Pump Up the Volume: Processing Large Data on GPUs with Fast Interconnects

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Goal

*Scale GPU-accelerated data management to **arbitrary data volumes**.*

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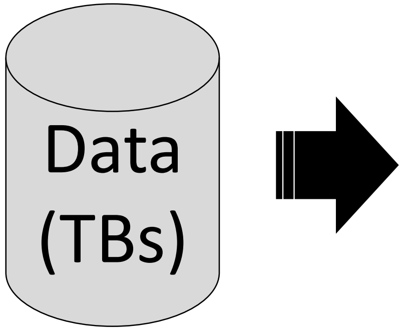
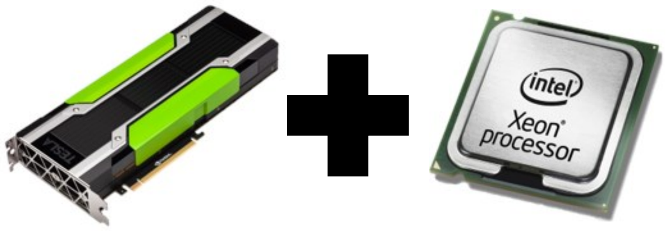


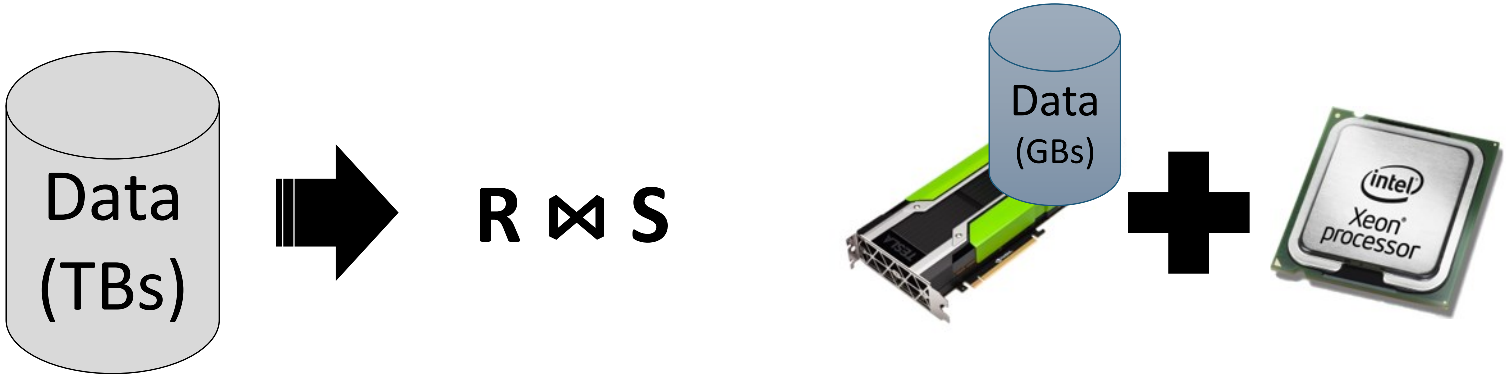
Data (TBs)

R ⋈ S



Goal

Scale GPU-accelerated data management to ***arbitrary data volumes.***

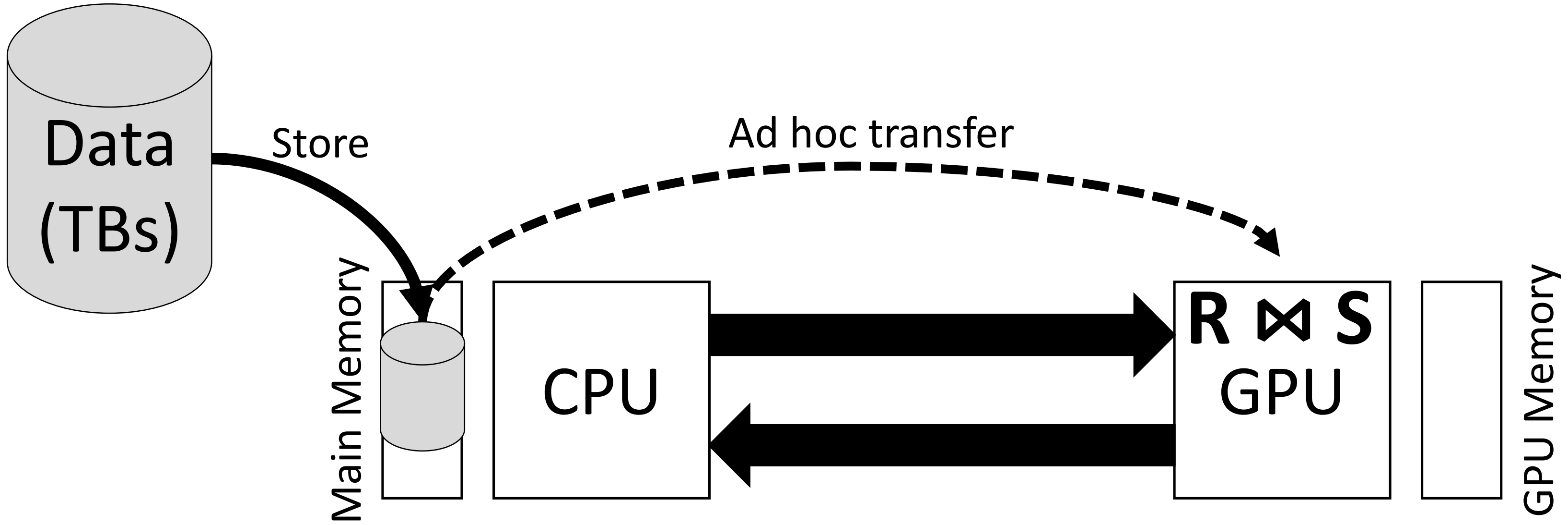


Data (TBs)

R ⋈ S

Data (GBs)

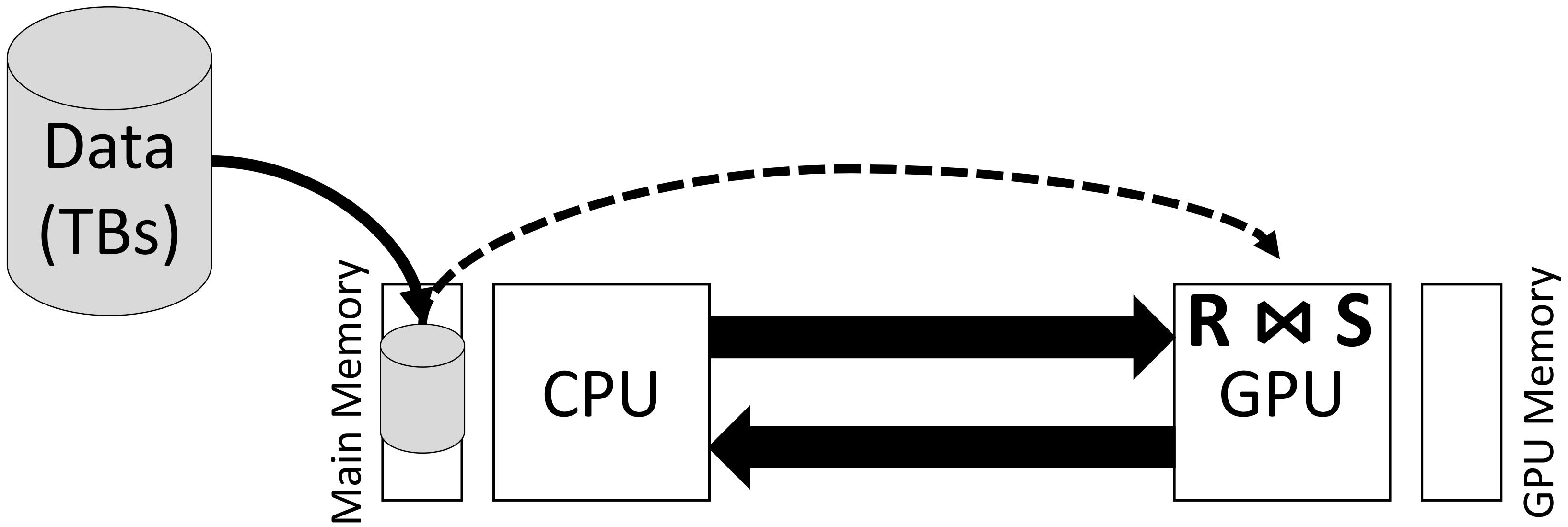
Problem 1: Transfer Bandwidth



Today’s GPU databases:

- Store data in main memory
- Perform data processing on GPU

Problem 1: Transfer Bandwidth



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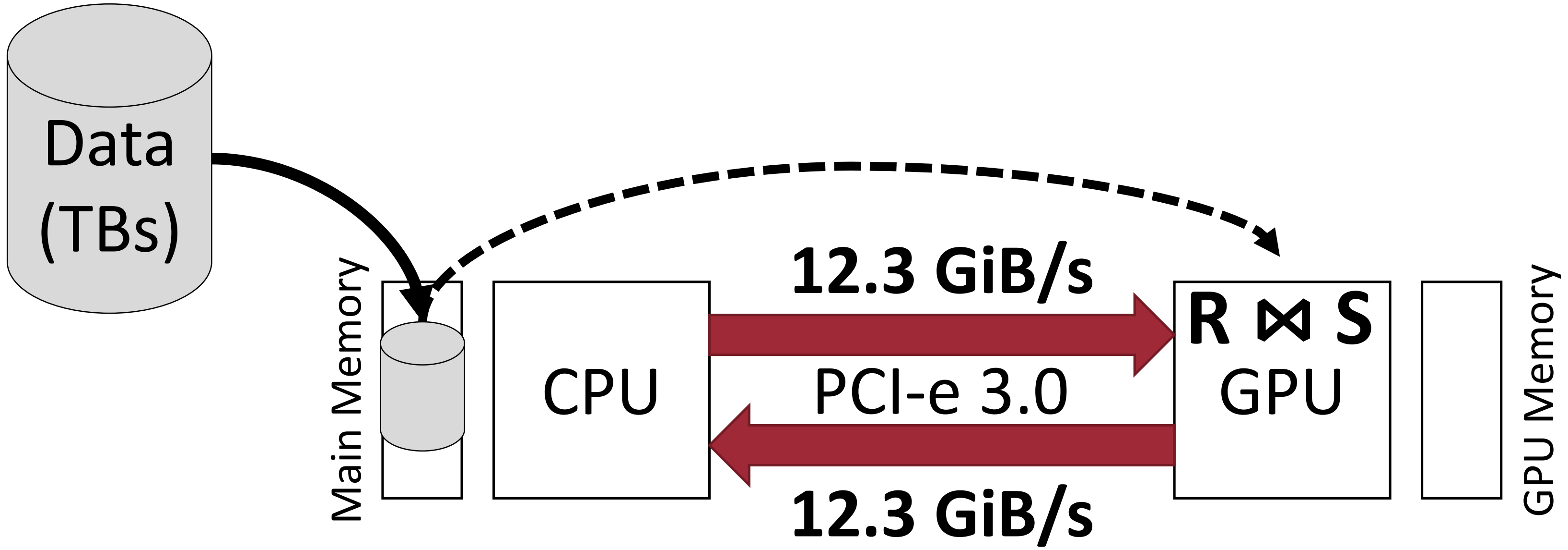
SQREAM

Problem 1: Transfer Bandwidth



- Ad hoc data transfer over PCI-e 3.0
- GPU capable of much higher throughput

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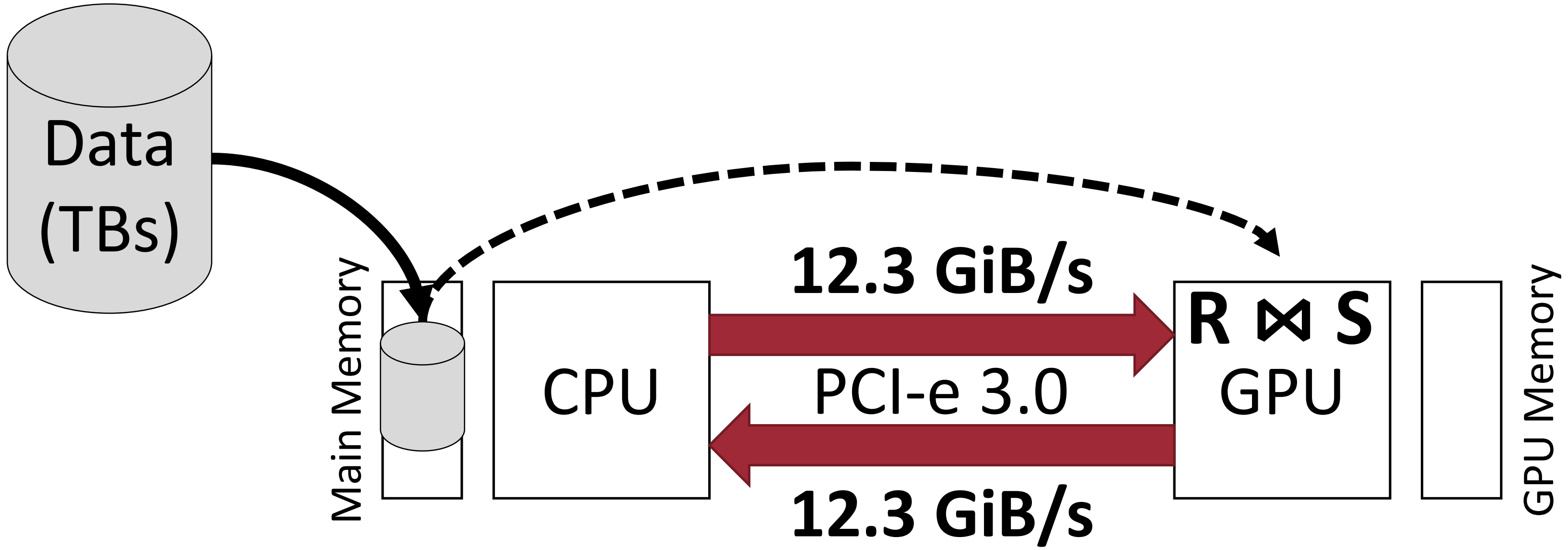

