An Interval Join Optimized for Modern Hardware

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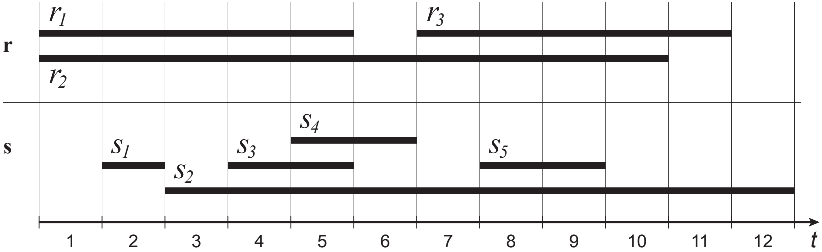
ICDE 2016, Helsinki, Finland

Interval Join



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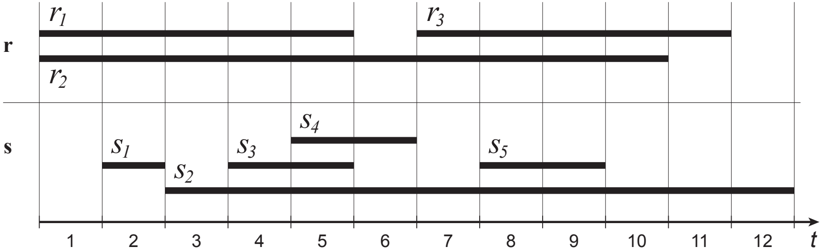

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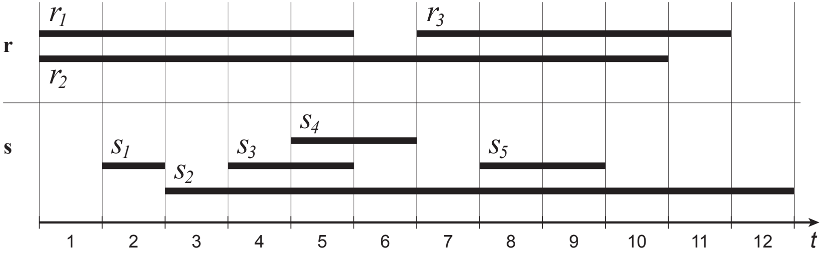

Problem: Find all pairs of intervals from **r** and **s** that overlap in time.
Answer: $\langle r_1, s_1\rangle$, $\langle r_1, s_2\rangle$, $\langle r_1, s_3\rangle$, $\langle r_1, s_4\rangle$, $\langle r_2, s_1\rangle$, $\langle r_2, s_2\rangle$, $\langle r_2, s_3\rangle$, $\langle r_2, s_4\rangle$, $\langle r_2, s_5\rangle$, $\langle r_3, s_2\rangle$, $\langle r_3, s_5\rangle$.

So, what's the problem?

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SELECT *
FROM r, s
WHERE r.Ts <= s.Te AND s.Ts <= r.Te
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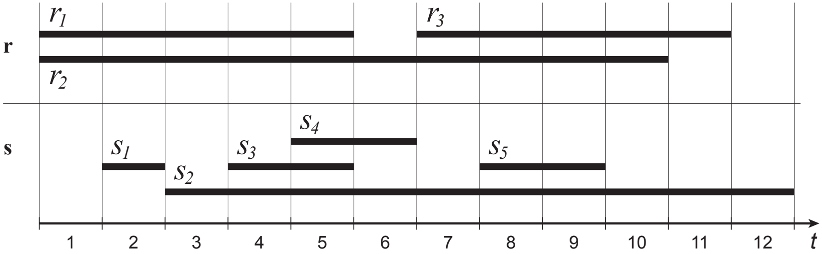
Join on two independent inequality predicates

No optimization in standard RDBMSs.

