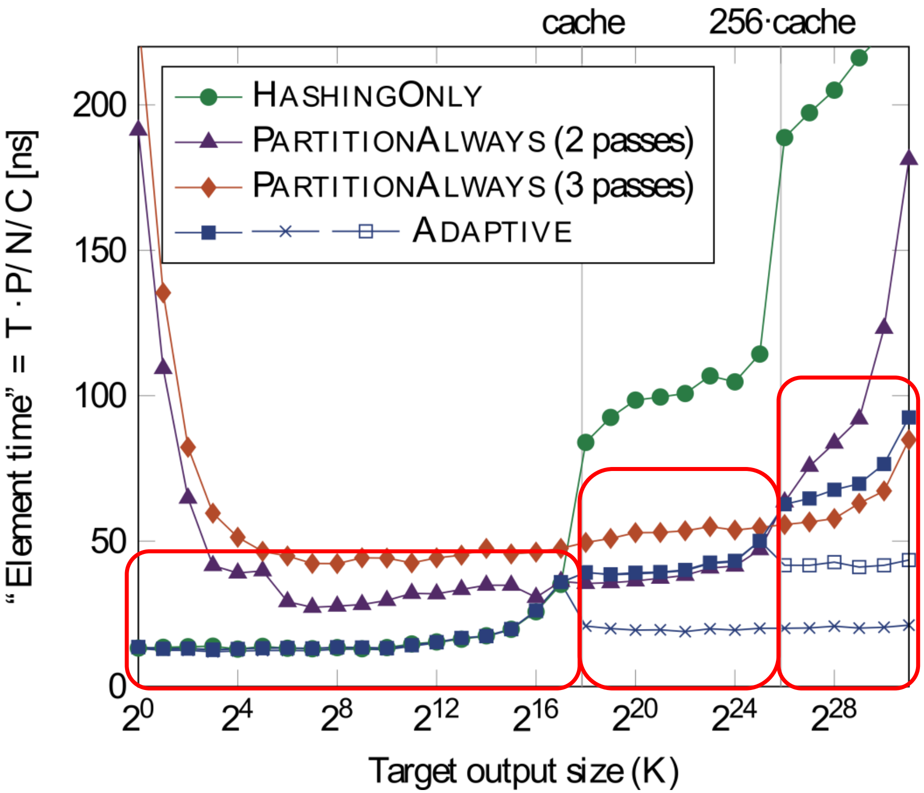
- Much **faster partitioning** (97% of speed of `memcpy` thanks to "Radix-Partitioning")
- No (early) aggregation → induced useless work for small output

Goal: use Hashing *iff* working set fits into cache.

Adaptation Mechanism (2/2)

Adaptive algorithm:





- **Partitioning** recurses when necessary
- **Hashing** ends recursion when possible efficiently

Our mechanism finds the right strategy *adaptively*.

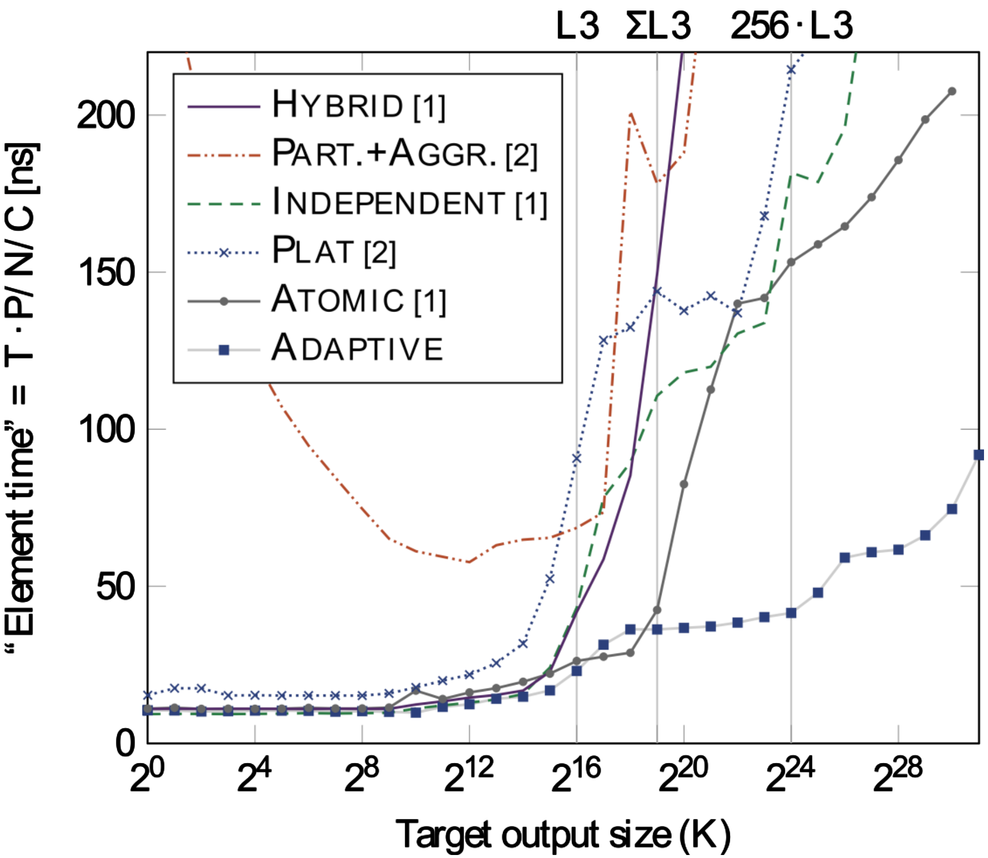
Evaluation: Comparison with Prior Work

State of the art:

- Implementations of :
  - Cieslewicz and Ross [1] & Ye et al. [2]
- 1-pass algorithms:
  - Hybrid
  - Atomic
- 2-pass algorithms:
  - Partition and Aggregate
  - Independent
  - PLAT

Result:

- "Adaptive" faster for $K > 2^{20}$
- Up to **factor 3.7** speedup



2 Xeon E7-8870 CPUs (each 10 cores), $N = 2^{32}$, uniform distribution.

Recursive processing is *crucial* for large outputs.

[1] J. Cieslewicz, K.A. Ross. Adaptive Aggregation on Chip Multiprocessors. In *PVLDB*, 2007. [2] Y. Ye, K.A. Ross, N. Vesdapunt. Scalable Aggregation on Multicore Processors. In *DaMoN*, 2011.

Summary and Outlook

- Observation: Hashing is **Sorting by hash value**.
- We can **combine them in a single algorithm** to combine their advantages.
- **Adaptation mechanism** provides robust, optimal performance up to **factor 3.7 faster** than prior work.
- What else to expect in the paper:
  - How to **parallelize**? How to integrate with **JiT** and **column-wise processing**?
  - How to tune hashing and sorting to **modern hardware**?
  - How to determine **thresholds**?
  - Why does it also work well in presence of **skew**?

Thank you