Interconnect bandwidth & GPU memory capacity limit scalability

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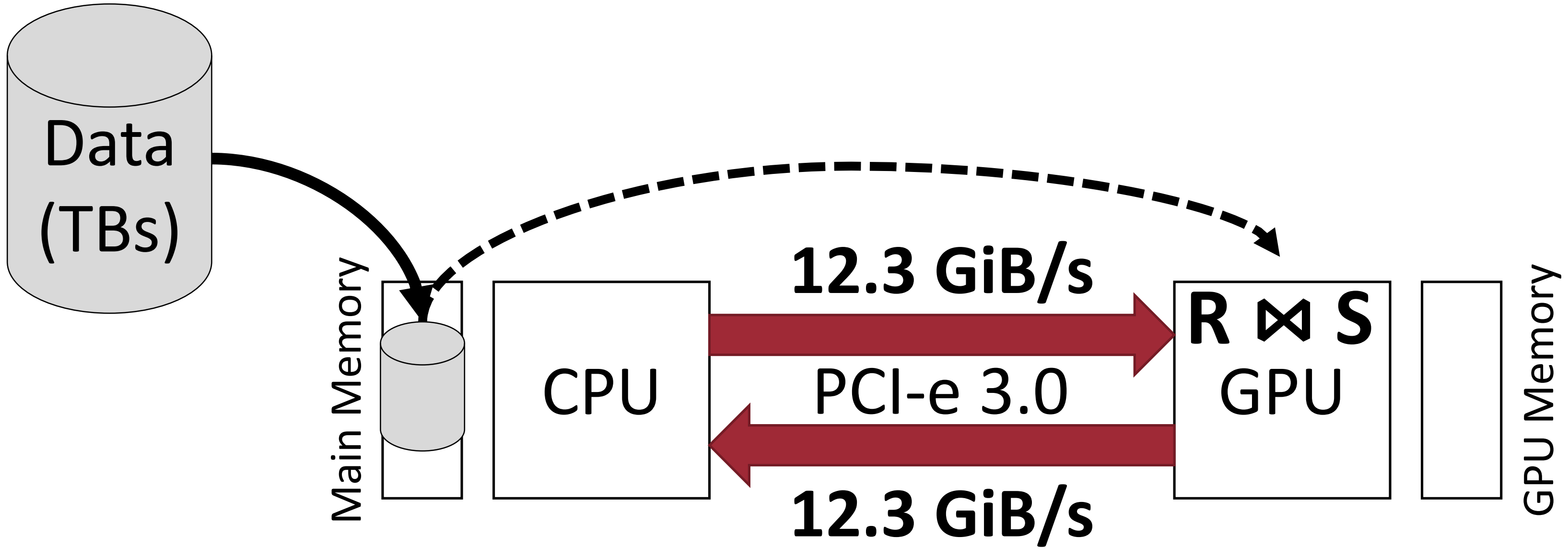
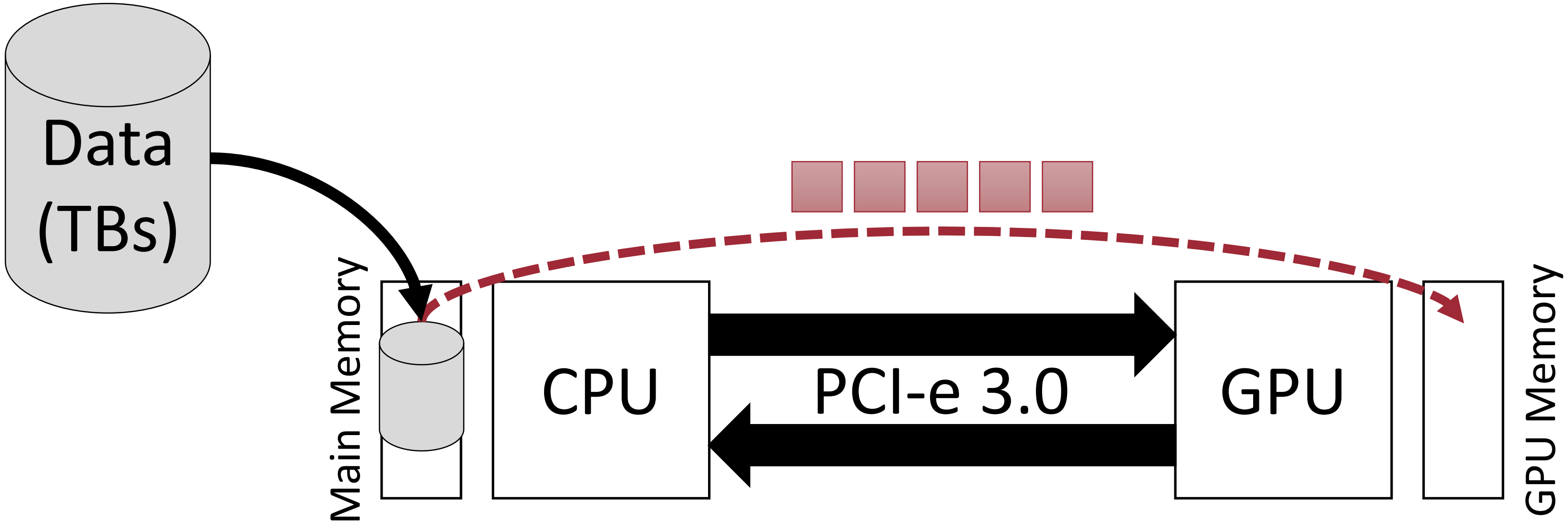


Interconnect bandwidth & GPU memory capacity limit scalability

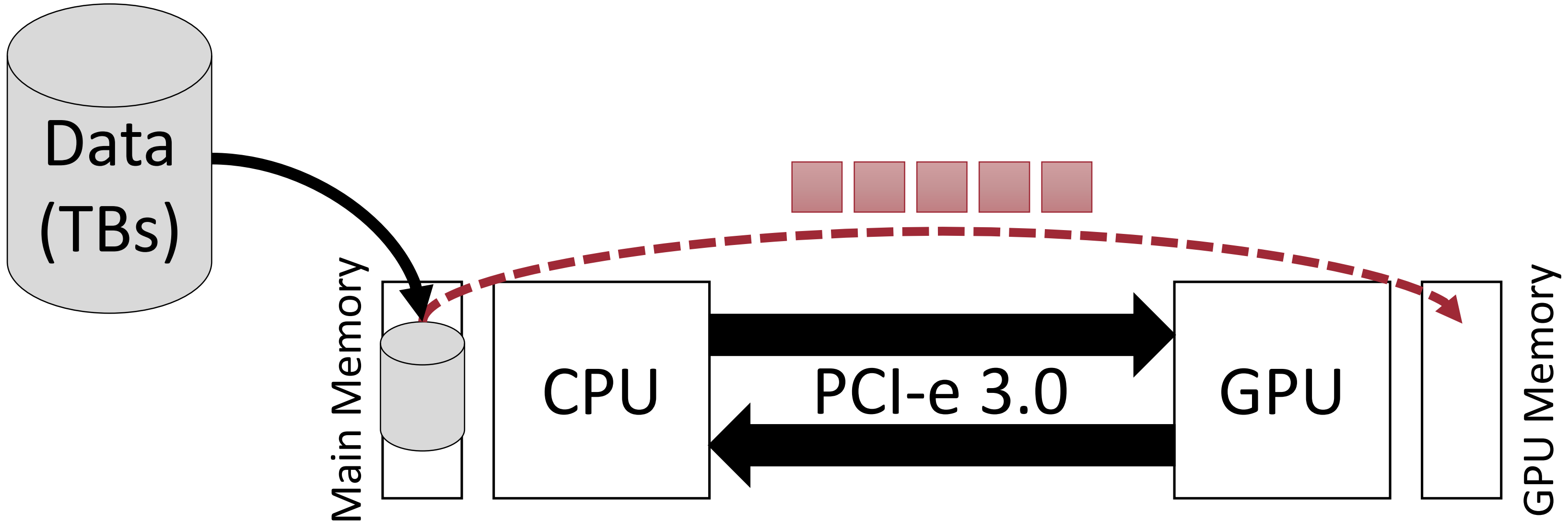
“Transfer bottleneck”

Problem 2: Course-Grained Cooperation



- Data-dependent memory accesses not possible
- Fine-grained CPU+GPU cooperation not possible

Problem 2: Course-Grained Cooperation



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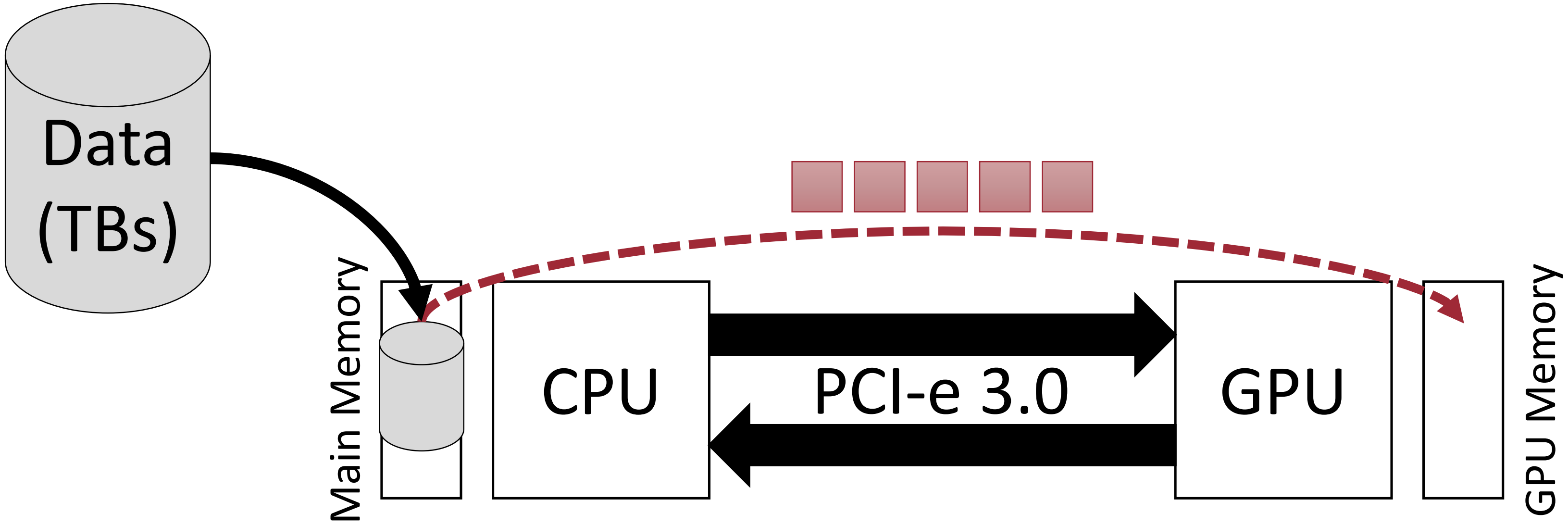
} Data structures