Endpoint Index



Idea: List interval endpoints $\langle T_s, \text{start}, TID\rangle$ and $\langle T_e, \text{end}, TID\rangle$ in chronological order

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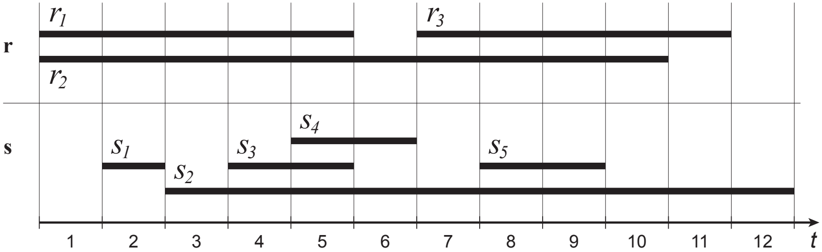

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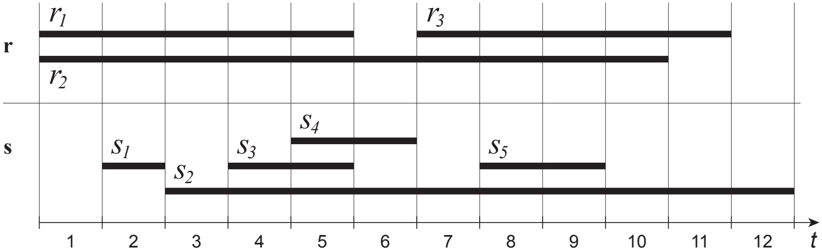
Result: Endpoint index for relation **r** is $[\langle 1, \text{start}, 1 \rangle, \langle 1, \text{start}, 2 \rangle, \langle 5, \text{end}, 1 \rangle, \langle 7, \text{start}, 3 \rangle, \langle 10, \text{end}, 2 \rangle, \langle 11, \text{end}, 3 \rangle]$.

Endpoint-Index-Based Interval Join



Active **r** tuples: {}
Active **s** tuples: {}
Result:

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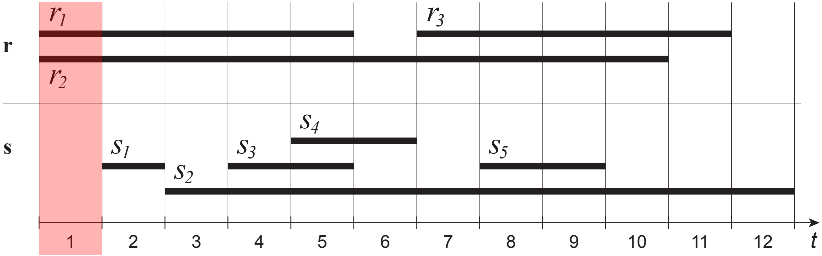

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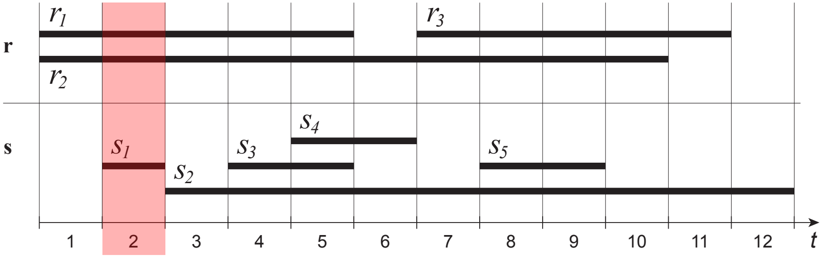

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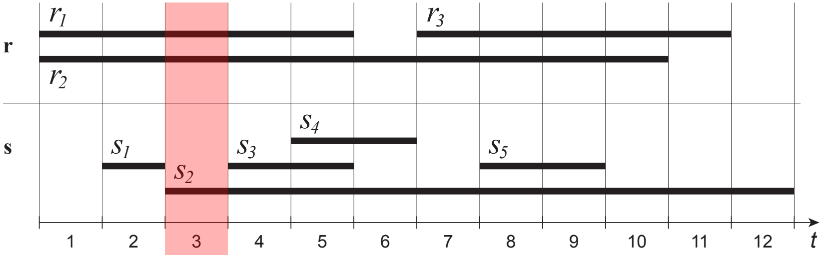

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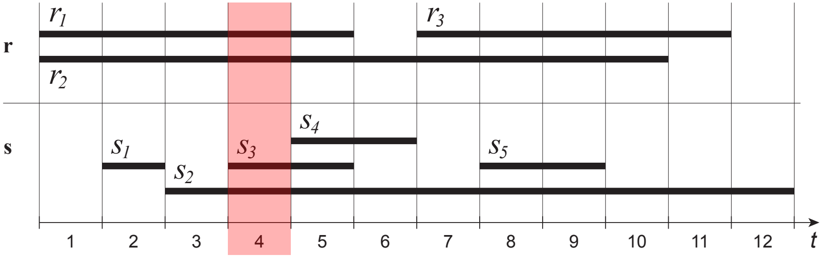