Problem 2: Course-Grained Cooperation



Non-cache coherence limits design space & co-processing

Game Changer

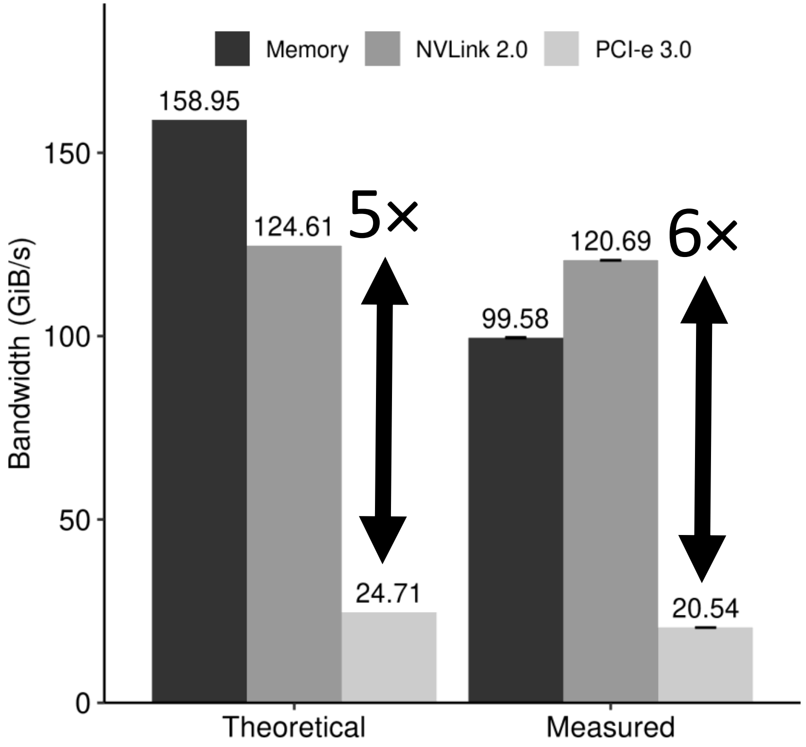
- Fast interconnects

  e.g., NVLink 2.0, Infinity Fabric, CXL

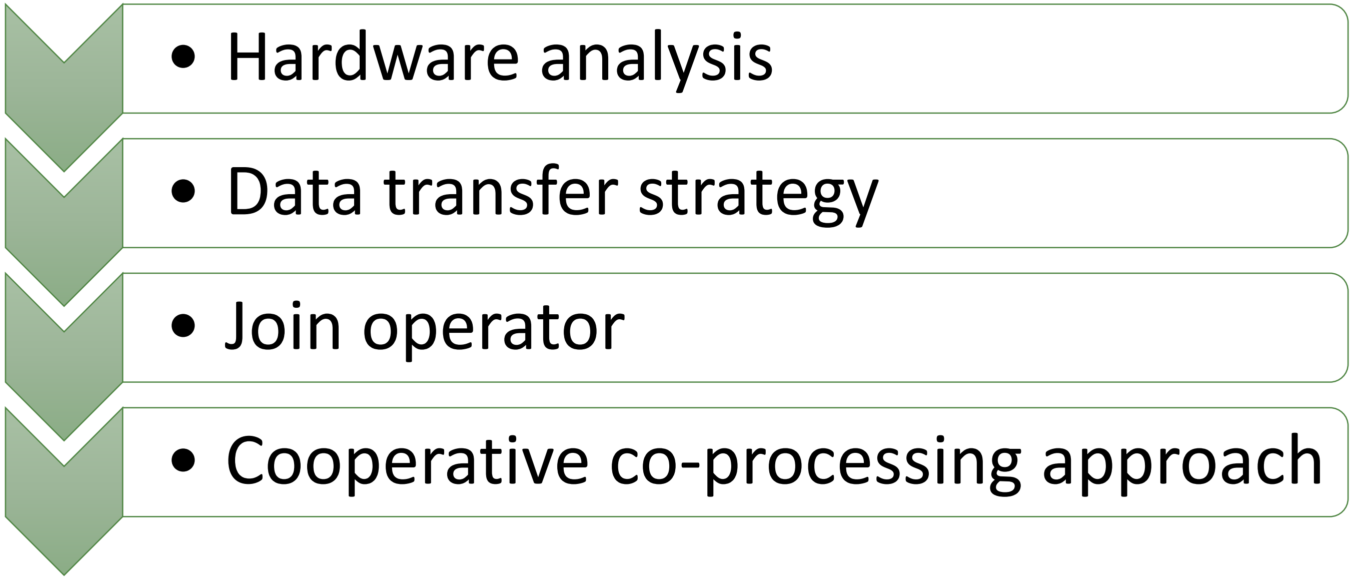
- High bandwidth (124 GiB/s total)
- System-wide cache-coherence

  - data-dependent memory access

  - fine-grained CPU+GPU cooperation

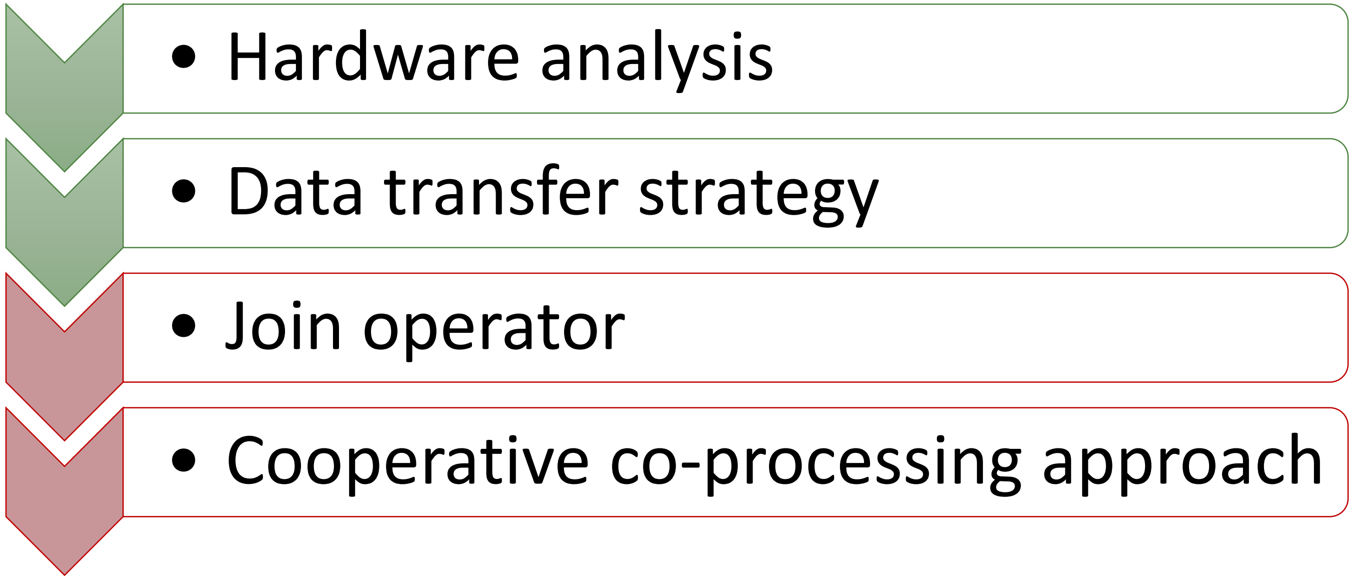


Contributions



- Hardware analysis
- Data transfer strategy
- Join operator
- Cooperative co-processing approach

Contributions



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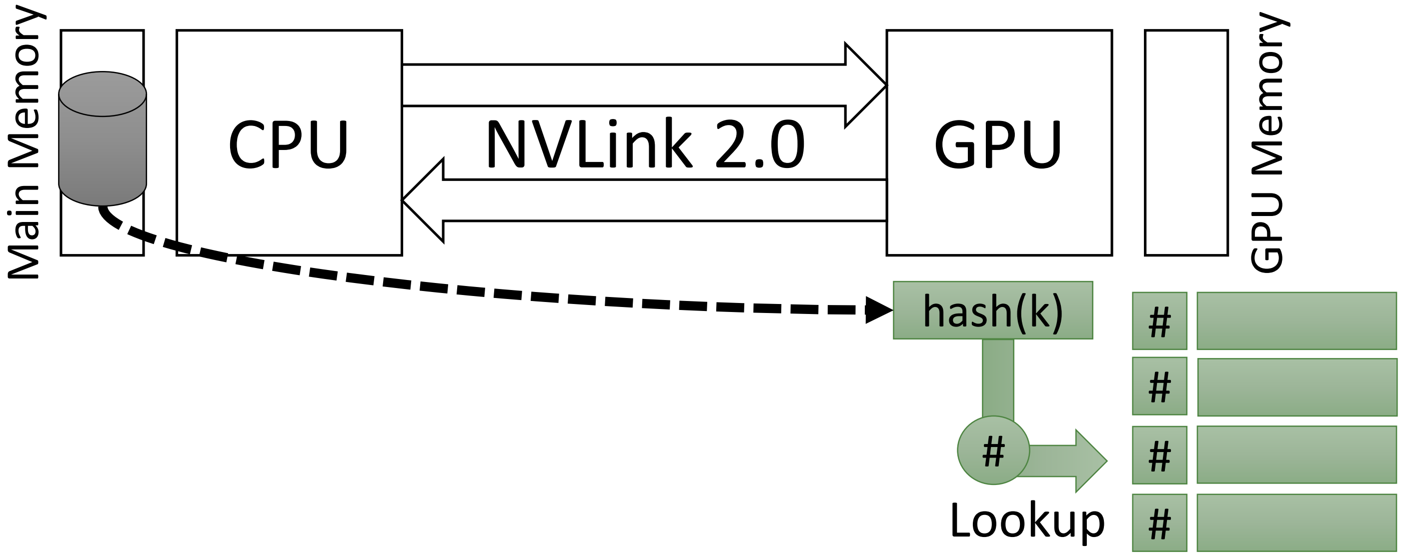
Solution

Hash Join

- Probe-side scaling
- Build-side scaling
- GPU+CPU Cooperation

Probe-Side Scaling



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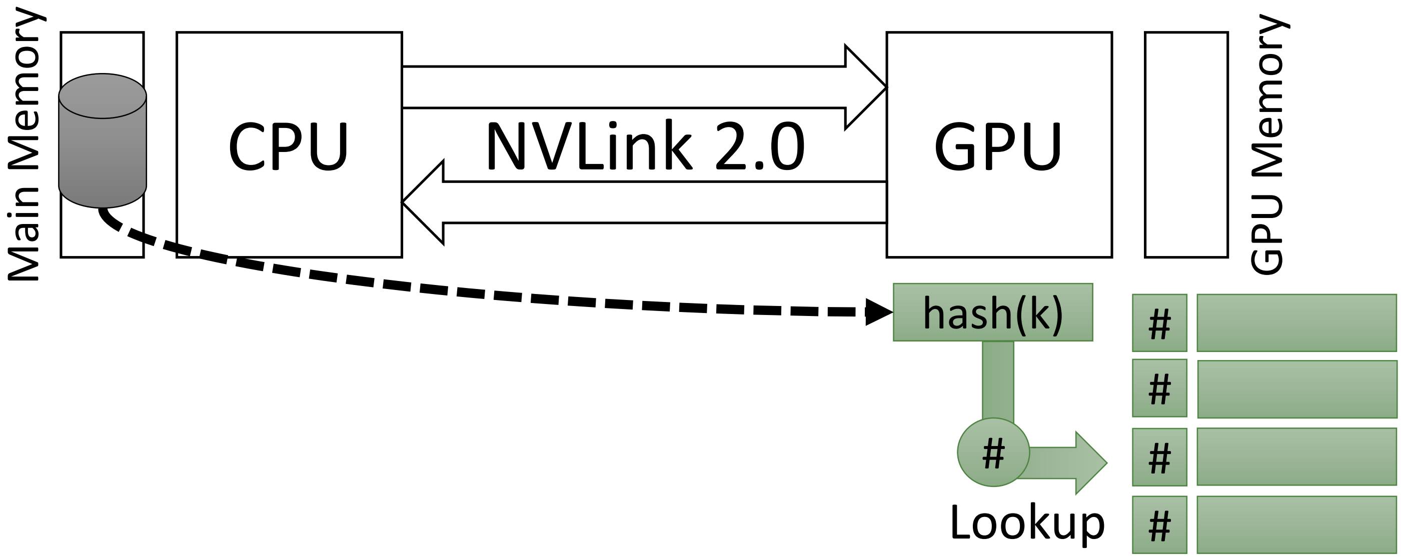
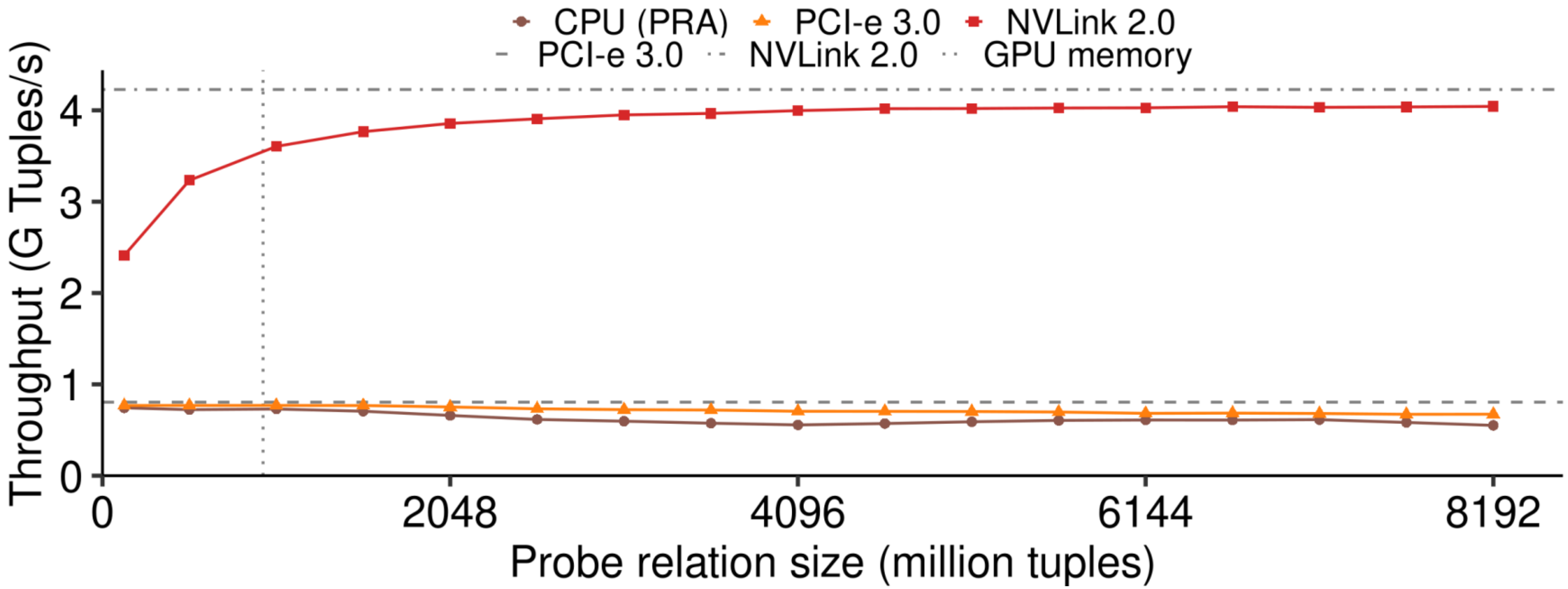


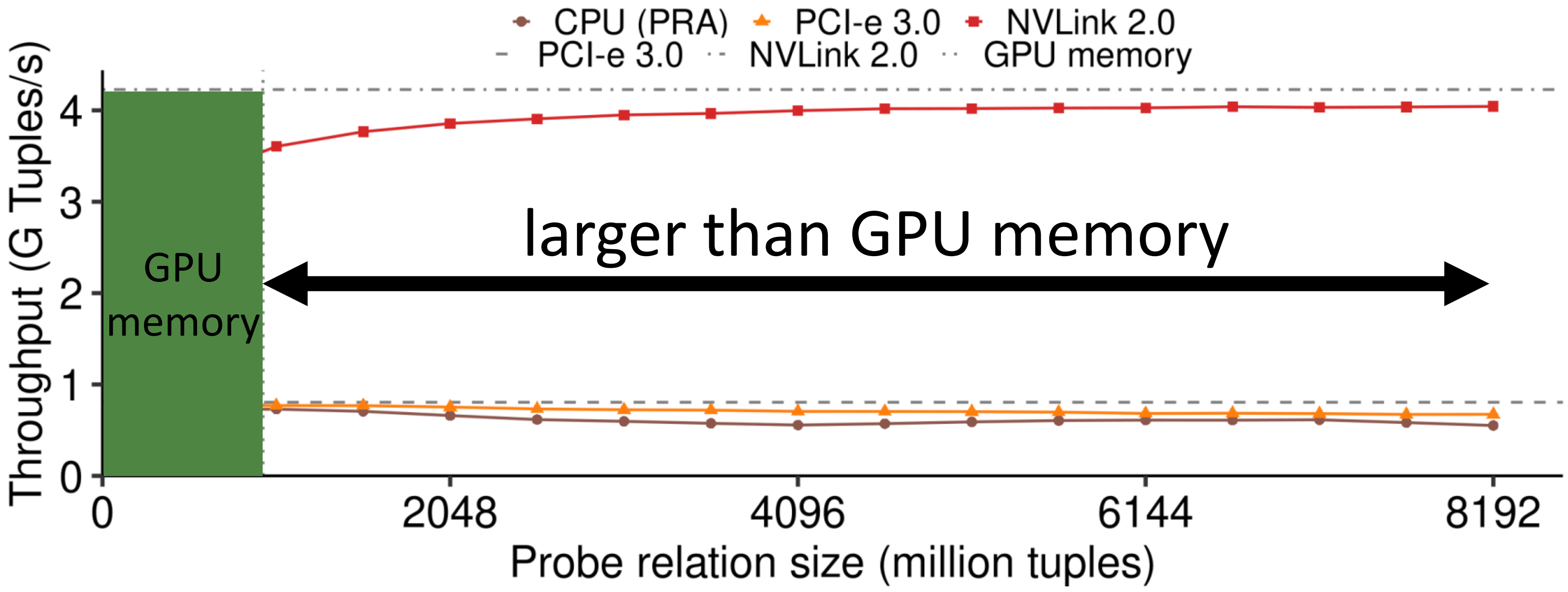
Interconnect feature: High bandwidth

Probe-Side Scaling



- Up to 2⋈122 GiB

Probe-Side Scaling



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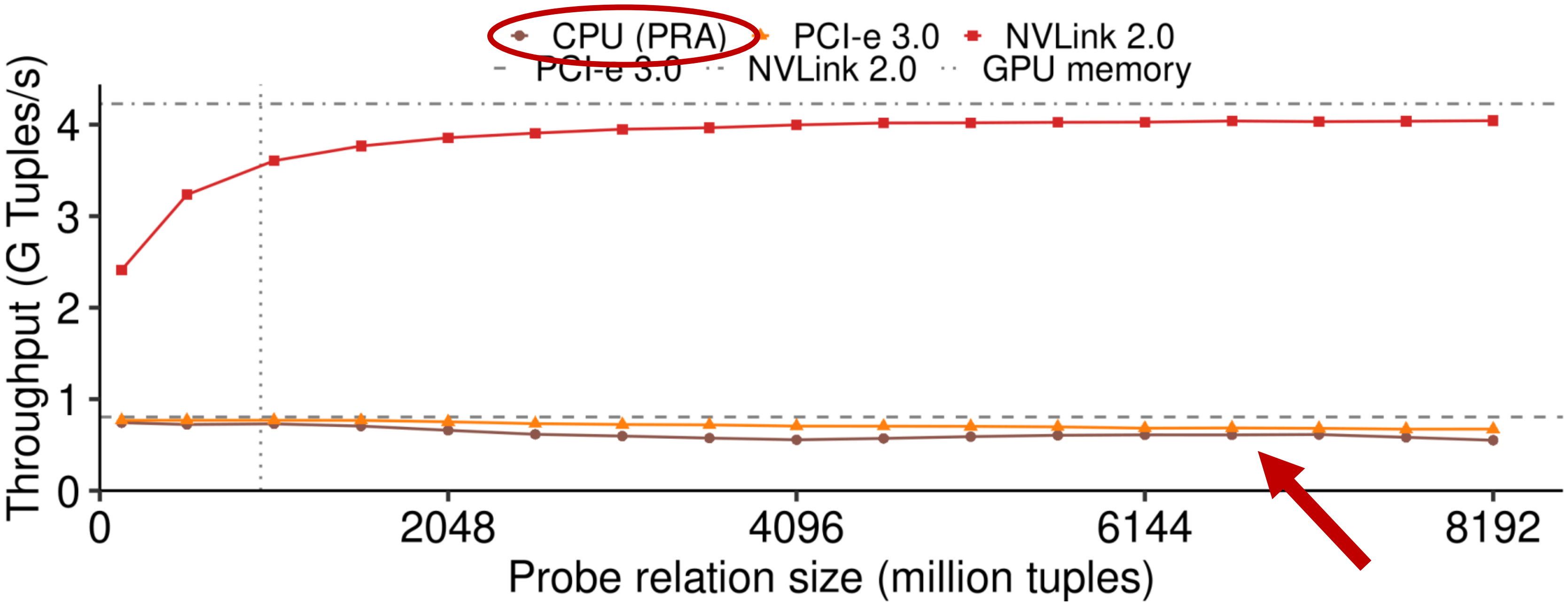

- Up to 2⋈122 GiB
- CPU baseline: Radix-partitioned hash join

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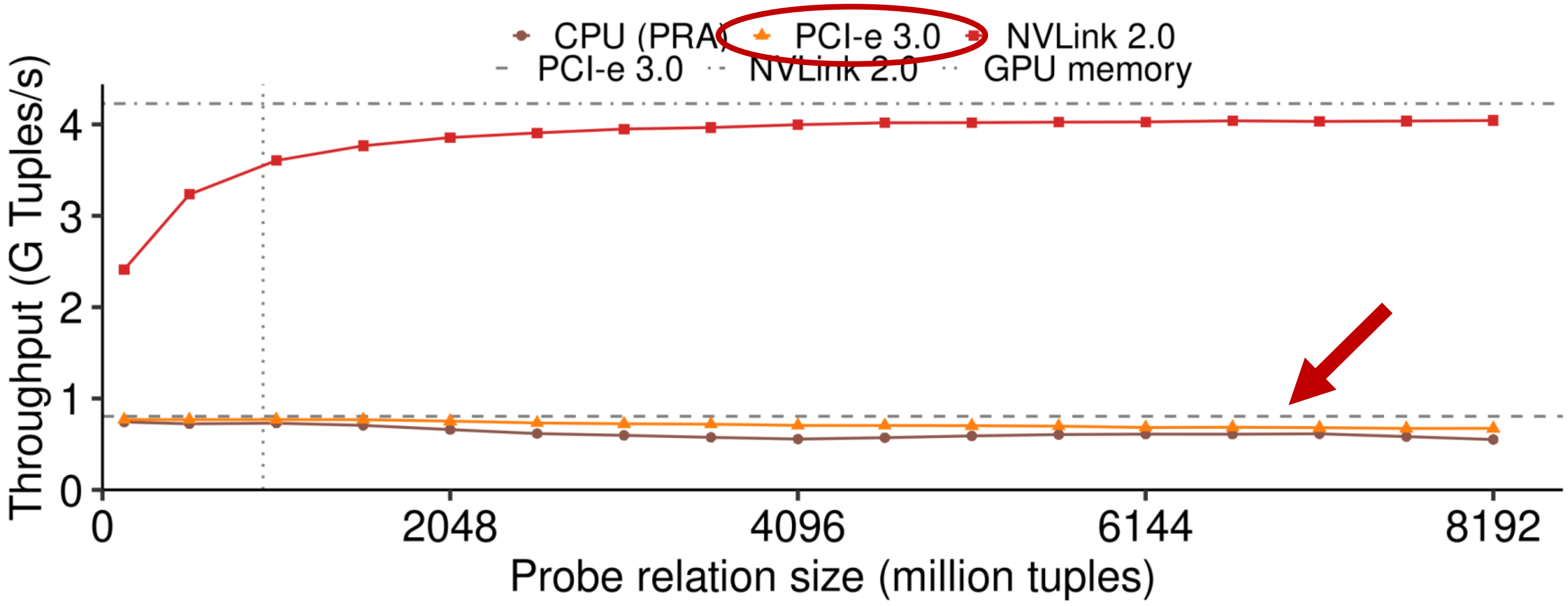

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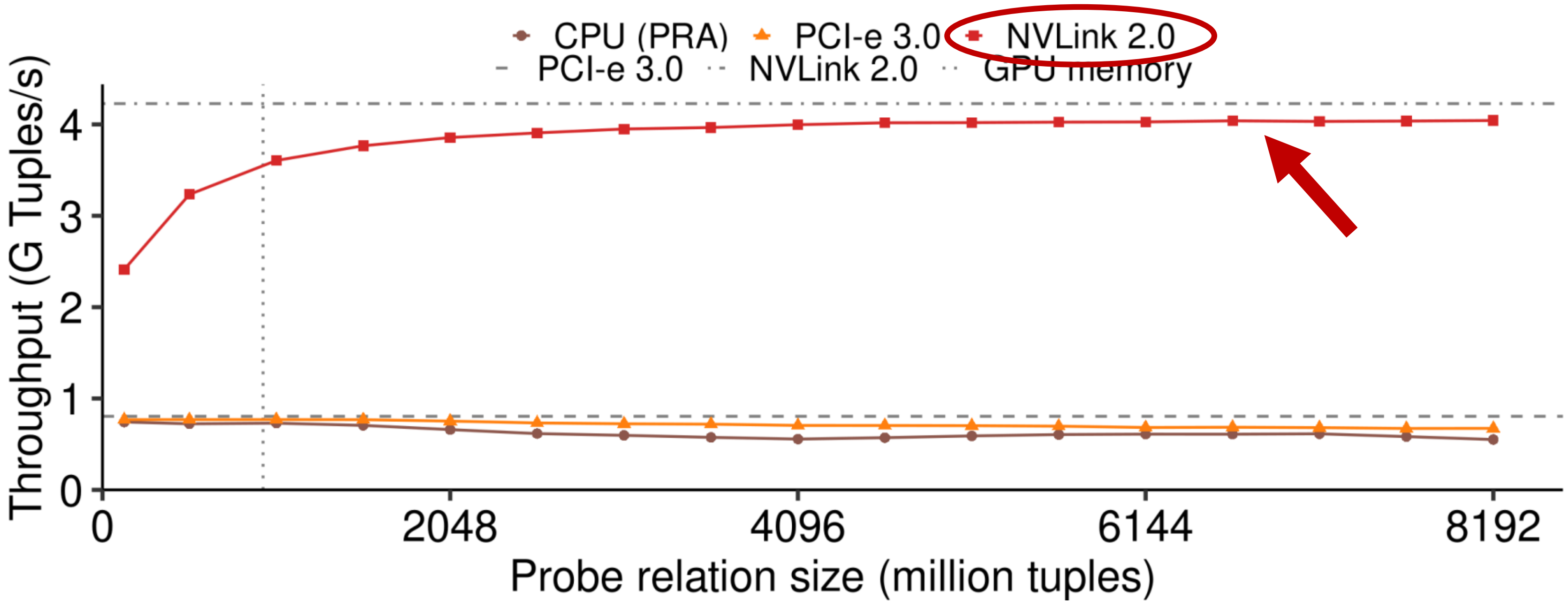

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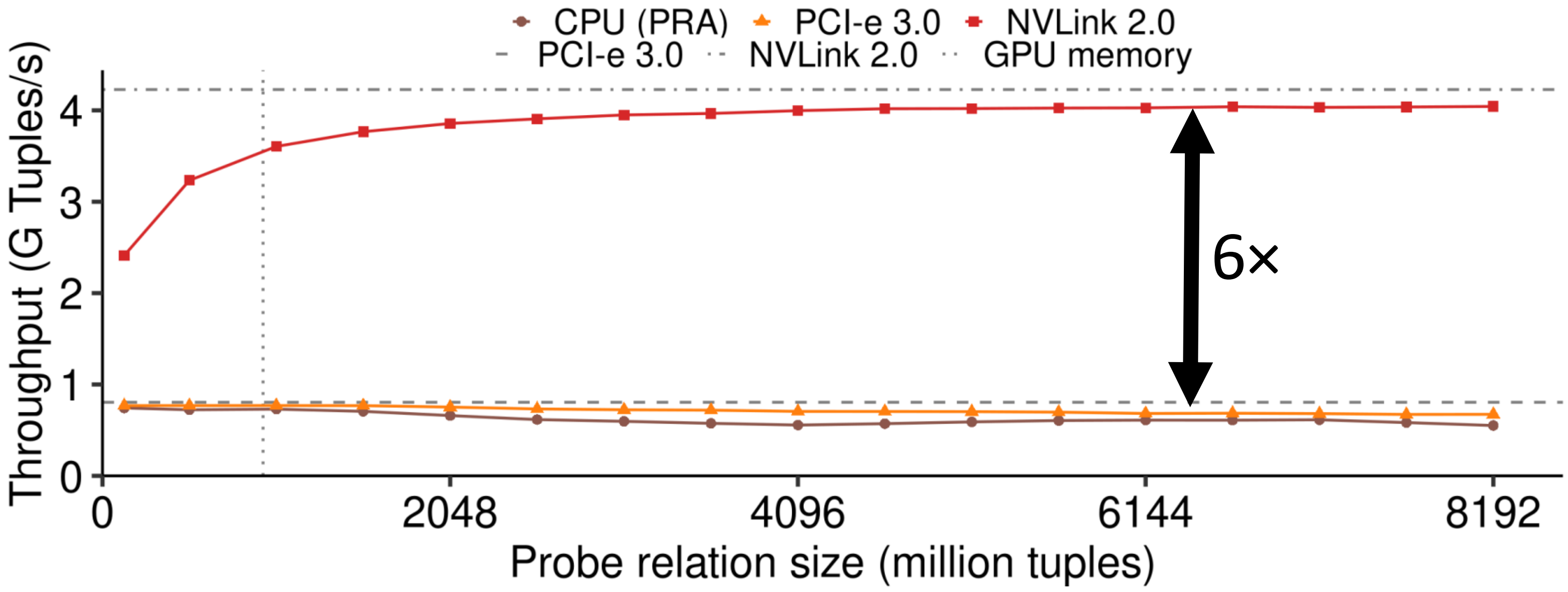