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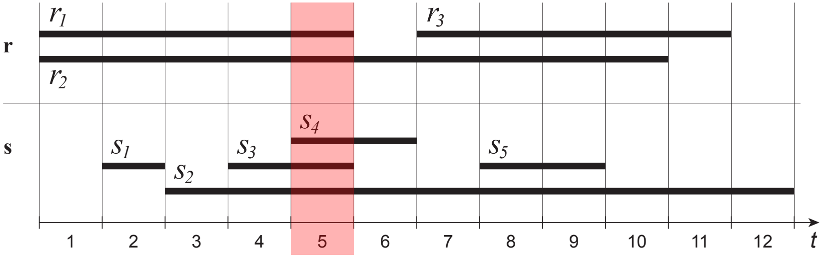

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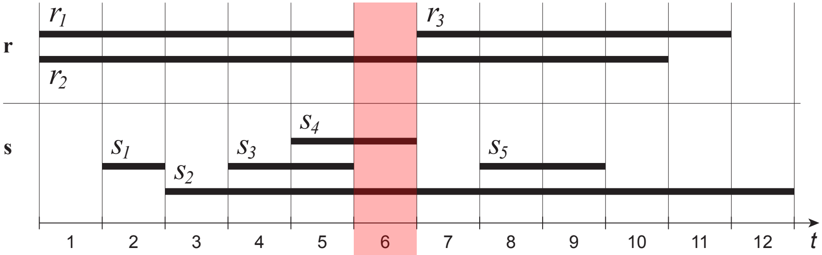

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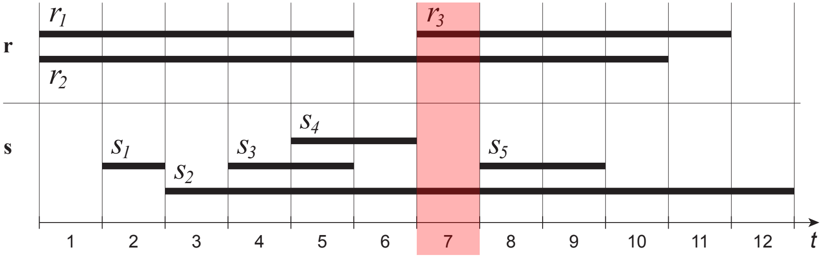

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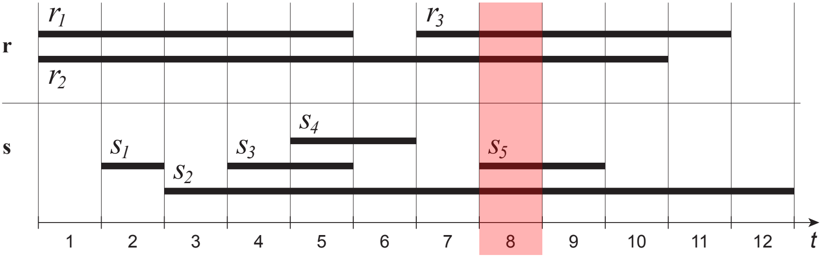

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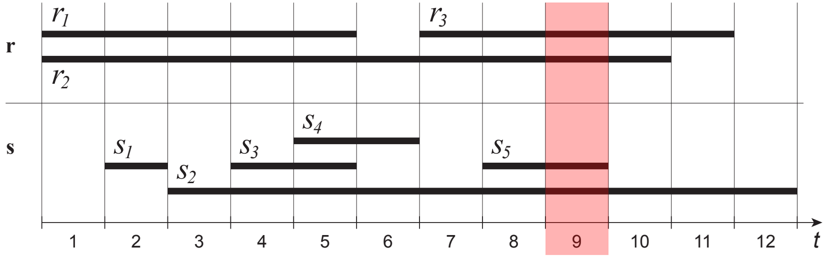

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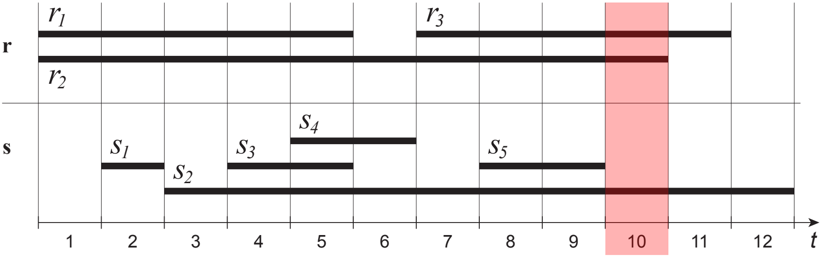