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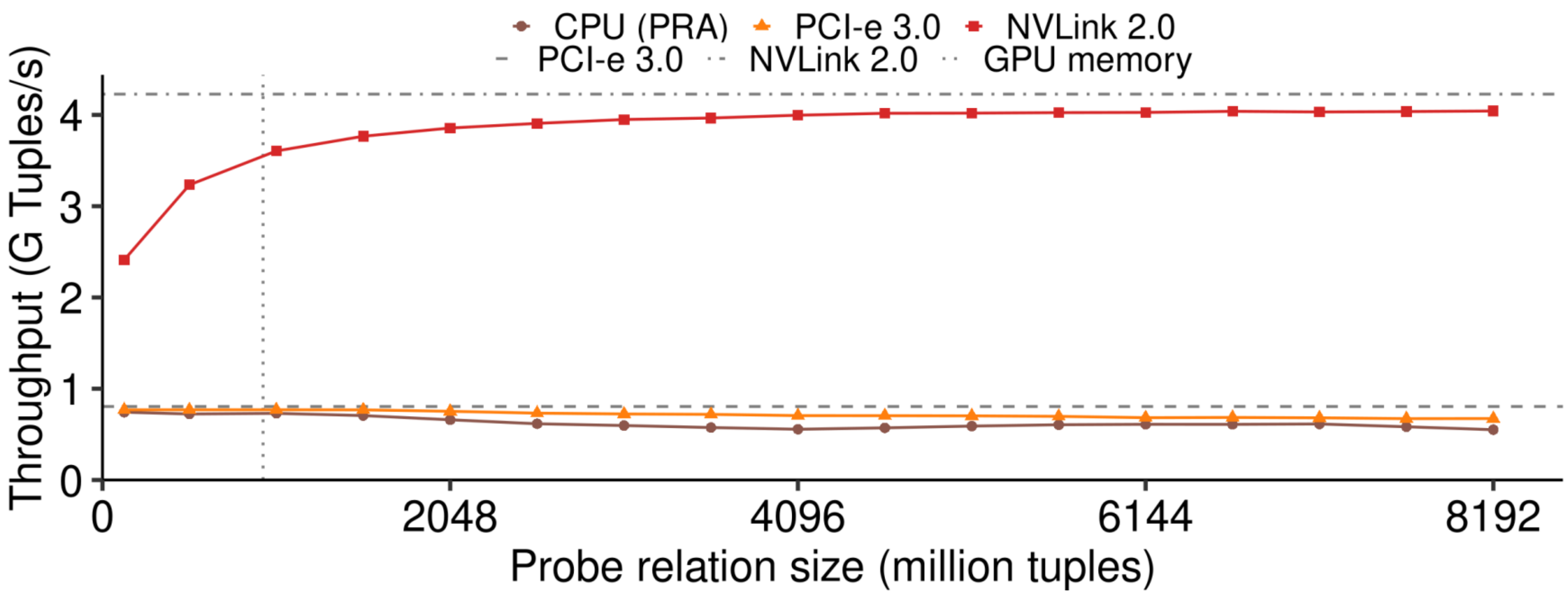
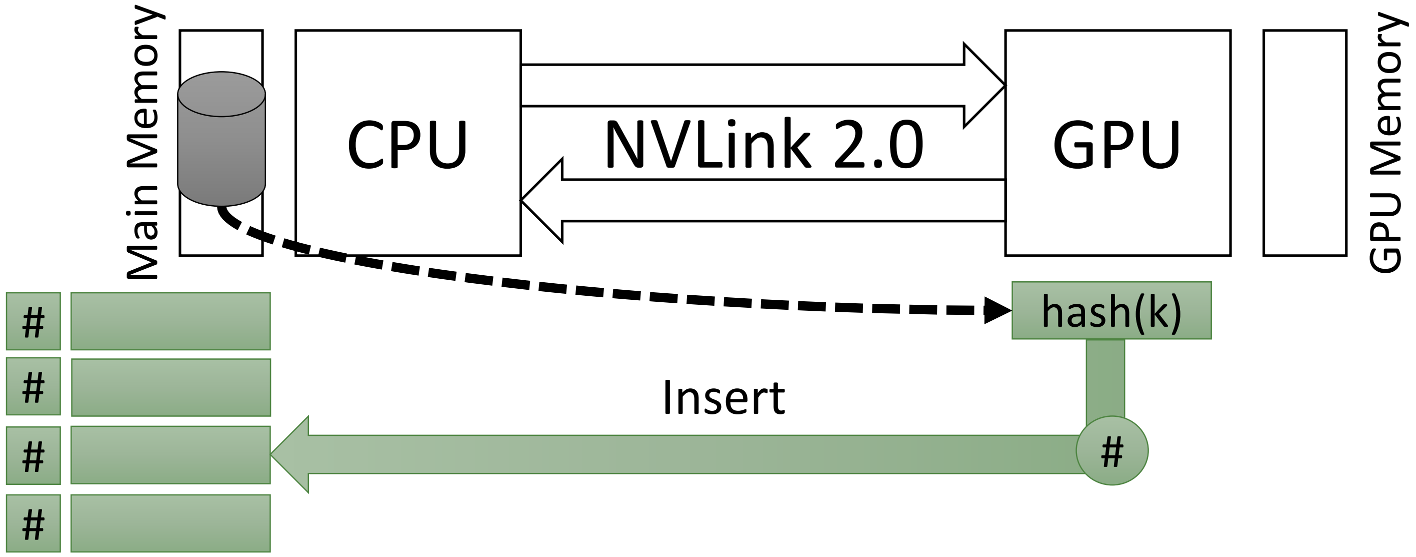


GPUs can efficiently process large, out-of-core data

Build-Side Scaling



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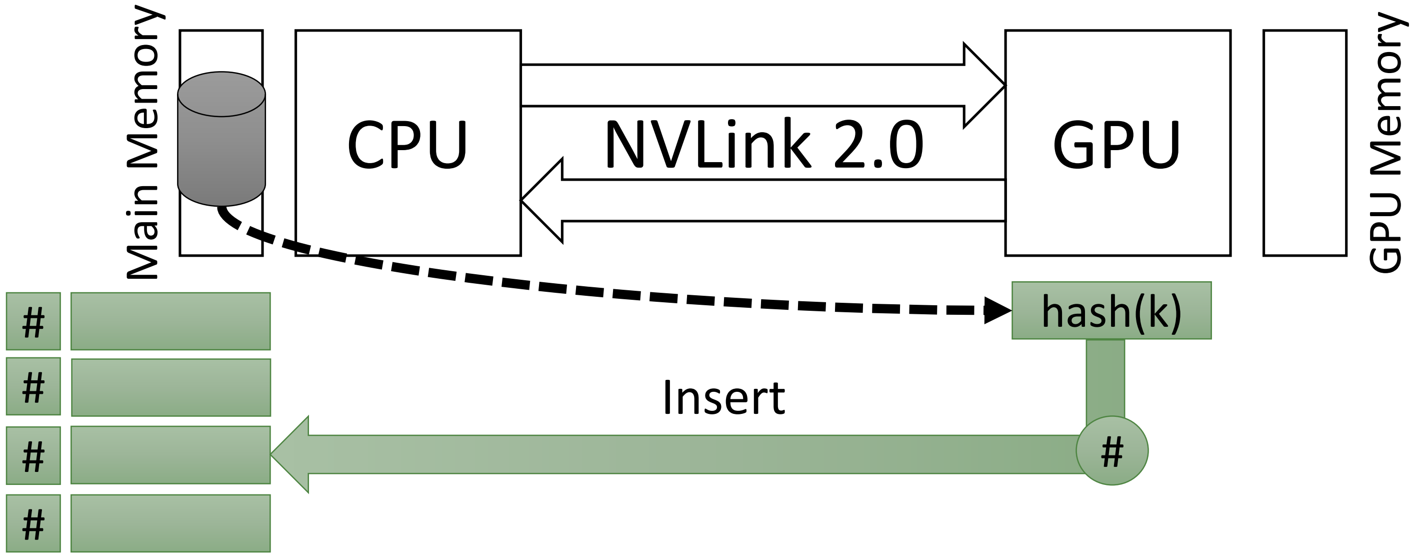
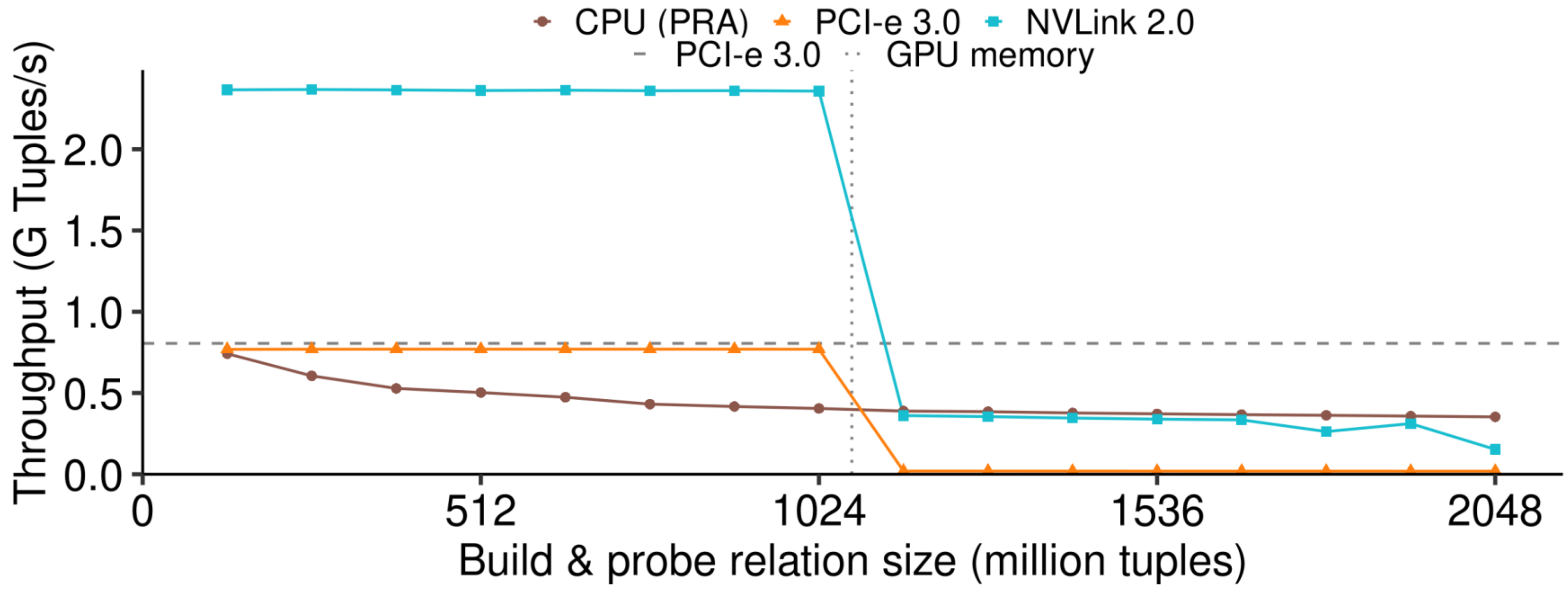


Interconnect feature: Data-dependent memory access

Build-Side Scaling



- Up to 30⋈30 GiB with a 30 GiB hash table **= 90 GiB**

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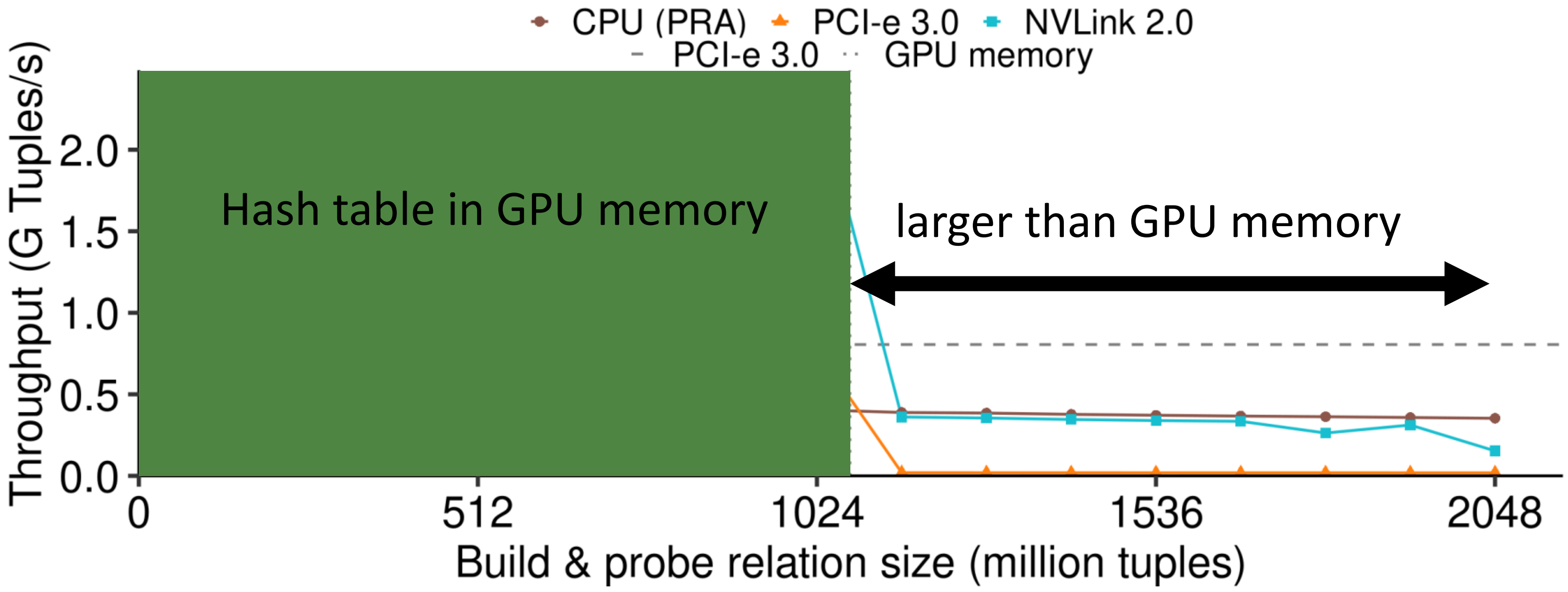

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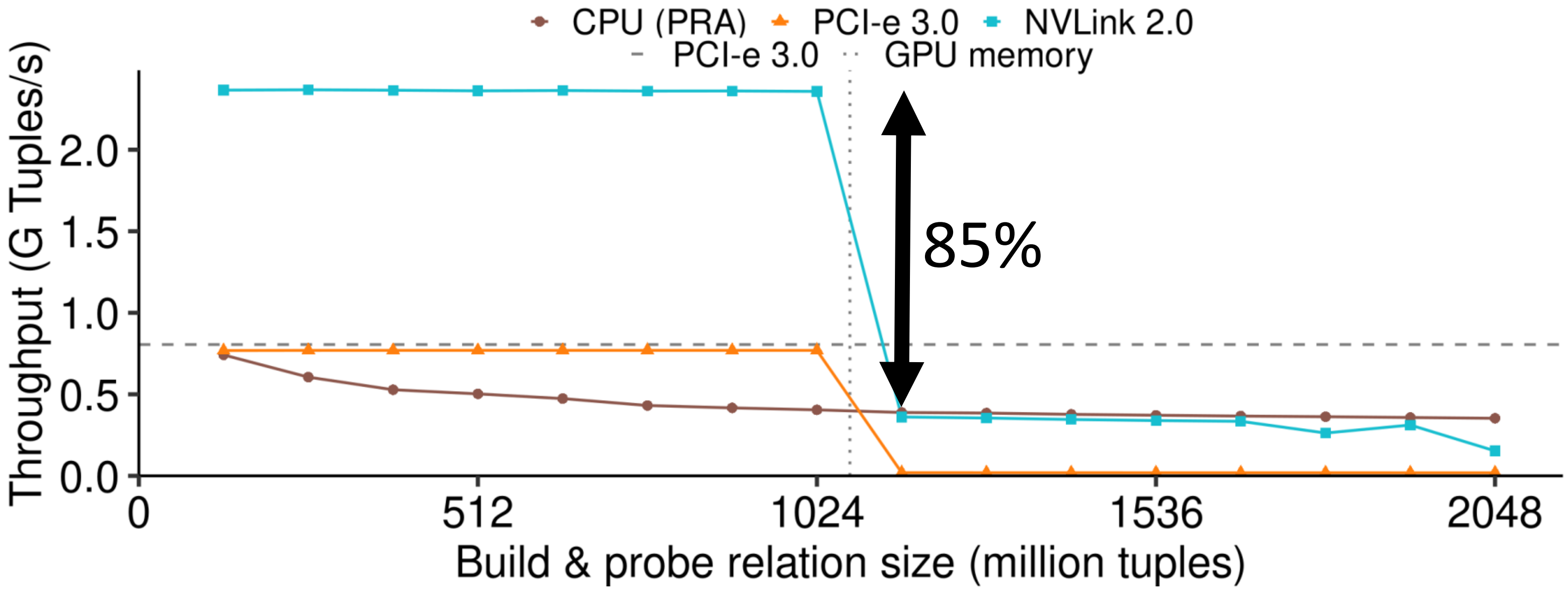

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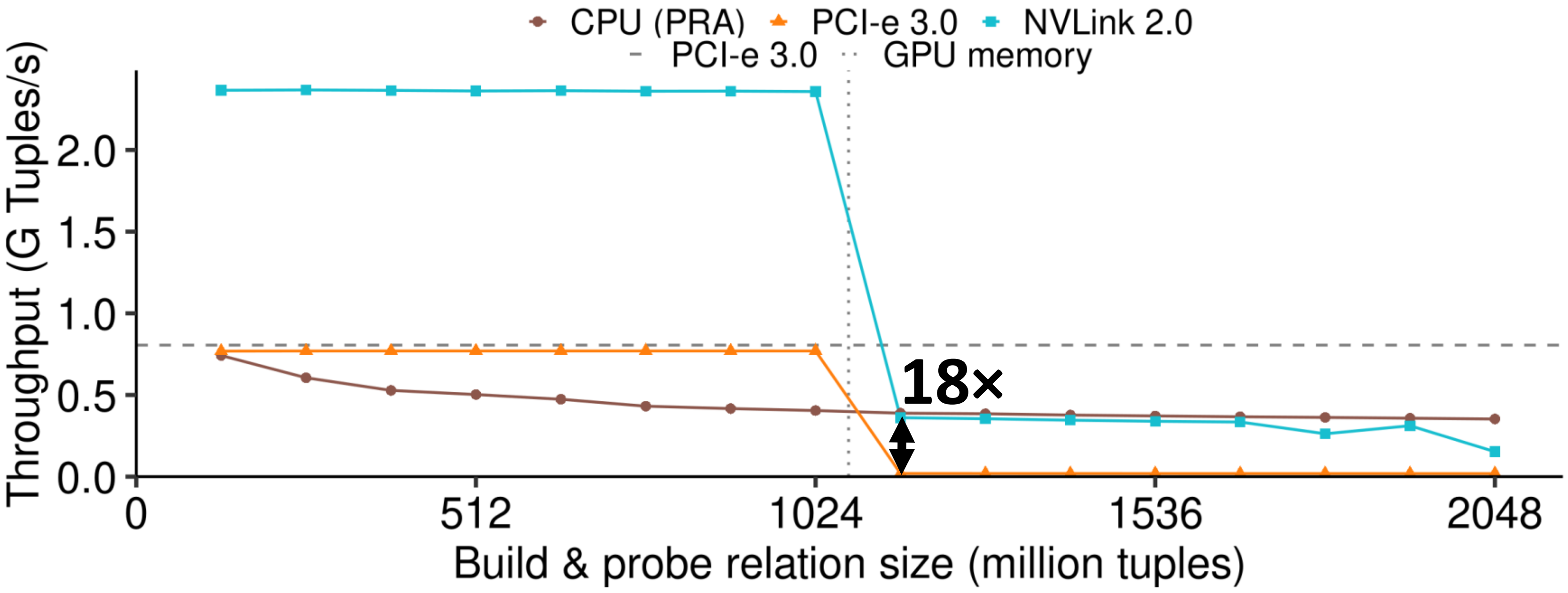

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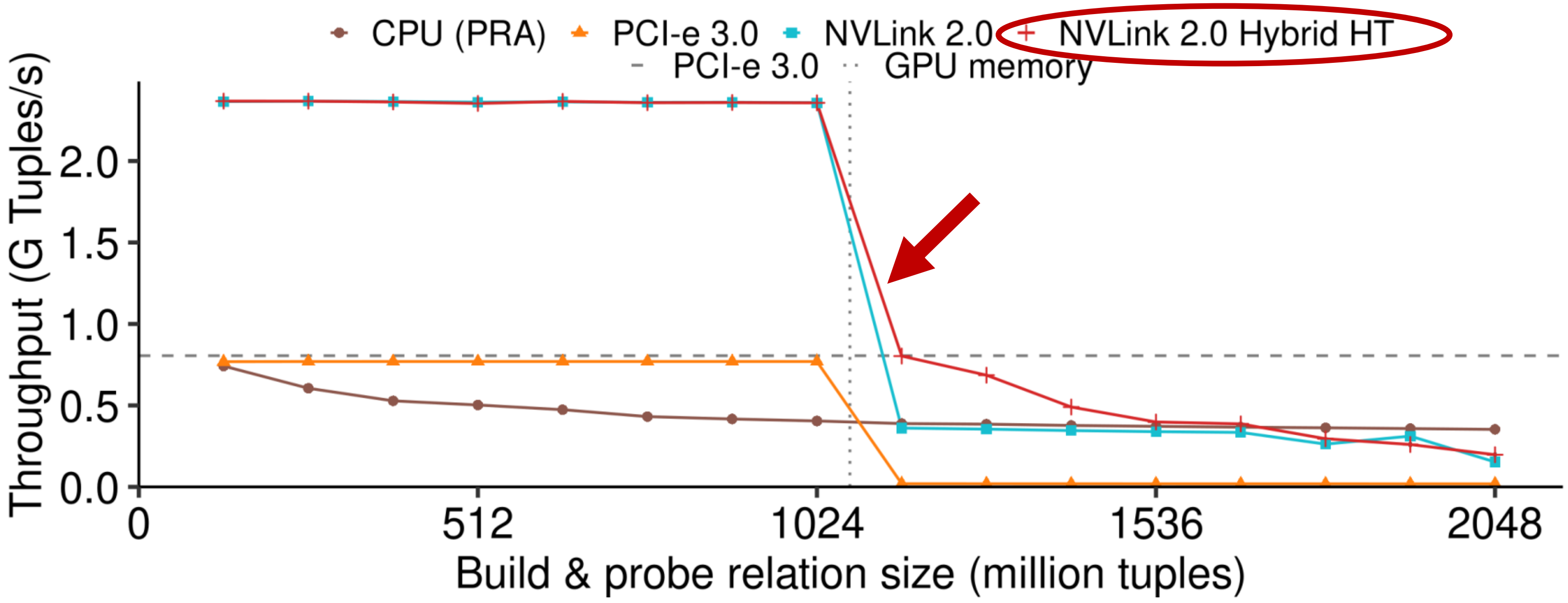

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- Hybrid hash table spills to CPU memory

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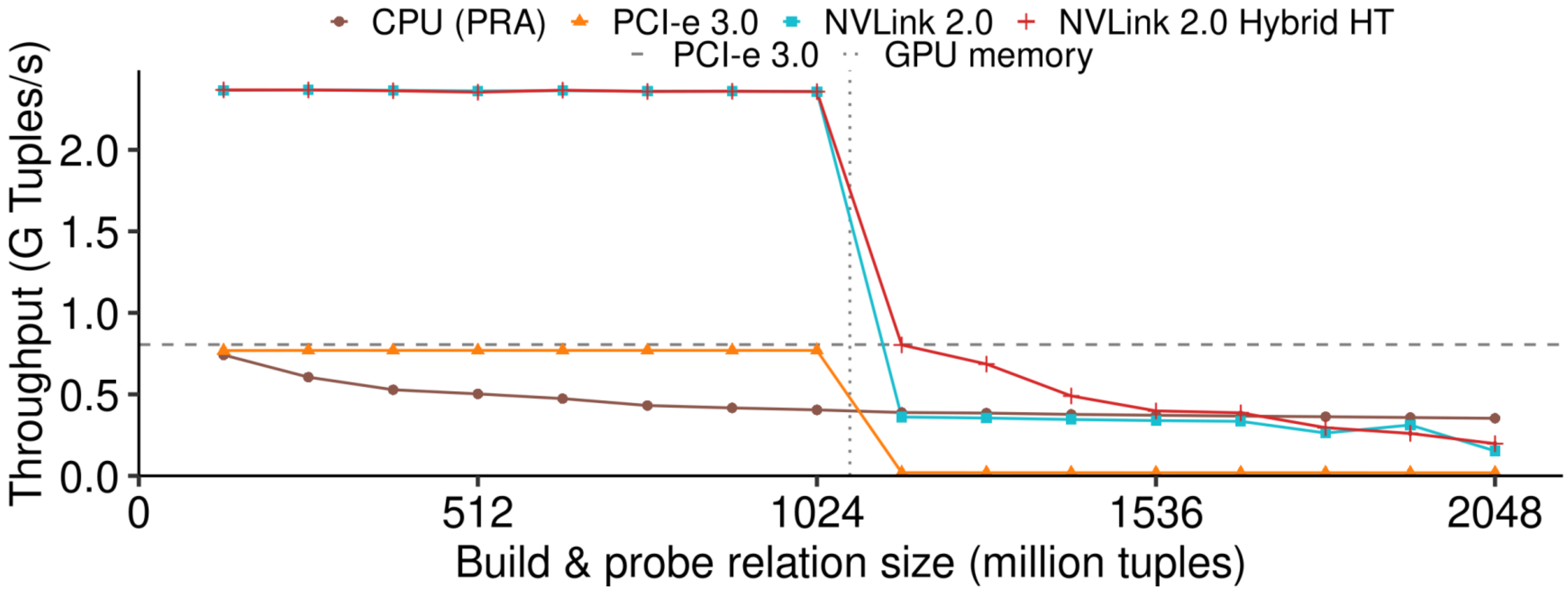