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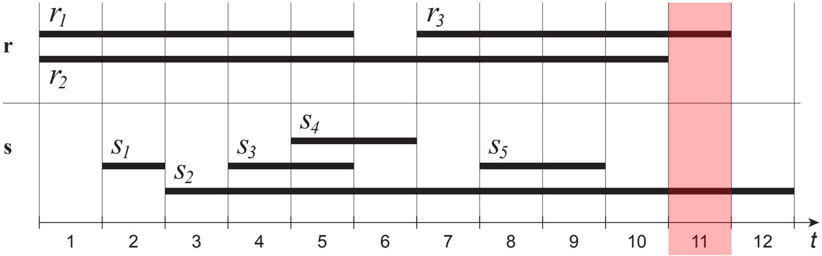

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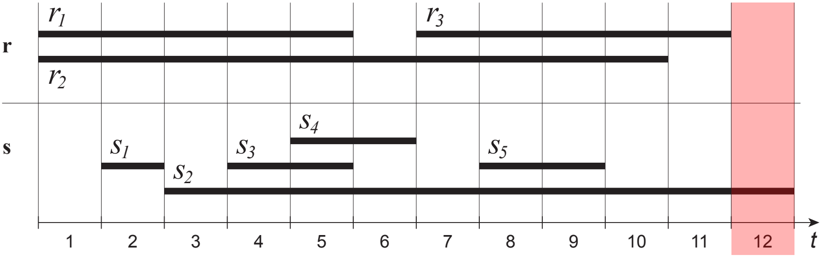

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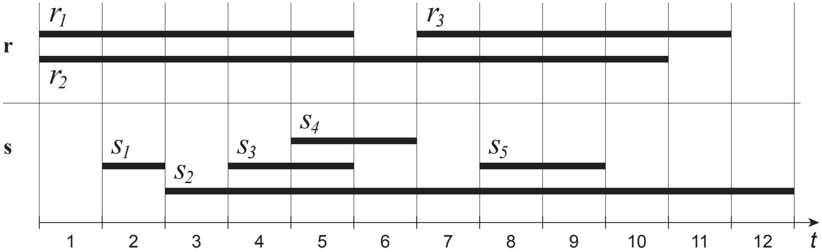

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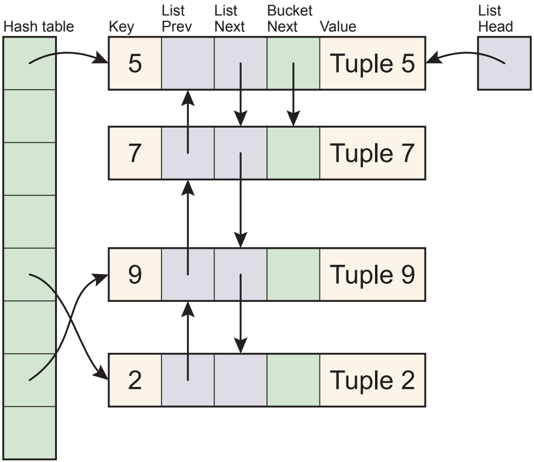
- Good candidate is hash map...
- ...but it's not very suited for scanning
- Existing solutions:
  - Scan through buckets (`std::unordered_map`, `java.util.HashMap`)
  - Connect elements via linked list (`java.util.LinkedHashMap`)