GPUs are able to operate on large, out-of-core data structures

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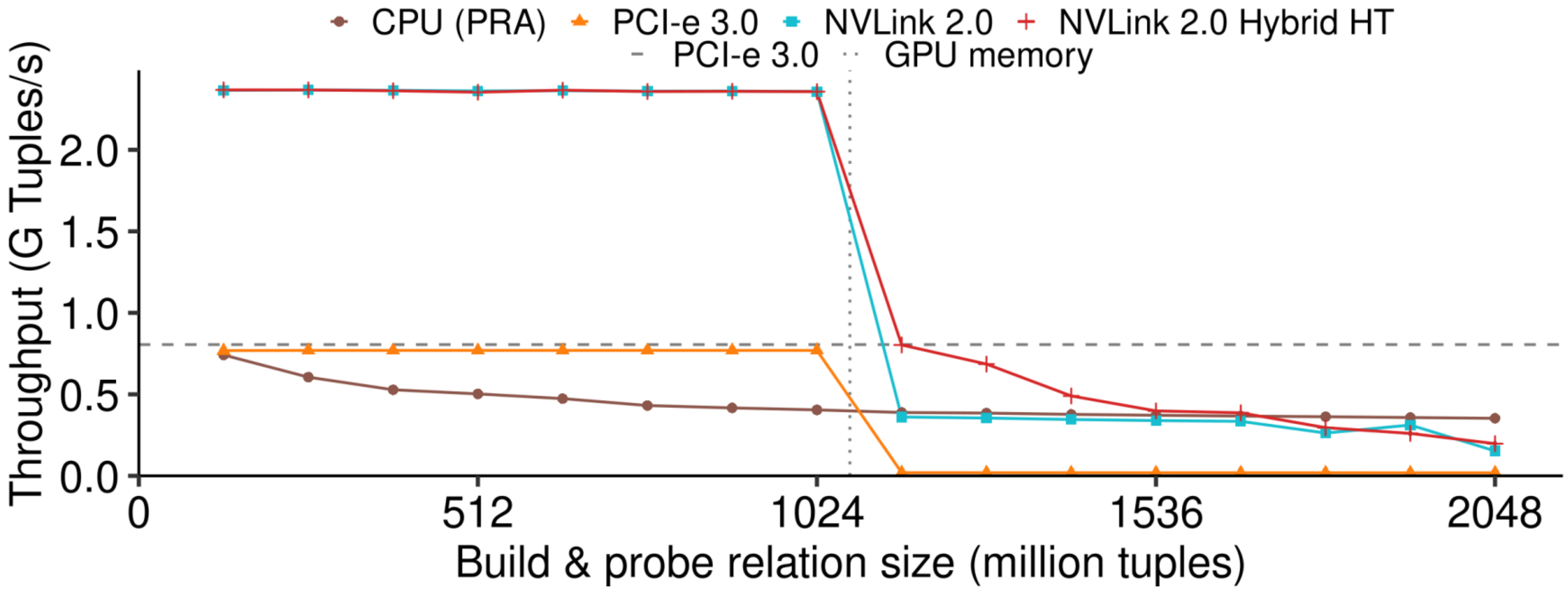
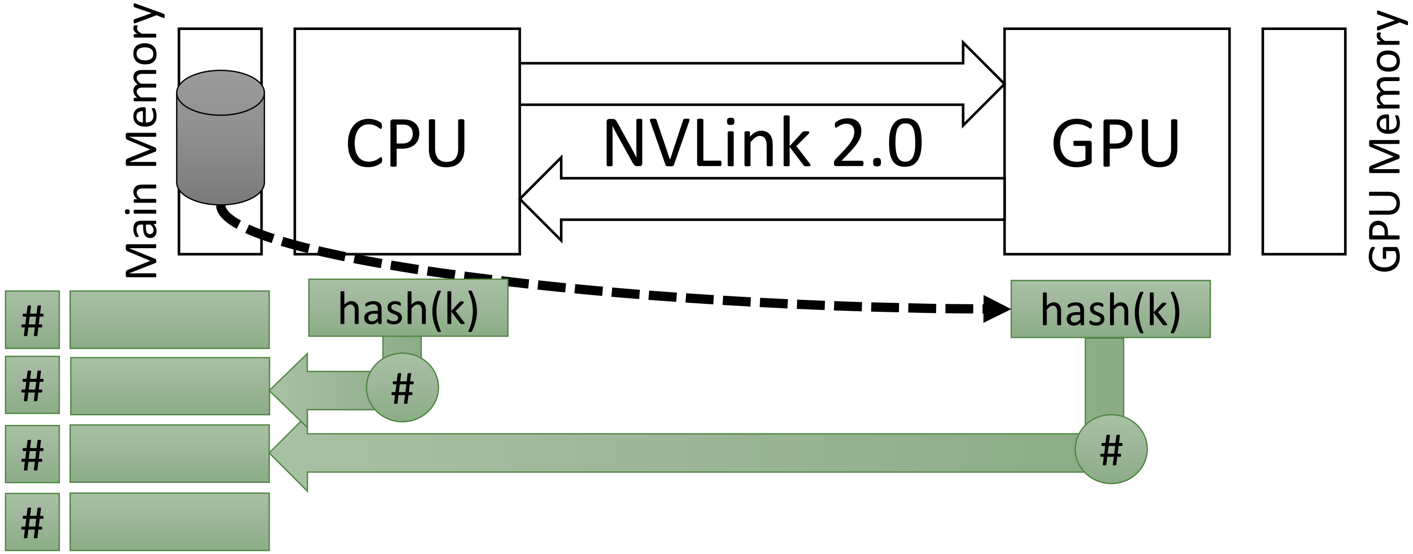


GPUs are able to operate on large, out-of-core data structures

… but should cache data structures in GPU memory

GPU+CPU Cooperation



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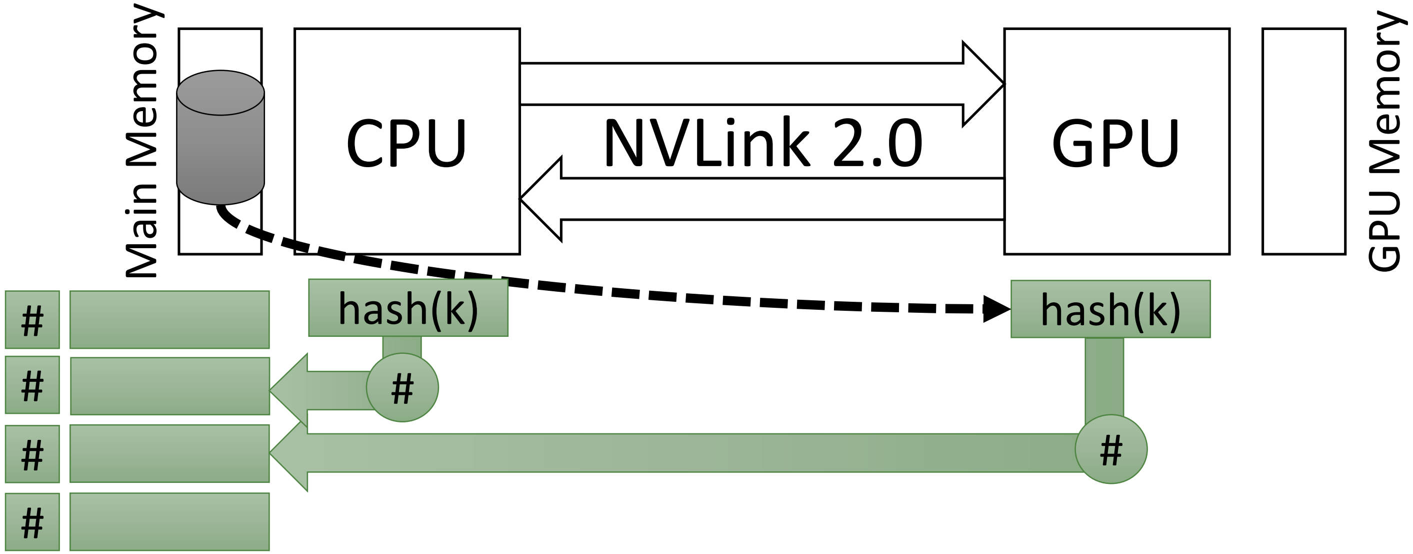

Interconnect feature: Cache coherence

GPU+CPU Cooperation

Throughput (G Tuples/s)
5
4
3
2
1
0
2 GiB ⋈ 32 GiB
4 MiB ⋈ 32 GiB
7.8 GiB ⋈ 7.8 GiB

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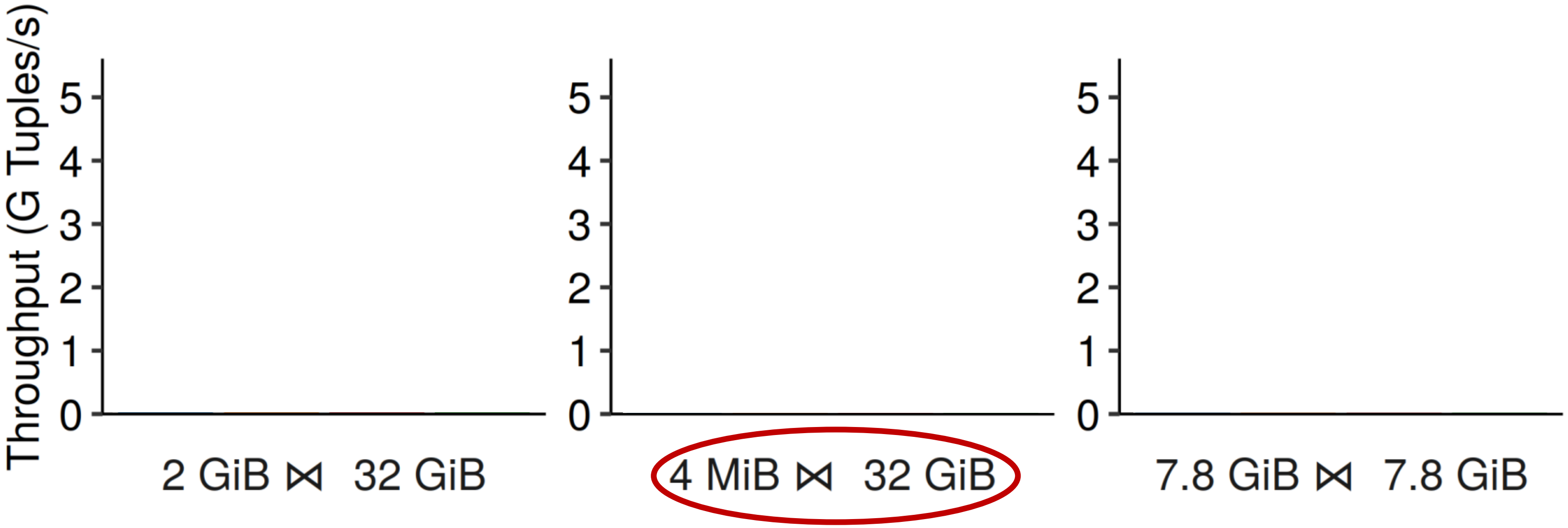

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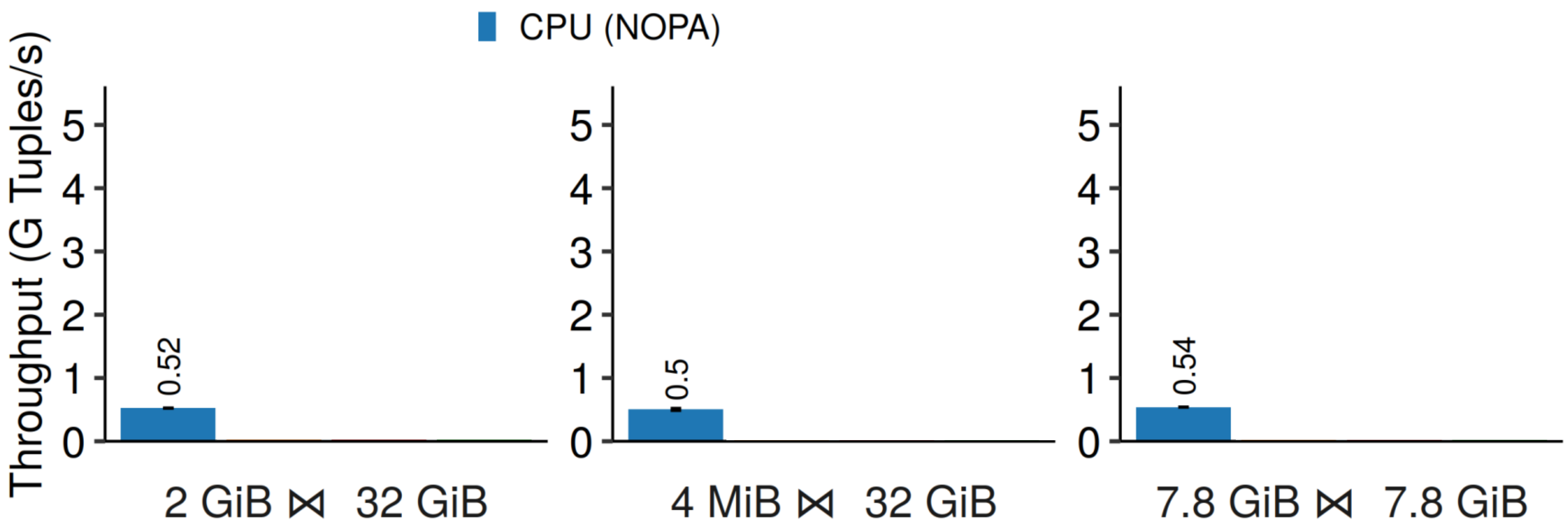

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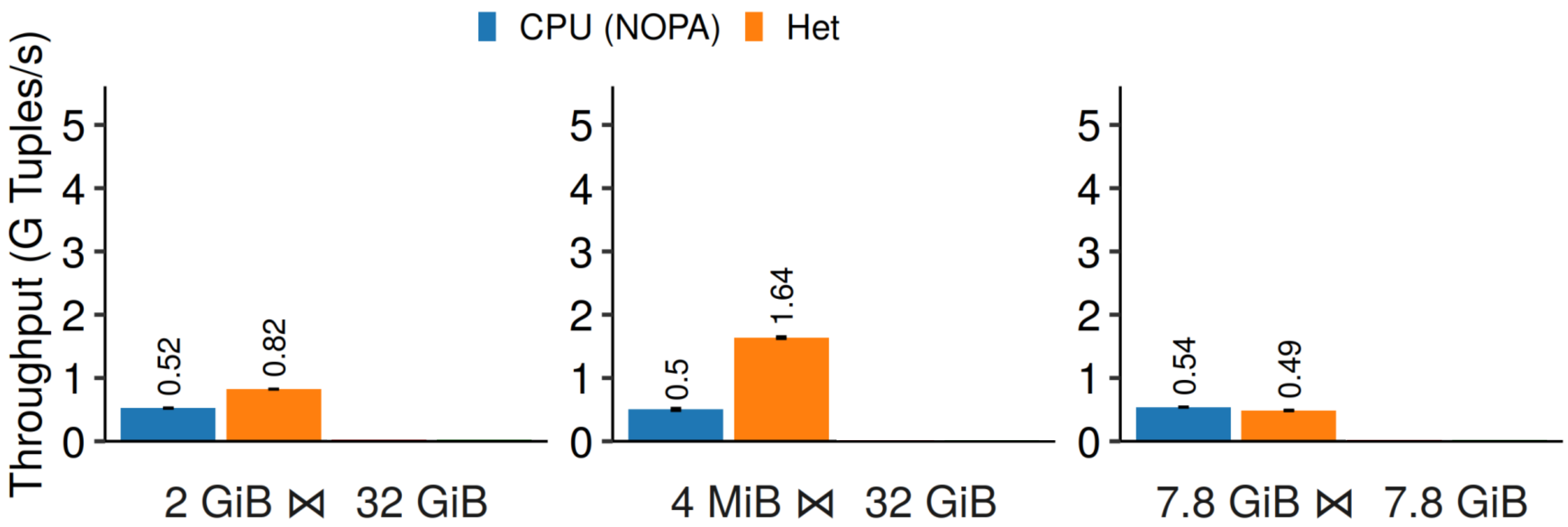

- Heterogeneous → GPU & CPU share hash table in CPU memory

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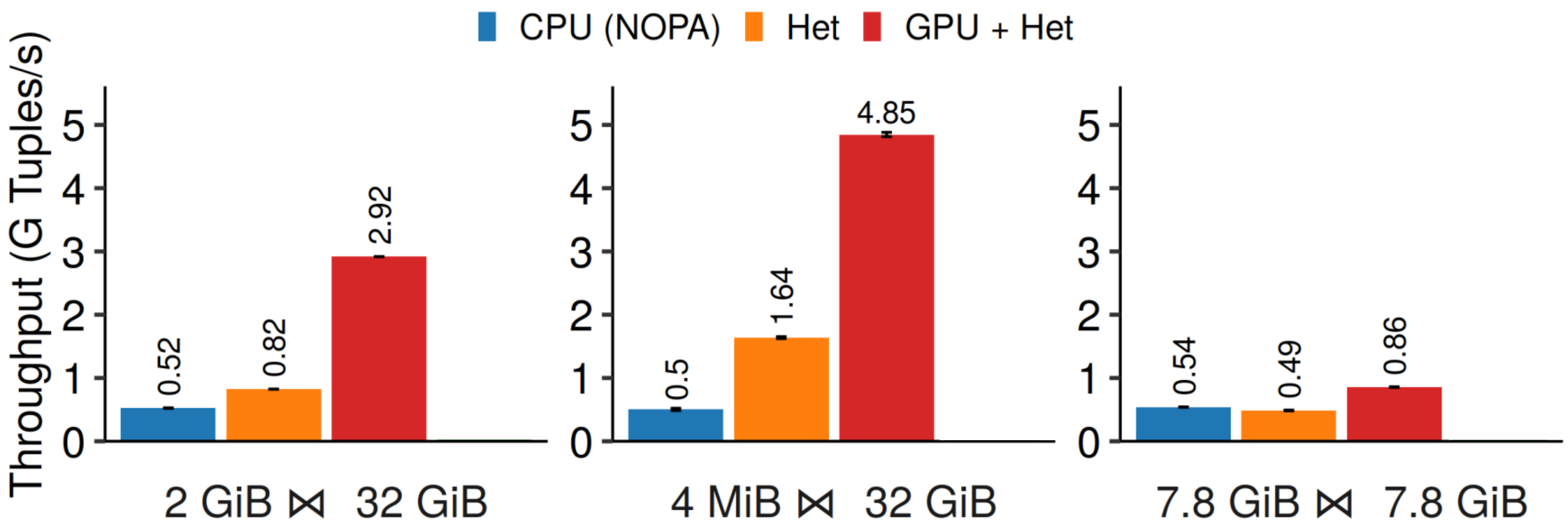

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- GPU + Het → GPU builds hash table in GPU memory, then copy it to CPU memory

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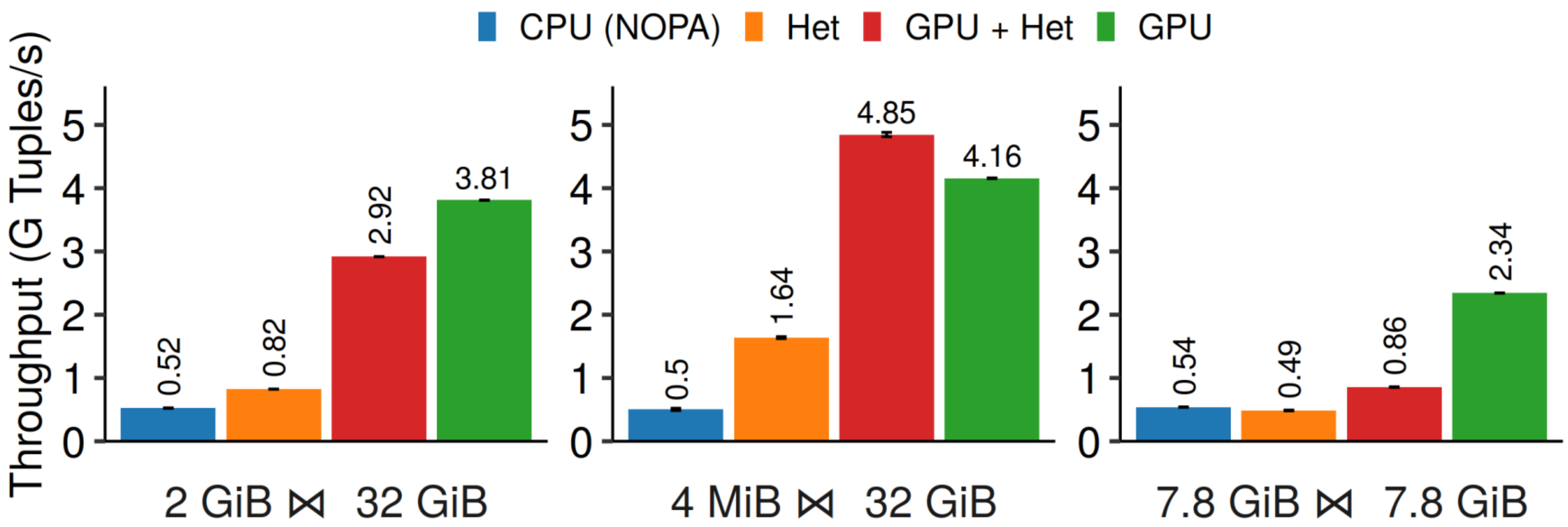

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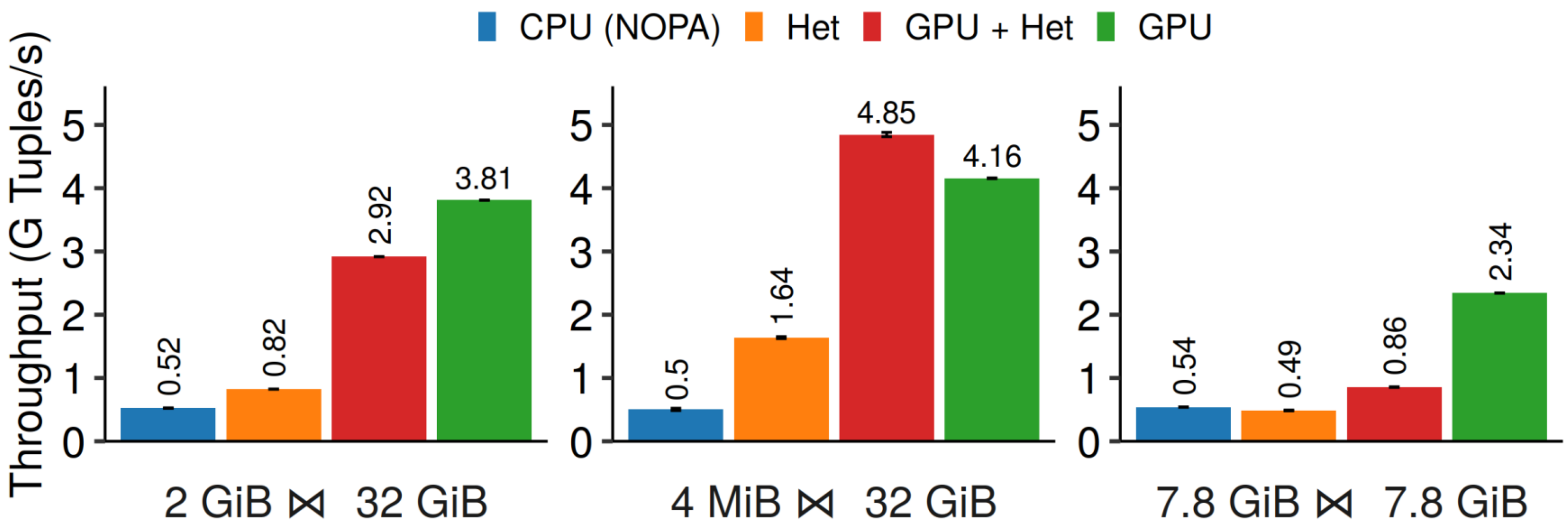
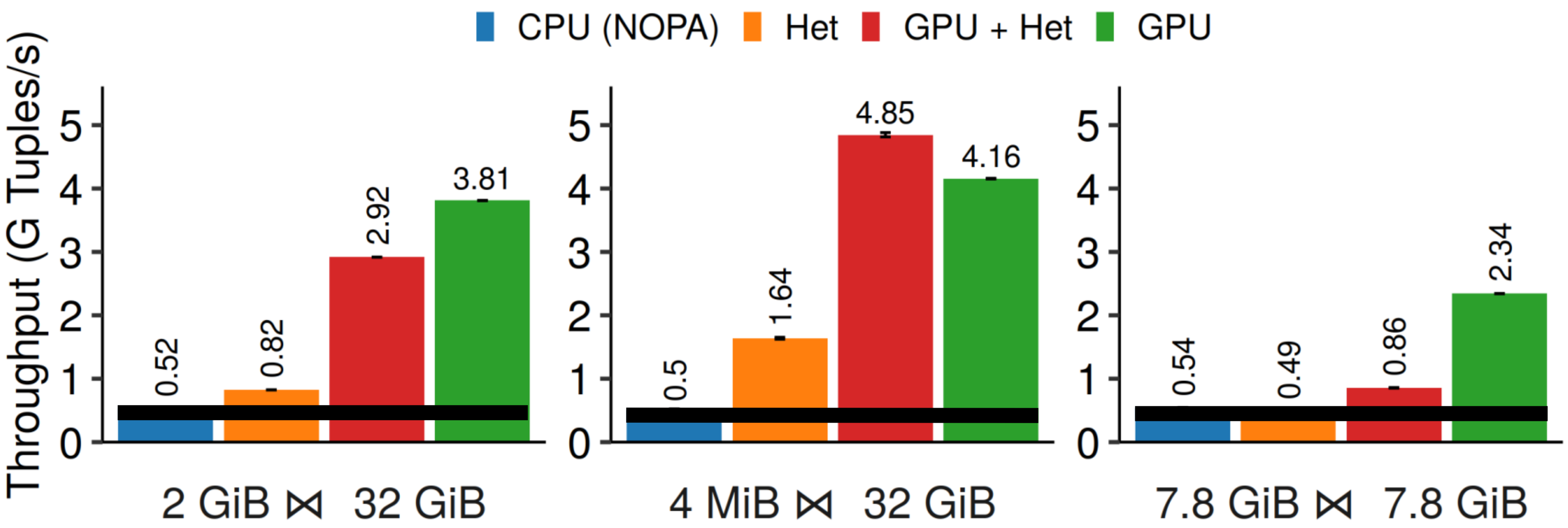


Scaling-up using co-processors makes performance more robust

GPU+CPU Cooperation



Scaling-up using co-processors makes performance more robust

Avoids worst-case, but using only GPU can be faster

Conclusion

*We explore **in which ways** fast interconnects **benefit databases**:*

- Out-of-core **data sets**
- Out-of-core **data structures**
- **Fine-grained** cooperative co-processing

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