Standard Linked Hash Map



Random vs. Sequential Memory Access

- Random memory access latency:
  - Within L1 cache (32 KB per core): 4 CPU cycles
  - Within L2 cache (256 KB per core): 11–12 cycles
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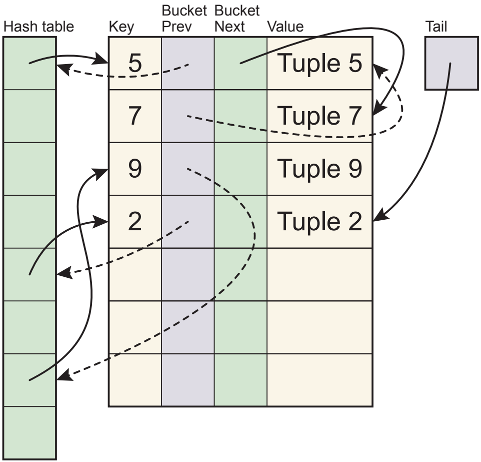
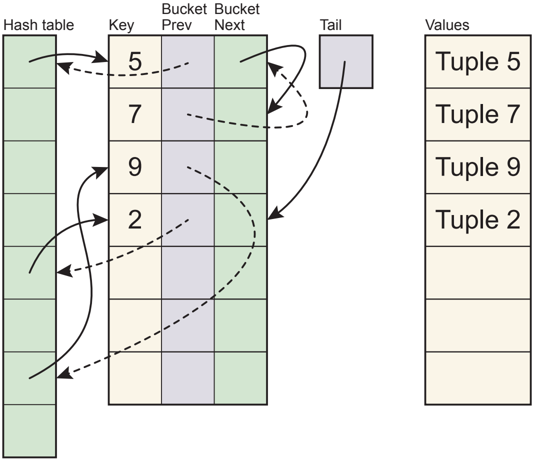
- Sequential RAM access speed:
  - A thread can read RAM at $\sim$10 GB/s
  - 1 ns (about 3 CPU cycles) for reading every 10 bytes

Gapless Hash Map



Gapless Hash Map (Separated Values)



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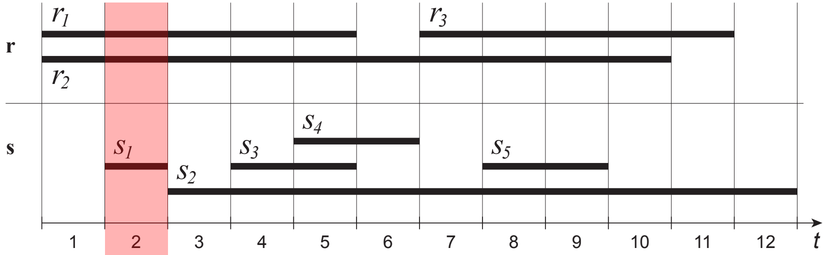

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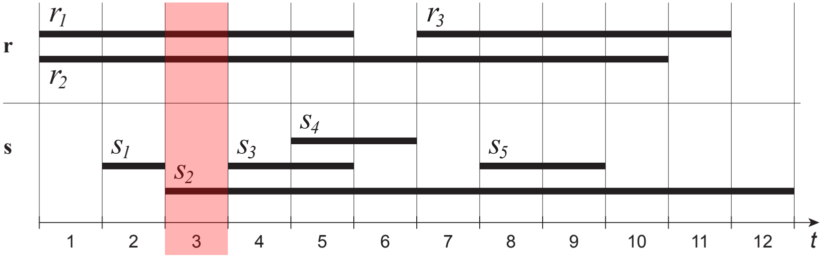

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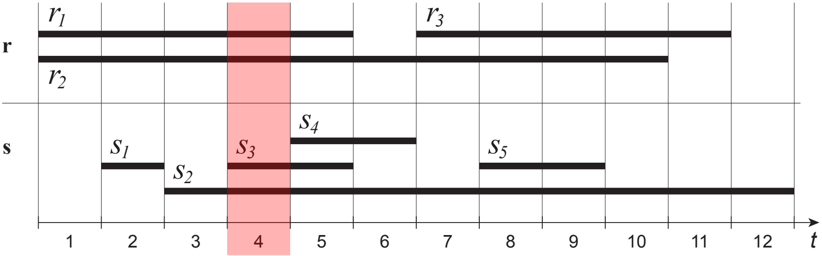

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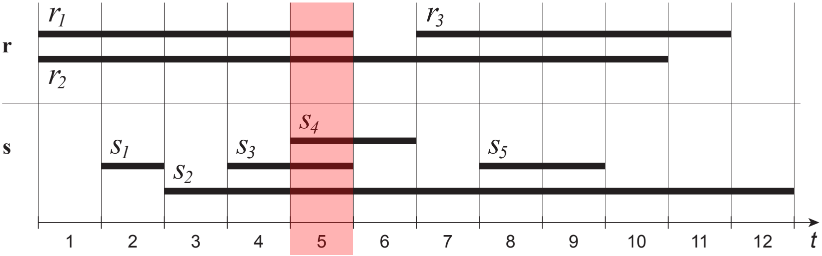

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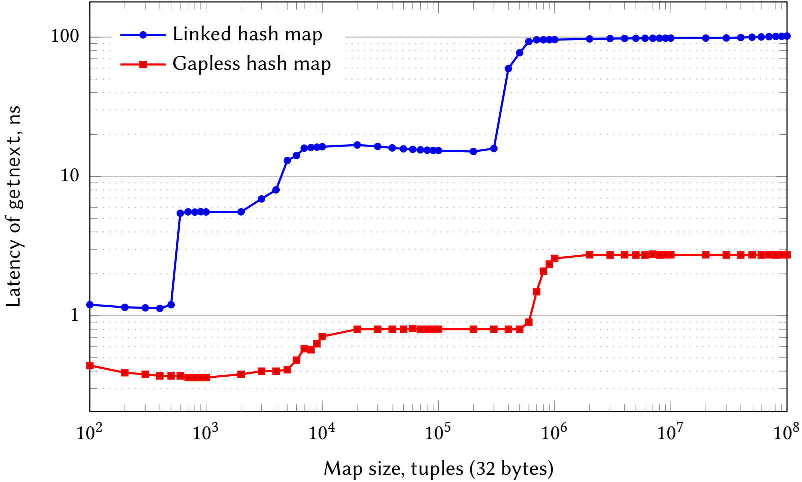
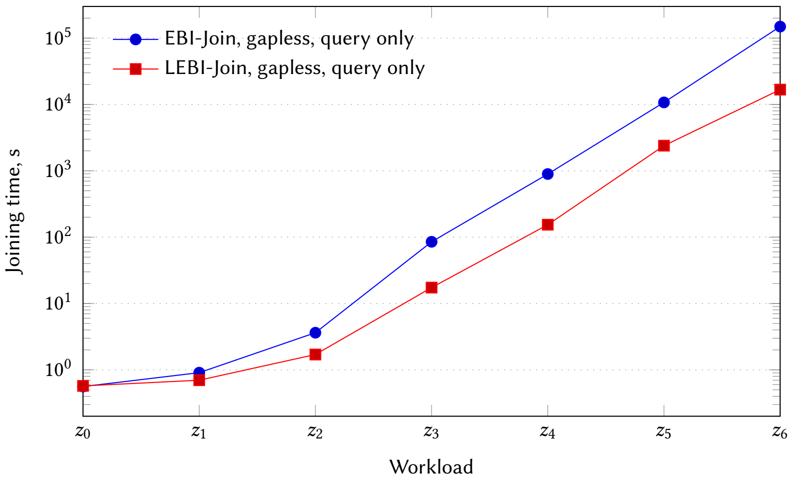
- Even sequential, RAM scan is slower than L1 cache scan
- Observation: In our demo the unmodified set of active **r** tuples was scanned 4 times in a row, once for each of s_1, s_2, s_3 and s_4.
- Idea: Collect these **s** tuples into small array fitting L1 CPU cache and produce cross-product with active set of **r** tuples by scanning it just once.

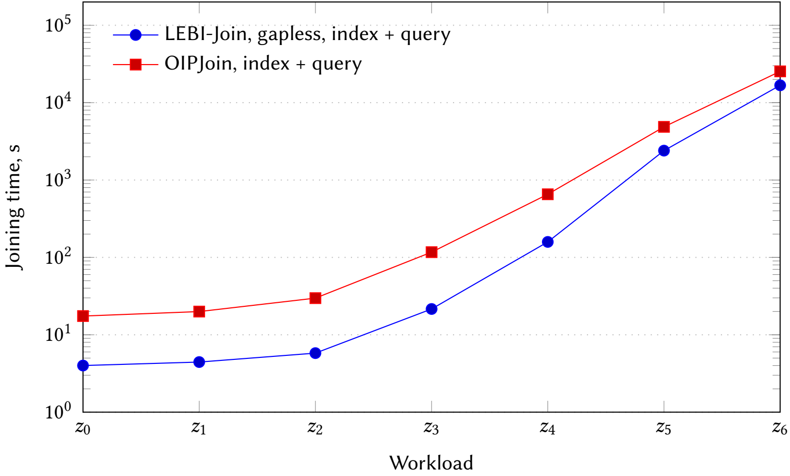
Hash map scanning performance



EBI-Join vs. LEBI-Join



Comparison With the State-of-the-Art



Conclusion

- We took the endpoint-index-based interval join (EBI-Join)
- We introduced two memory-hierarchy-aware optimizations for it:
  - Gapless hash map
  - Lazy evaluation technique (LEBI-Join)
- With these optimizations we are able to outperform the state-of-the-art